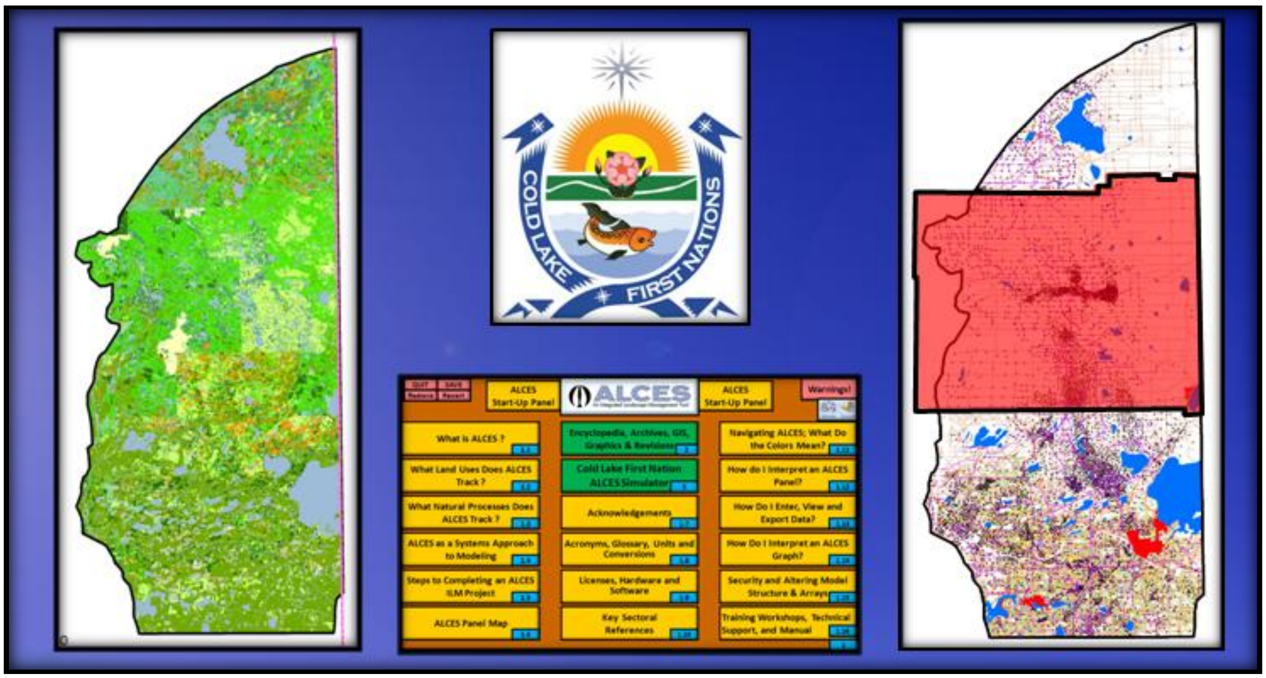
The Cumulative Effects of Historic, Current and Future Land-uses on the Peoples and Landscape of Cold Lake First Nations



Prepared for the Cold Lake First Nations

Prepared by ALCES Landscape and Land-use Ltd

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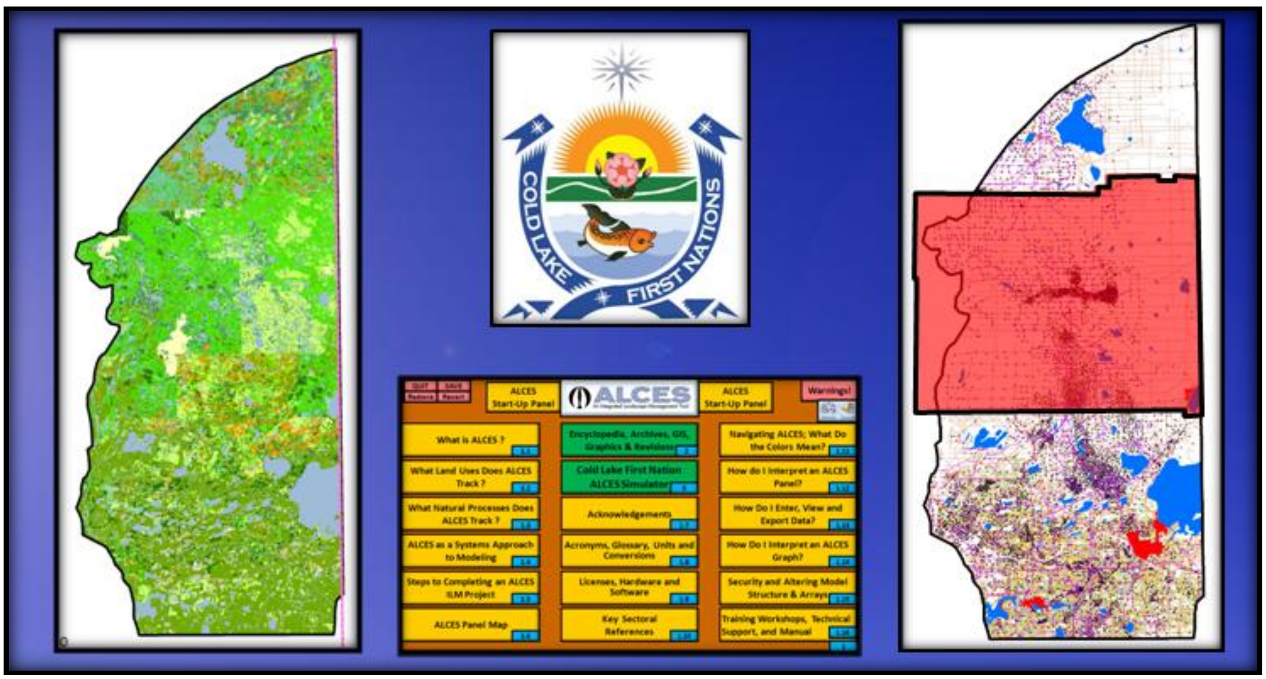

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October 2012

OVERVIEW

The Cold Lake First Nations (CLFN) ALCES project described in this report was triggered by an understanding by CLFN that individual environmental impact assessments (EIA) are inadequate in scale, scope and temporal dimension to properly inform the community about both benefits or liabilities of multiple overlapping land uses. An individual project is not necessarily unusual in technology, scale, or scope in comparison to others. It is but one example of many that have preceded it, and one of dozens to hundreds of projects that will emerge on the CLFN traditional lands in decades to come.

Like many stories dealing with aboriginal culture and modern land-use, this one is neither simple nor linear. It involves a First Nations whose landscape has changed rapidly, who continue to aspire to maintain a culturally rich ability to participate in traditional activities (hunting, fishing, trapping, gathering), but also recognize the need to embrace components of Alberta's contemporary economies and society. This community has growing anxiety about the integrity of their Traditional Territory. Ultimately, CLFN argue they deserve a meaningful conversation about their destiny based upon a scientifically credible and realistic examination of the existing state of cumulative impacts upon their Traditional Territory. CLFN is also mindful of the probability of significantly more encroachment in the future. With this in mind, the CLFN have commissioned the CLFN ALCES project to determine the ecological, economic, social and cultural impacts of current and future oil extraction.

This report presents results of the CLFN ALCES® land-use scenario modelling for the Cold Lake First Nations Study Area (CLFN SA), which has been completed at the request of the Cold Lake First Nations (CLFN). It uses the ALCES® landscape cumulative effects simulation model (www.alces.ca) to examine and understand the collective impact of the region's growing population, residential, agriculture, oil, military, park, and transportation sector footprints, and to account for the historic, current and future growth trends in population and industrial activities. By tracking the impact of plausible future growth scenarios (currently driven by the energy sector) on leading indicators such as water quality and demand, employment, air emissions, and wildlife habitat, the ALCES® model can determine the potential economic, social and ecological outcomes of each growth scenario. The model also investigates the relative influence of important natural processes, such as fire, on ecological indicators.

The results of each landscape simulation are presented at multiple spatial scales, and include CLFN Traditional Territory, CLFN SA (Alberta side only; hereafter referred to as CLFN SA), specific sub regions (CLAWR, north of CLAWR, agricultural white area, region south of CLAWR and north of White Area), and for quarter township (5 x 5 km) grid maps.

An analysis of the outputs of the ALCES® model illustrate that the current CLFN SA landscape has undergone a profound transformation during the past 100 years. Key historical land-use drivers have been the settlement of non-aboriginal peoples, growth of the cropland/livestock sectors in the south, the military land-use in the central portions of the CLFN SA, and, more recently, the infrastructure of the hydrocarbon sector throughout the study area where heavy oil and bitumen deposits occur. Relative to the pre-industrial era, few areas within the study area that are accessible to CLFN have maintained their ecological integrity. As CLFN shares strong cultural linkages to these remnants, they are concerned that ongoing land management and industrial activities will hinder their aspirations to pursue traditional activities.

The results of future simulations indicate that the CLFN landscape will continue to change at a rapid rate, and that future transformation will be lead by the bitumen sector. Of the 6.3 B m^3 of bitumen that is considered recoverable given current technologies, only 0.3 B m^3 (4.7%) has been extracted to date. The remaining 95% yet to be extracted will require an extensive network of seismic lines, wellsites, access roads, pipelines and processing plants. Simulations conducted in the CLFN ALCES® model indicate that moose, fisher, fish, and edible berry populations are highly likely to decline in response to an increasingly industrialized landscape. It is not uncommon for individual In Situ projects in the region to produce ~71 M m^3 (35,000 bpd for 35 years). To emphasize why we need to broaden the discussion about regional land management, ~88 projects of similar scale will be required to extract the remaining proven bitumen reserves. Furthermore, it is generally understood that the volume of recoverable bitumen will increase through time as new extraction technologies are developed and refined.

Acknowledgements
Many people contributed significantly to this project. We would like to thank the following organizations and individuals for their time and for sharing their knowledge and expertise with the ALCES Group: DS Environmental (Dan Smith), Birchwood Resources (Alex Lemmens), Integrated Ecology Group (Justin Straker, Shanti Berryman, Ann Garibaldi), and Sharna Nolan.

A special gratitude is extended to the people of Cold Lake First Nations, who kindly shared their time, stories, and graciously hosted the ALCES Group during field trips. Specific thanks are extended to Jill Janvier for coordinating interviews between the ALCES team and community members.

Caveat and Disclaimer
This report was prepared by the ALCES Landscape and Land-use Group for the Cold Lake First Nations.

List of Acronyms

ALCES	Alberta Landscape Cumulative Effects Simulator
BPD	Barrels per Day
CEMA	Cumulative Environmental Management Association
CLAWR	Cold Lake Air Weapons Range (also known as Primrose Air Weapons Range)
CLFN SA	Cold Lake First Nations Study Area
CLFN	Cold Lake First Nations
CSS	Cyclic Steam Stimulation
ERCB	Energy Resources Conservation Board
FMA	Forest Management Agreement Area
FT	Footprint Type
GIS	Geographic Information System
GOR	Gas to Oil Ratio
HSI	Habitat Suitability Index
INFI	Index of Native Fish Integrity
LT	Landscape Type
RNV	Range of Natural Variation
SAGD	Steam Assisted Gravity Drainage
SEWG	Sustainable Ecosystems Working Group

List of Units

B	Billion
ha	hectare (100 x 100 m)
M	Million
m^3	cubic meter
PPM	parts per million
T	Trillion
T/D	Tonne/day

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1. BACKGROUND

The *Densuline* peoples of Cold Lake First Nations have resided in the boreal mixed wood forests of east central Alberta for approximately 10,000 years. For 98% of this time, they existed as nomadic Hunter-Gatherers whose distribution and activities were shaped by seasonal and inter-annual variation in climate, and the diversity of landforms that comprised this landscape. The CLFN/*Denesuline* community's pre-European era numbers likely fluctuated from a few hundred to a few thousand. Represented by a collection of nomadic family clans, their continuous movements across a traditional network of trails and non-permanent settlements reflected their need to find and harvest populations of moose, fish, and berries (among other foods, medicines and resources). As food resources would become locally depleted, these nomadic groups would continue their traditional movements, locating new food sources elsewhere, and allowing depleted areas to recover. The vast area of their Traditional Territory, and the low density of their numbers, allowed for a "spatial-temporal" system of movement and food harvest that was sustainable in time and space.

Approximately 200 years ago the arrival of Europeans to the CLFN region catalyzed a series of incremental land-use changes that continues today. The inclusion of CLFN into the trapping industry substantially altered their economy and social fabric, but still allowed them to continue a dynamic lifestyle that was based on the land and the natural resources of the boreal forest. Both the CLFN and the wildlife upon which they depended relied heavily on the ability to migrate in poorer weather, and follow ancient migratory trails or seasonal indicators to seek better resources. The migration of people and animals are closely associated with the cultural milestones in traditional lifestyles and land management, and prompt cultural ceremonies or activities. The signing of Treaty Six in 1876 ushered in a new era that introduced CLFN to the concept of Treaty Reserve lands, and would later lead to partial restrictions of movement. The arrival of permanent communities of Europeans and agriculture in the southern reaches of their Traditional Territory altered the southern portion of their landscape and its capacity to sustain traditional activities. During this period, some members of the CLFN community became active members of the farming and livestock industries.

In 1952, a land-use decision by the Governments of Canada and Alberta profoundly affected the peoples of CLFN. The establishment of the Cold Lake Air Weapons Range (CLAWR, also referred to as Primrose Air Weapons Range), ~470,000 ha (within CLFN on the Alberta side) and located in the middle of their Traditional Territory, prevented CLFN members from accessing the central portions of their traditional lands and made it logistically difficult to gain access to the northern regions. When the CLAWR was closed to the public in the late summer of 1954, "the economy of Cold Lake communities collapsed almost immediately." (Indian Claims Commission Report, p. 75).

The advent of forced residential schooling from the 1920s to the 1970s caused a permanent discontinuity in community structure and inter-generational transfer of traditional knowledge. This discontinuity is reflected among differences expressed by elders and younger generations, whose aspirations for traditional lifestyles and participation in cash economies now sometimes clash.

Squeezed between expanding agriculture to the south and an exclusionary military land-use to the north, CLFN has struggled during the past six decades to maintain some semblance of traditional activities in a small sub-region that is currently undergoing a massive transformation caused by the hydrocarbon sector. The emergence of the heavy oil sector in the 1960s, and more recently a bitumen development play, has lead to a dense network of seismic lines, wellsites, access roads, processing plants, and pipelines across much of the southern half of the CLFN Traditional Territory. Collectively these energy sector footprints have fragmented the boreal forest landscape, creating an abundance of roads and other linear features, but also restricting access by CLFN to traditional lands through the establishment of gates and other administrative obstructions. The ongoing transformation of the CLFN Traditional Territory by the energy sector is a story best described as year-by-year incrementalism, or "death by a thousand cuts". The ~28,000 ha and 28,500 km of current and direct energy sector footprint is the result of hundreds of individual historical projects, each described and assessed individually, and largely out of context of the need for a dialogue focused on appropriate scales of time and space. The situation is exacerbated by the recognition that only a very small fraction (~5.5%) of recoverable bitumen and heavy oil has been extracted to date. The key point is that the energy sector on CLFN Traditional Territory is at the very early stages of its development, yet has already made a marked and lasting signature on these lands.

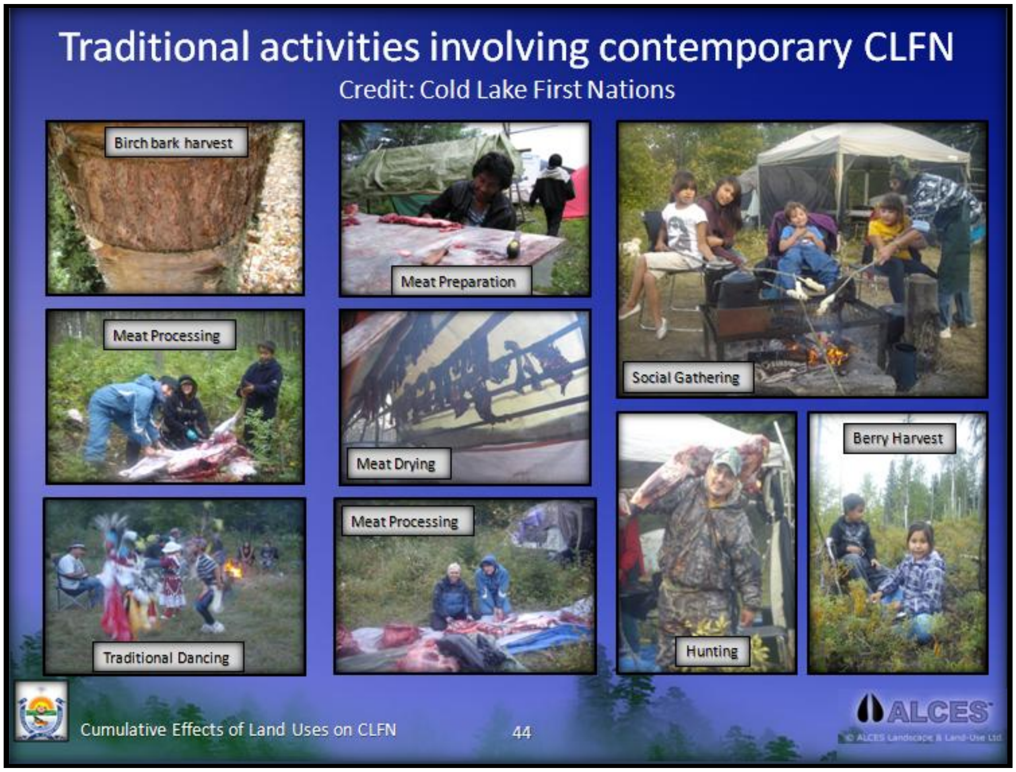


Figure 1. Traditional activities involving the contemporary CLFN communities. Photos taken during the past few years and provided by the Cold Lake First Nation community.

Figure 2. Changes in the CLFN SA caused by land-uses have lead to increasing concerns of the environmental and cultural integrity of the region.

2. STUDY AREA

The traditional lands of CLFN (2.11 M ha) are located within the boreal mixedwood forests of east-central Alberta and west central Saskatchewan (Figure 3). Recognizing the jurisdiction of the ERCB is within the Province of Alberta, the specific study area of this project represents that portion of the CLFN traditional lands located within Alberta (1.12 M ha). This region is hereafter referred to as CLFN SA (Cold Lake First Nations Study Area).

2.1 THE PHYSICAL LANDSCAPE

(portions of text adapted from *"Relationships between Stand Age, Stand Structure and Biodiversity in Aspen Mixedwood Forests in Alberta"(Stelfox et al., 1995))*

The study area is generically located between 55.10-55.44° north latitude, 110.0-111.10° west longitude, and varies in elevation from 650–700 m a.s.l. Although this area has regionally similar geomorphology, climate, and plant communities, considerable local variation is prevalent (Kabzems et al. 1976; Figure 4). A general geophysical description of the area is found in Clissold and Tress (1974).

The major bedrock formations underlying the region are Devonian strata of limestone, dolomite, shale, and evaporite. Outcroppings of both Devonian and Cretaceous bedrock are visible along some deep river valleys.

The soils to the west of the area were described and mapped by the Alberta Soil Survey (Kocaoglu 1975; Kocaoglu and Bennett 1983) and are typical of the boreal plains of northeastern Alberta. A soil map indicating agricultural potential illustrates those parts of the region that have been cultivated or have cultivation potential (Figure 54). Soils vary over the undulating topography in the general region, with Orthic Gray Luvisol and Eutric Brunisols dominating the upland aspen portion of the topographic gradient (Wynnyk et al. 1963). Parent material is mostly sedimentary rocks weathered in situ or translocated by glacial activity.

Most soils are classified as sandy clay loam with a clay content of 20–40%. Gray luvisols predominate on moderately well-drained, medium-textured moraine and lacustrine material. These soils are most commonly formed beneath forest canopies on well- to imperfectly drained deposits. Well-drained glaciofluvial and eolian sands are characterized by dystric and eutric brunisols. Organic soils occur in bogs, fens, peatlands and along most riparian channels.

The climate of the study region is continental, humid to sub-humid, and microthermal (Dcf, Koeppen) with cold winters (daily mean temperature –15.2°C ± 4.8 S.D.) and hot summers (daily mean temperature 14.9°C ± 1.2 S.D.) (Longley 1970; Table 1). Average precipitation and temperature of the CLFN SA, relative to Alberta, are shown in Figure 5.

Surface water was an important source of transportation to the CLFN. Surface water, both moving (lotic) and standing (lentic) are common features of the study area (Figure 6, Figure 7, Figure 8), with lentic features comprising 8.3% and lotic features comprising 0.19% of CLFN SA. Metrics of selected lake bodies are summarized in Figure 9. Reduction in volume flow of the Beaver River during the past several decades (Figure 10) appear correlated to a declining precipitation trend (Figure 11) but also suggest the importance of net upstream extractions of water relating to agriculture, domestic demand, and other land-uses.

2.2 PLANT COMMUNITY STRUCTURE

The boreal mixedwood forest is a mosaic landscape comprised of stands that vary in tree composition, age, size, shape, and dispersion (Peterson and Peterson 1992; Figure 4, Figure 15). Trembling aspen and white spruce dominate boreal mixedwood on upland mesic sites with medium-textured soils. Past vegetation classifications in Alberta have largely focused on aspen as a seral stage for conifer-dominated climax communities (Corns and Annas 1986; La Roi 1992). However, aspen can also occur as a climax community throughout the low and mid mixedwood ecoregion (Fairbarns 1992; Kabzems et al. 1986). Although mixed stands of aspen and white spruce are typical of much of the boreal mixedwood region (Kabzems et al. 1976), pure stands of each species and others do occur (Thorpe 1992; Burton et al. 1994).

Balsam poplar, paper birch, black spruce, jack pine, tamarack, and balsam fir can be locally abundant throughout the boreal mixedwood forest. Topographically depressed areas with impaired drainage are generally dominated by black spruce and tamarack, whereas willow communities are common near lake margins and continuous and intermittent streams. Pines are found primarily in xeric sites.

2.3 NATURAL DISTURBANCES

Although much of the variability found in forest communities is caused by variation in soil type, elevation, and topography (Oliver 1992), natural disturbances occurring since the retreat of continental glaciers have contributed to high levels of heterogeneity in boreal landscapes (Pickett and White 1985; Attiwill 1994; Figure 12). During this post-glaciation period, boreal forests experienced flooding, insect attacks, and windstorms, but fire was the primary disturbance that shaped these communities (Rowe and Scotter 1973; Kelsall et al. 1977; Barney and Stocks 1983; Johnson 1992). Vegetation patterns created by fire on the boreal landscape are complex and dynamic because fire cycles vary both in space (Payette et al. 1989) and time (Bradshaw and Zackrisson 1990; Clark 1990; Bergeron 1991). Differences in stand size of boreal mixedwood forests caused by spatial variability in fire disturbance events have been reported by Rowe and Scotter (1972), Eberhart and Woodard (1987), Johnson (1992), and Engelmark et al. (1993). Temporal and spatial variation in fires in northeast Alberta are shown in Figure 13 and Figure 14 respectively.

During recent decades, the role of natural disturbances in boreal forest systems has changed as human land-use practices and attitudes have altered the intensity, recurrence, and geographic extent of flooding, fire, and insect infestations. On the one hand, improved fire suppression may have reduced the rate of wildfire in the boreal mixedwood forests of Alberta during the last several decades (Murphy 1985; Delisle and Hall 1987; Burton et al. 1994). In the boreal forests of Alberta, fire return interval increased from 38 years in pre-settlement times to 90 years by the late 1960s (Murphy 1985). But, on the other hand, anthropogenic disturbances are now common and growing in prevalence in Alberta's boreal forests (Dancik et al. 1990). Some land-use disturbances, such as agriculture, seismic activity, urban sprawl and transportation corridors, permanently remove patches or corridors of forests from the mixedwood mosaic. Other disturbances, such as commercial logging, permit the forest to persist, although in a different form and subjected to altered ecological processes (Maser 1994).

The current age structure of aspen mixedwood forests in northeastern Alberta varies from 0 to 150+ years (Alberta Land and Forest Services 1994). The initial forest age class structure of forests in CLFN SA is shown in Figure 16and Figure 17. The reduced frequency of young forests is generally attributed to effective fire suppression (Murphy 1985), although climate change has been implicated (Johnson and Larsen 1991). For northeastern Alberta, approximately 20% of the merchantable landbase is classified as older than the 70 year rotation currently used for harvest of trembling aspen (Alberta Forest Service 1985). The age structure of this forest biome is therefore projected to change under conventional forest harvest practices.

For the purposes of this project, the fire regime was simulated as a random draw from a negative exponential distribution with a mean fire return interval of 80 years.

Table 1. Long-term temperature at the Lac La Biche station (Atmospheric Environment 1981).

Extreme	Extreme	Mean Maximums						Mean Minimums				
Maximum	Minimum	May	June	July	August	Sept		Nov	Dec	Jan	Feb	March
34	-48	16	20	22	21	15		-11	-19	-24	-19	-13

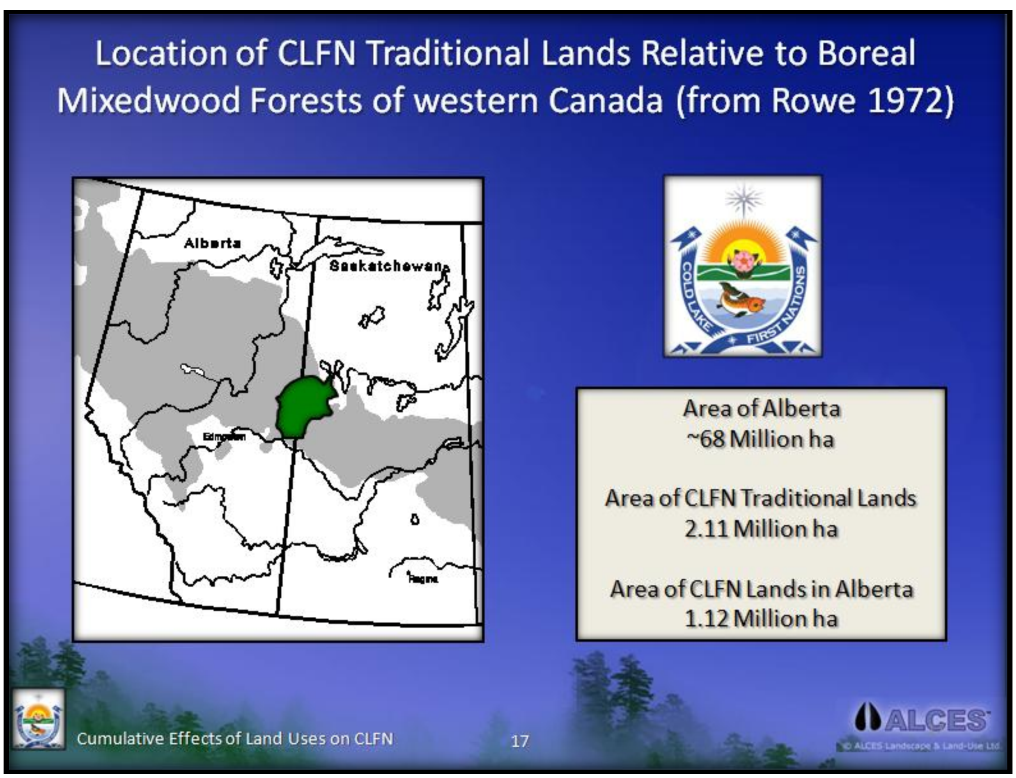


Figure 3. Location of the traditional lands of the CLFN (green) within the boreal mixedwood forest (grey) in western Canada (modified from Rowe 1972).

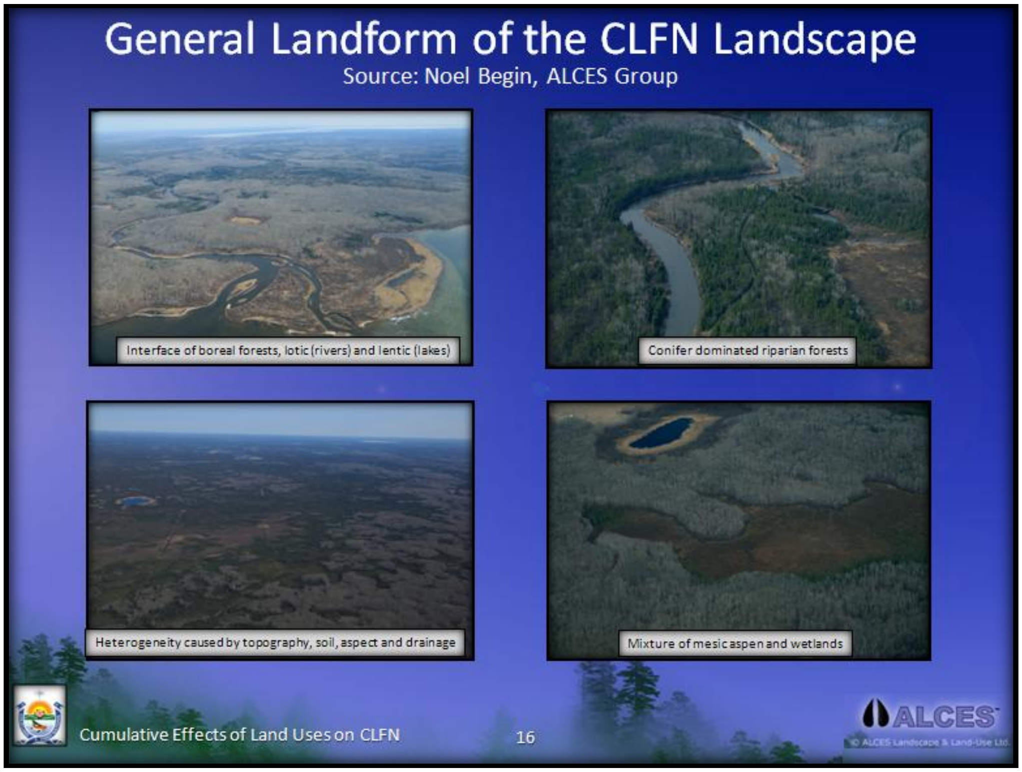


Figure 4. Examples of general landform, physiognomy, and plant community structure within the study area.

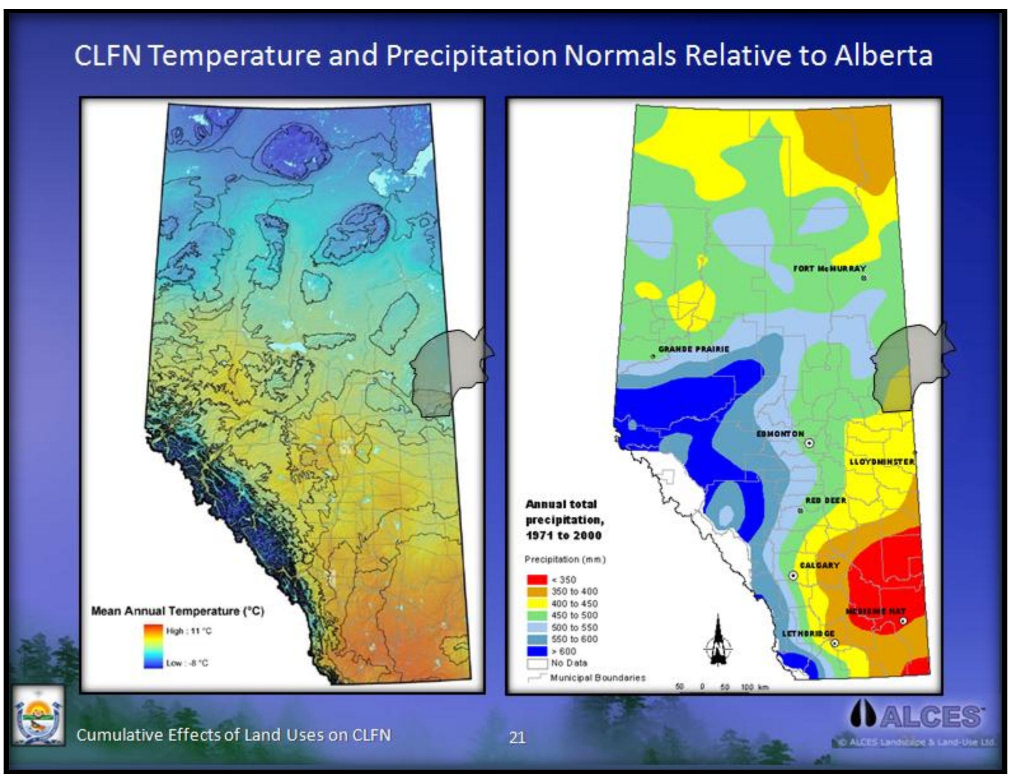


Figure 5 Average precipitation and temperature in CLFN SA in relation to provincial patterns. Source: Alberta Environment (online).

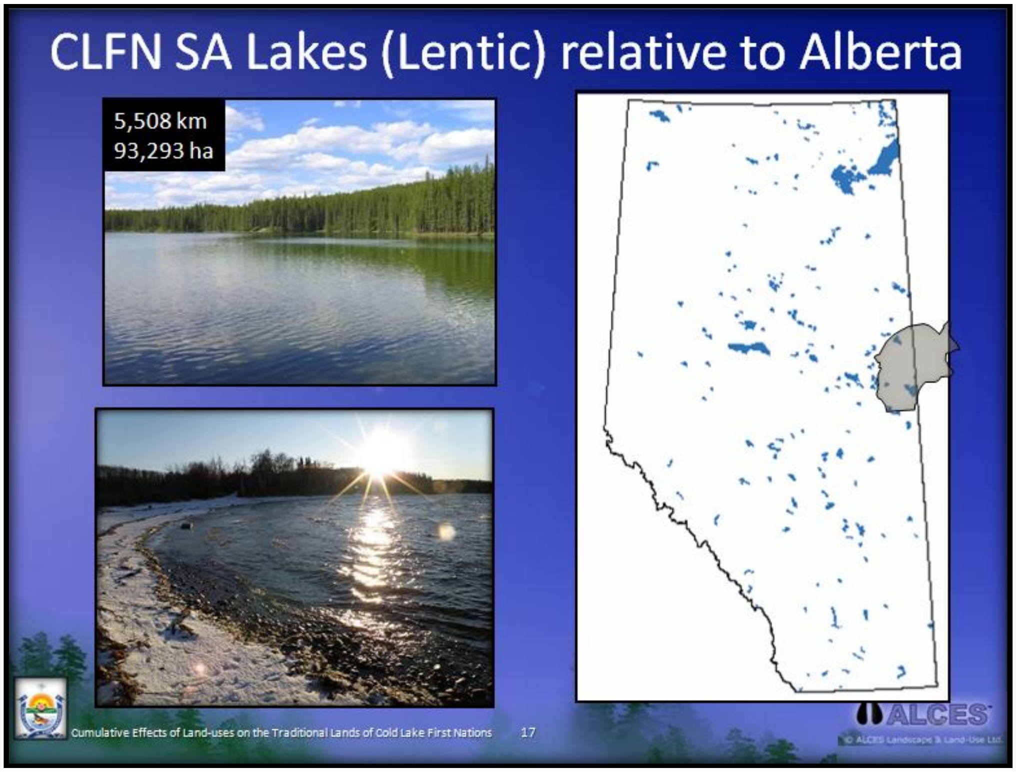


Figure 6. Major Lakes of CLFN SA in relation to provincial pattern. Source: Alberta Environment (online).

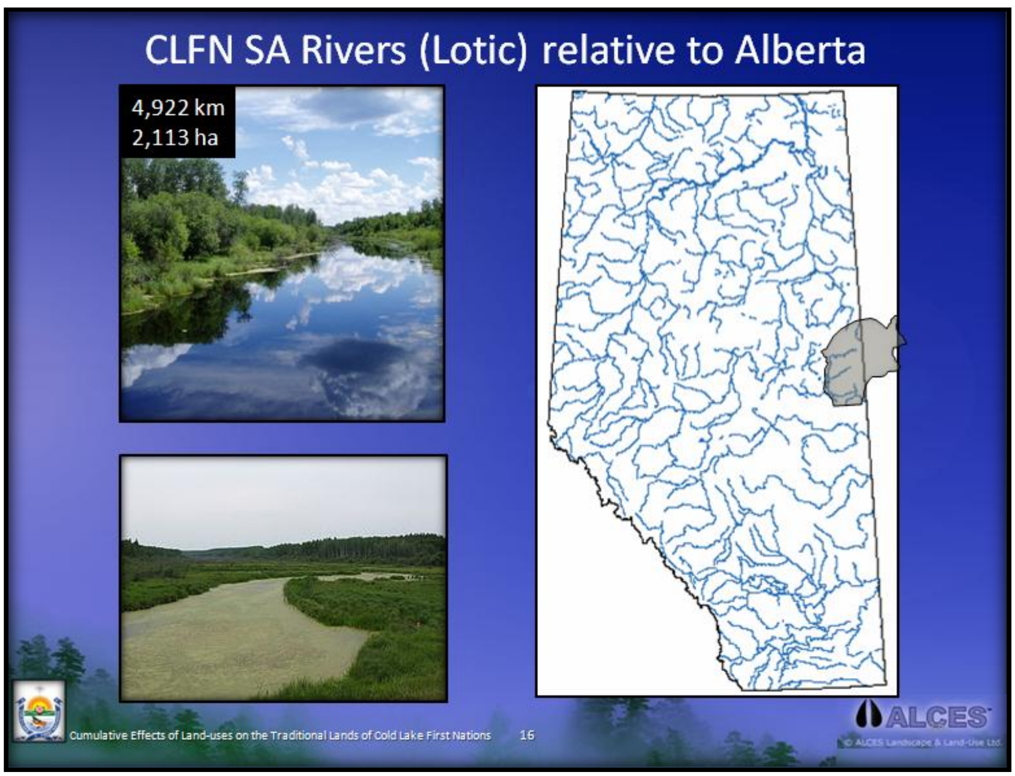


Figure 7. Rivers of CLFN SA in relation to provincial pattern. Source: Alberta Environment (online).

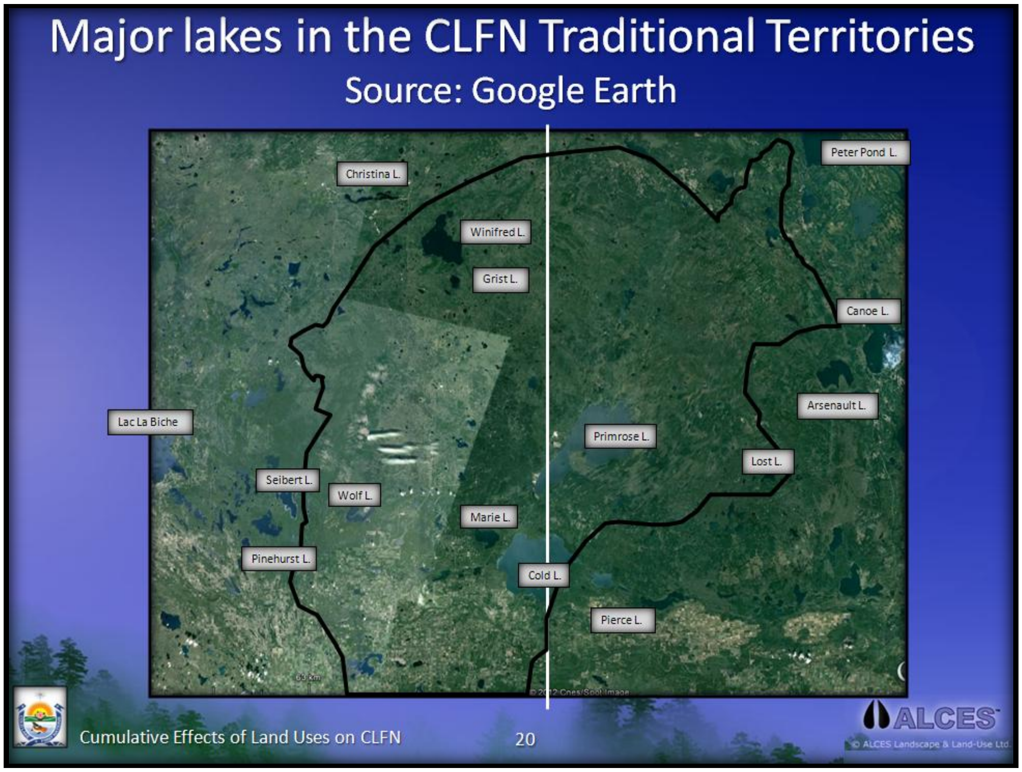
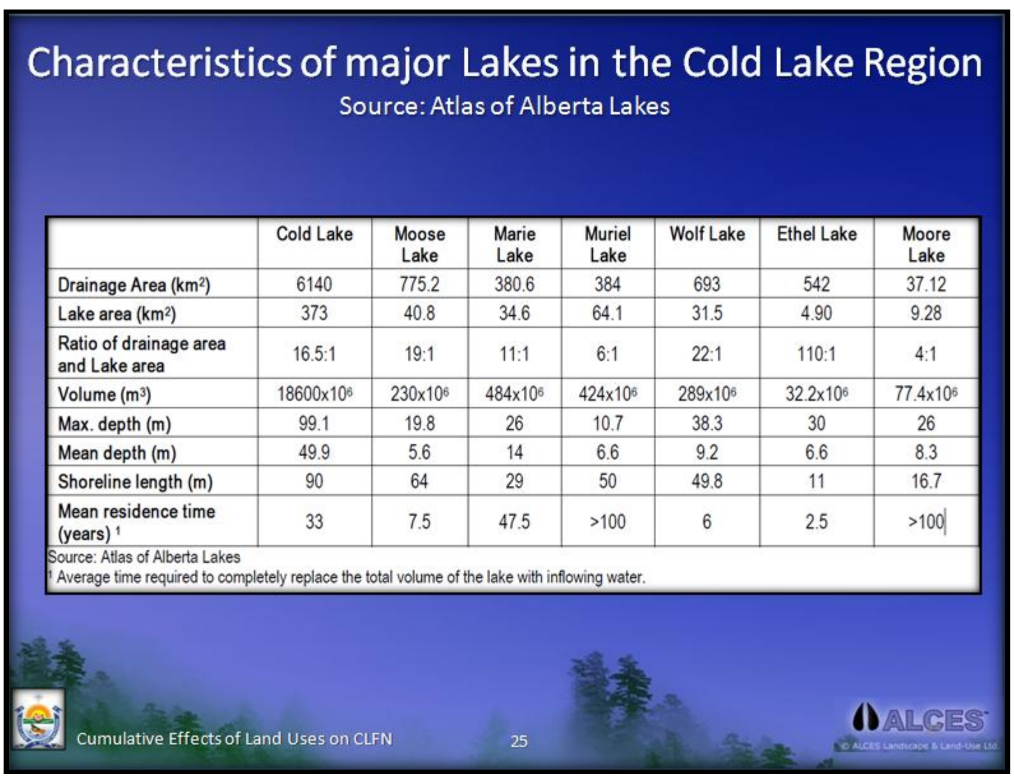


Figure 8. Some of the major lakes of the CLFN Traditional Territory. Source: Google Earth.


Characteristics of major Lakes in the Cold Lake Region

Source: Atlas of Alberta Lakes

	Cold Lake	Moose Lake	Marie Lake	Muriel Lake	Wolf Lake	Ethel Lake	Moore Lake
Drainage Area (km^2)	6140	775.2	380.6	384	693	542	37.12
Lake area (km^2)	373	40.8	34.6	64.1	31.5	4.90	9.28
Ratio of drainage area and Lake area	16.5:1	19:1	11:1	6:1	22:1	110:1	4:1
Volume (m^3)	18600x10^6	230x10^6	484x10^6	424x10^6	289x10^6	32.2x10^6	77.4x10^6
Max. depth (m)	99.1	19.8	26	10.7	38.3	30	26
Mean depth (m)	49.9	5.6	14	6.6	9.2	6.6	8.3
Shoreline length (m)	90	64	29	50	49.8	11	16.7
Mean residence time (years) [1]	33	7.5	47.5	>100	6	2.5	>100

Source: Atlas of Alberta Lakes

[1] Average time required to completely replace the total volume of the lake with inflowing water.

Figure 9. Characteristics of selected major lakes in the Cold Lake Region. Source: Atlas of Alberta Lakes.

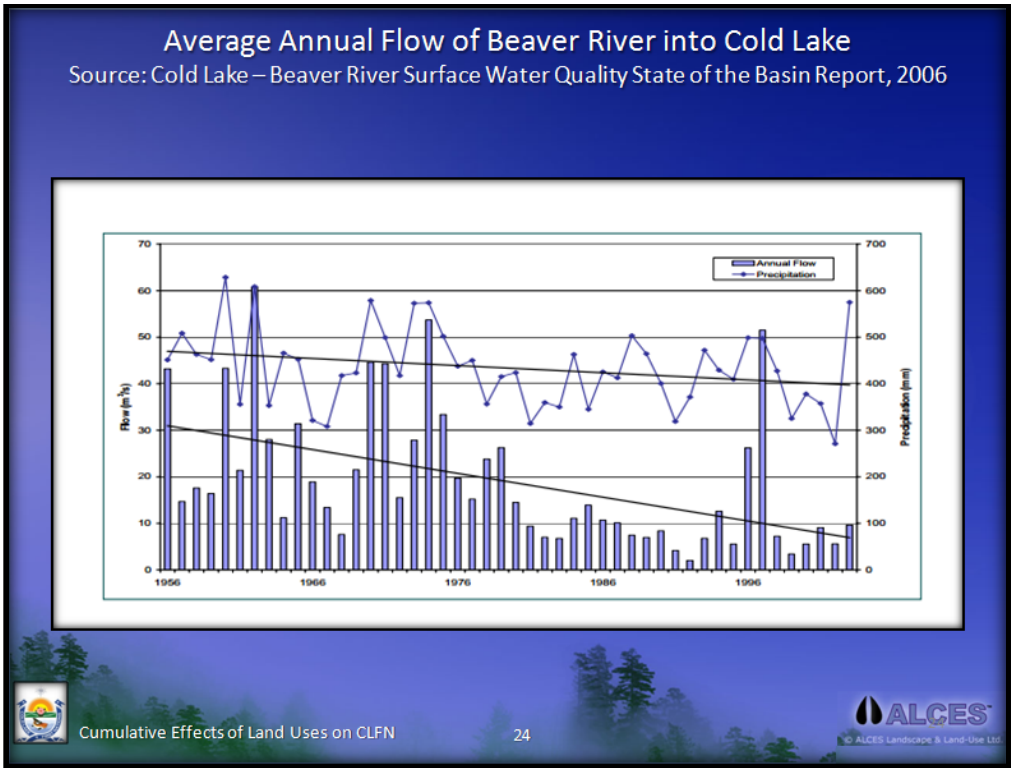
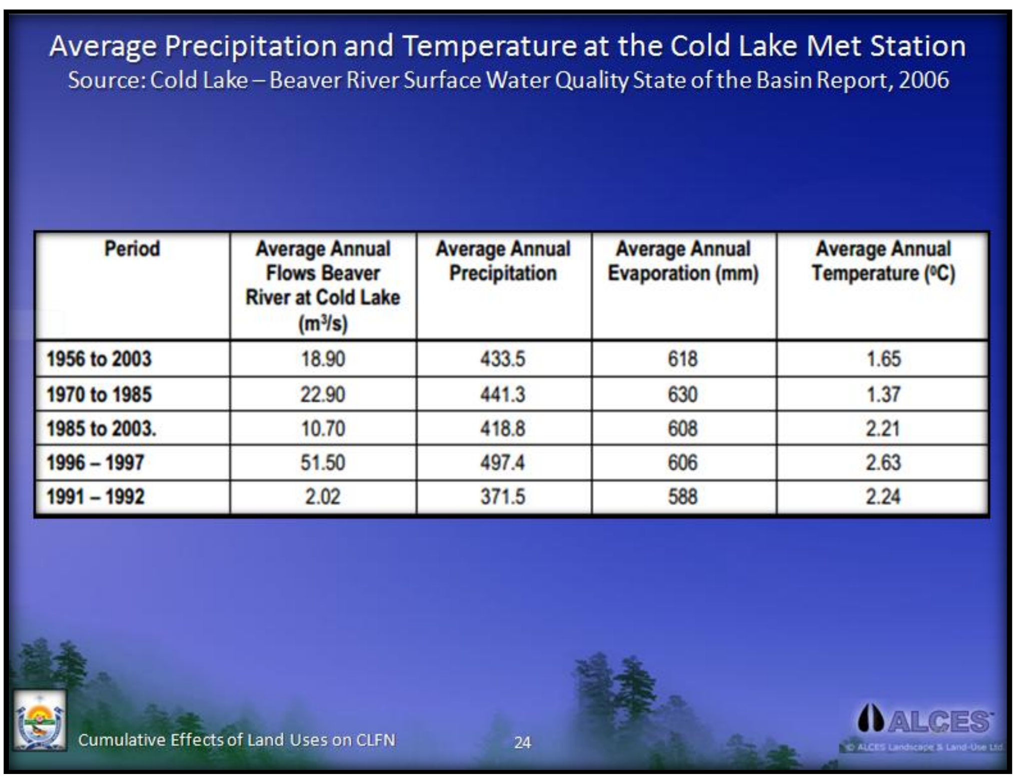


Figure 10. Temporal changes in precipitation and flow of Beaver River into Cold Lake. Source: Cold Lake – Beaver River Surface Water Quality State of the Basin Report, 2006.



Period	Average Annual Flows Beaver River at Cold Lake (m^3/s)	Average Annual Precipitation	Average Annual Evaporation (mm)	Average Annual Temperature (°C)
1956 to 2003	18.90	433.5	618	1.65
1970 to 1985	22.90	441.3	630	1.37
1985 to 2003.	10.70	418.8	608	2.21
1996 – 1997	51.50	497.4	606	2.63
1991 – 1992	2.02	371.5	588	2.24

Figure 11. Average annual precipitation, temperature at Cold Lake. Source: Cold Lake–Beaver River Surface Water Quality State of the Basin Report, 2006.

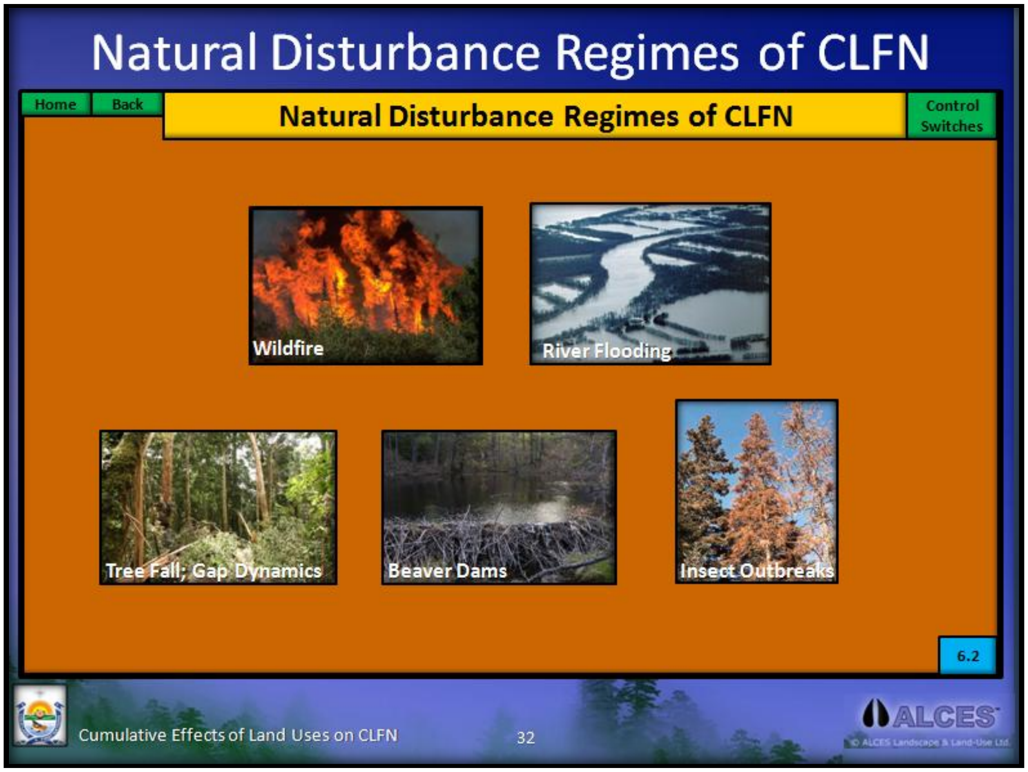


Figure 12. The natural disturbance regimes of the CLFN SA.

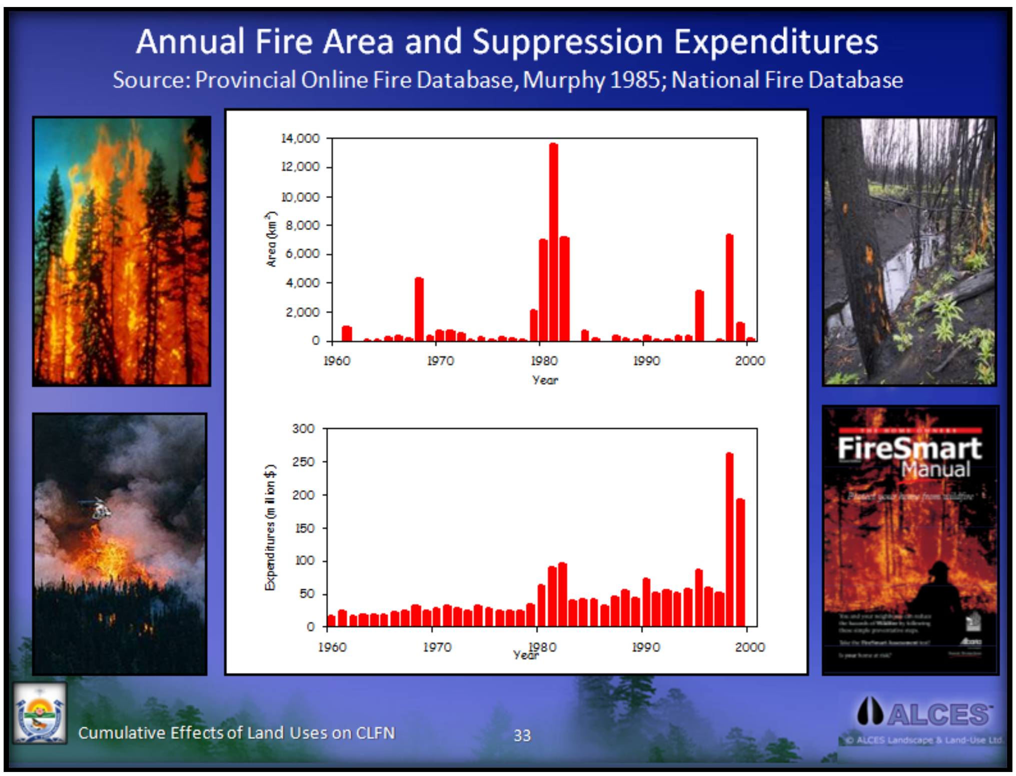


Figure 13. Annual area burned in Alberta, illustrating episodic nature of large fire events. Source: SRD Historical Fire Database.

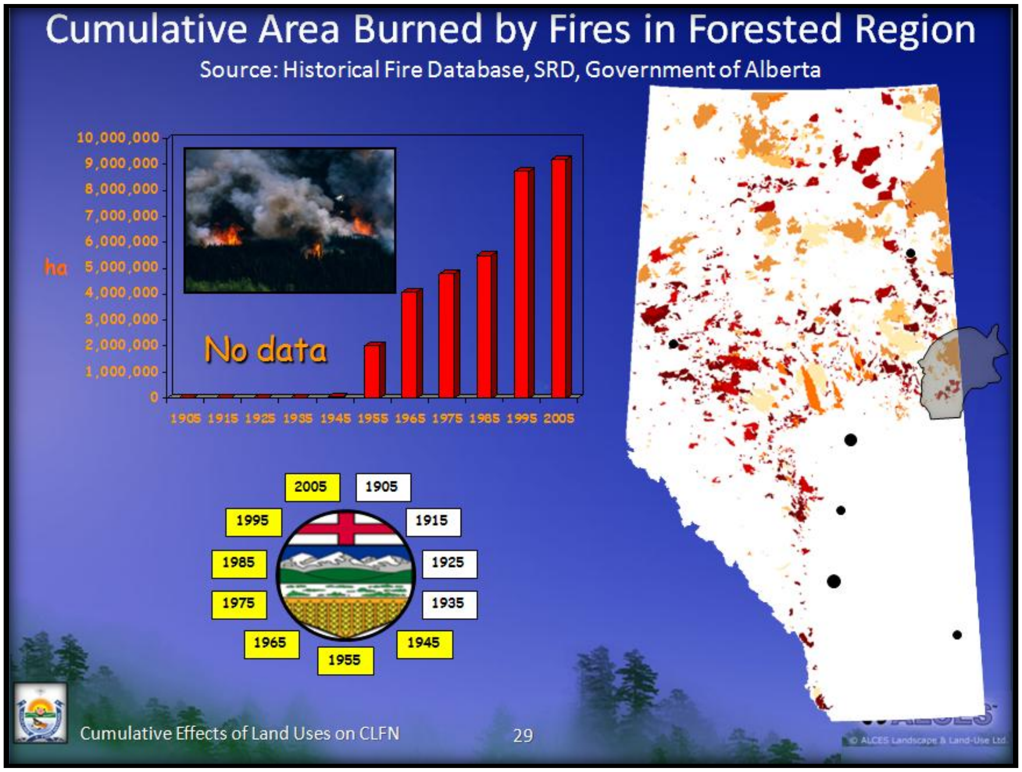


Figure 14. Cumulative area burned in Alberta and distribution of large fire events within CLFN SA. Source: SRD Historical Fire Database.

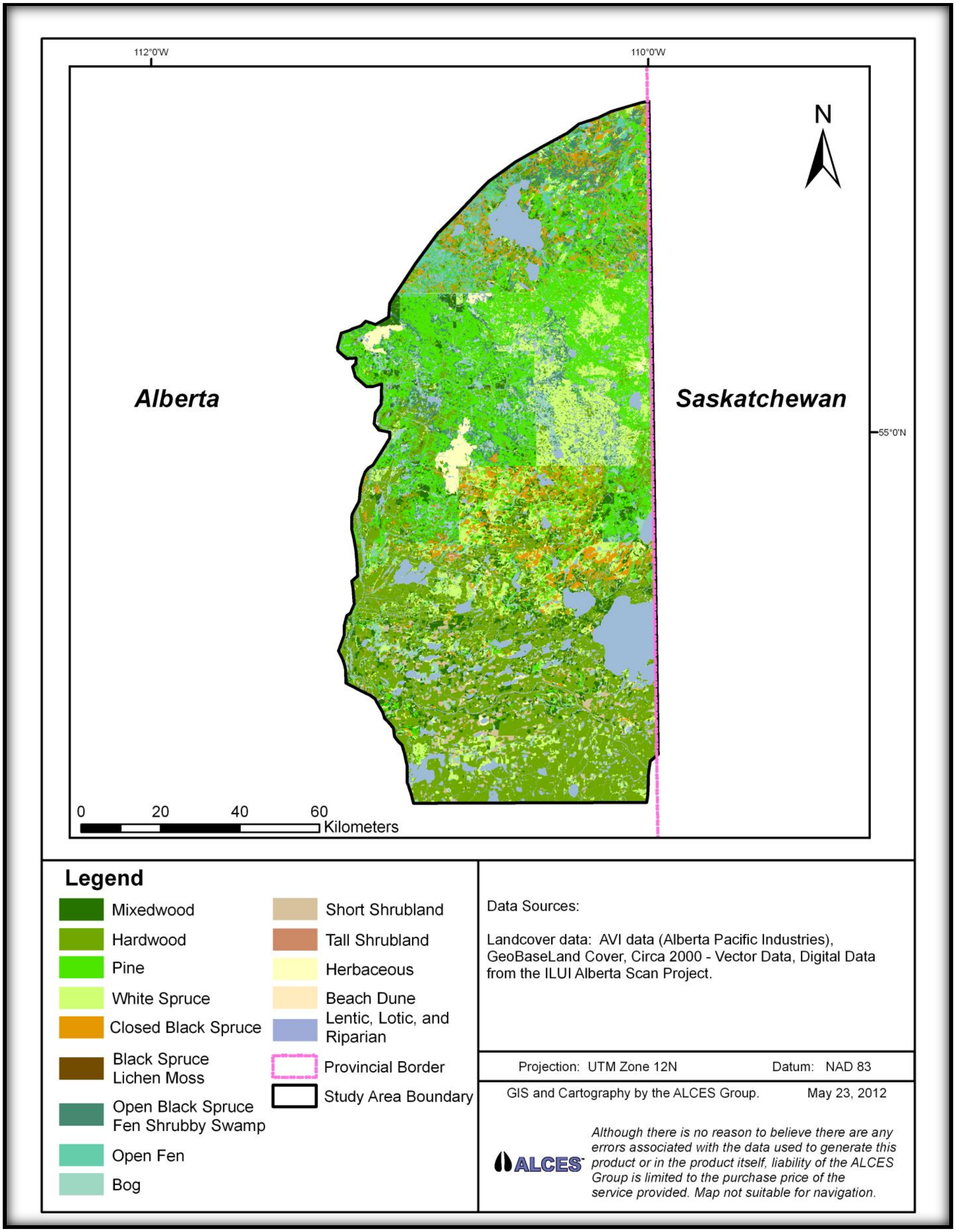


Figure 15. Pre-Industrial landscape composition of CLFN SA.

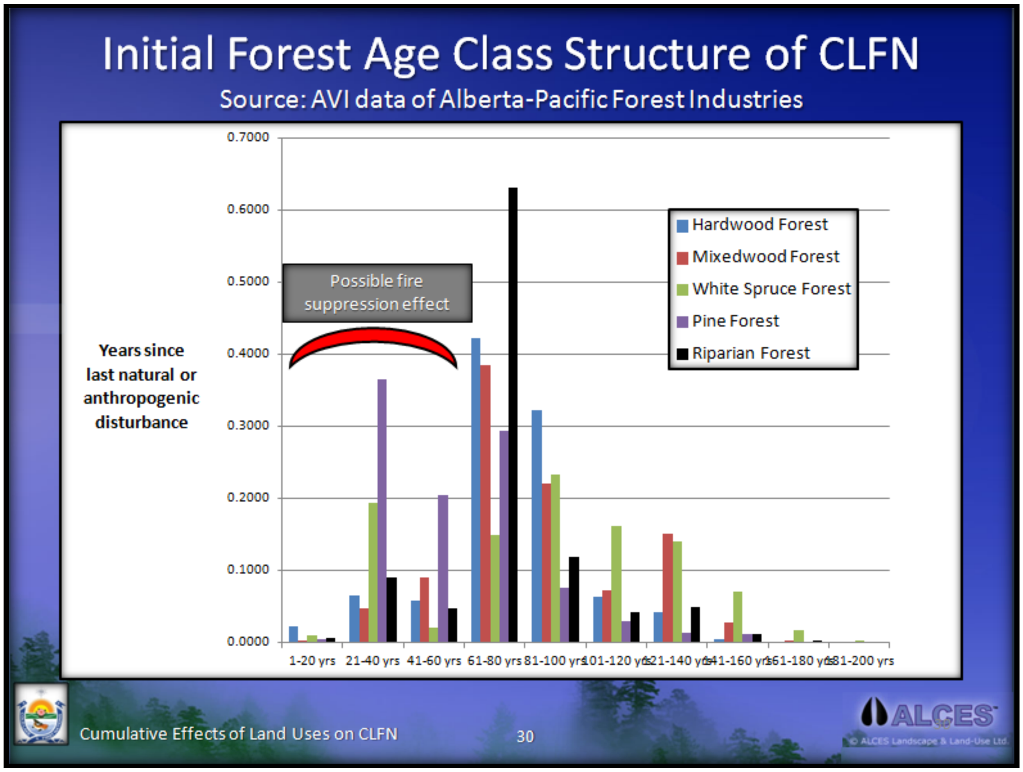


Figure 16. Initial forest age class structure of different forest types within CLFN SA.

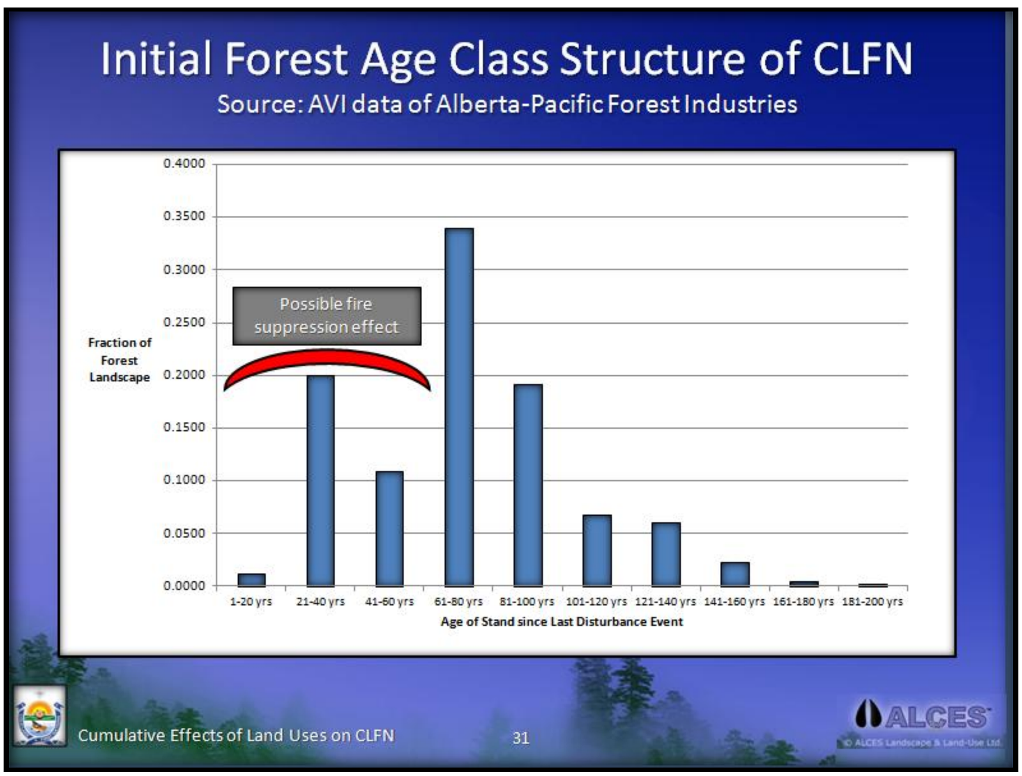


Figure 17. Initial forest age class structure of combined forest types within CLFN SA.

2.4 BIODIVERSITY

Alberta's boreal mixedwood forest landscape in which CLFN SA is located supports a diverse assemblage of organisms, including 40 fish species (Nelson and Paetz 1992), five amphibians (Russell and Bauer 1993), one reptile (Russell and Bauer 1993), 236 birds (Francis and Lumbis 1979; Semenchuk 1992), and 45 mammals (Pattie and Hoffmann 1992; Smith 1993). Taxonomic richness of arthropods in the boreal forest is poorly documented, but is believed to be remarkably high. For example, insect taxa in Canada's boreal forest have been estimated at 220,000 species, of which only half have been enumerated (Danks and Foottit 1989).

Based on distribution maps in Moss (1983) and Vitt et al. (1988), conservative estimates indicate a rich diversity of plants in Alberta's boreal mixedwood forests, including 600 vascular species, 17 ferns, 104 mosses, 13 liverworts, and 118 lichens.

The diverse assemblage of biota in the CLFN SA was instrumental to the sustenance, physical comforts, and spiritual welfare of the CLFN people. In contrast to the highly disaggregated approach adopted by most scientists, their world view of the regional landscape and its biotic components has been highly integrative.

3. THE CASE FOR CUMULATIVE EFFECTS ASSESSMENT

The landscape of the CLFN SA has been collectively, and incrementally, transformed by a suite of overlapping land-uses that include CLFN, residential, agriculture, Provincial Parks and Recreation Areas, and the sectors of oil, mining, transportation, and military (Figure 29).

Since the arrival of European culture to the CLFN SA, a series of land-uses have unfolded that have profoundly affected landscape composition and ecological function (Figure 18. Generalized sequence of arrival and magnitude of land-uses in the CLFN SA.). As described previously, each land-use has affected CLFN peoples in many ways, and impacted or constrained the ability of CLFN to continue their traditional activities on Traditional Territory. Individual human initiated projects, including each quarter section that has been or continues to be deforested for crops, each well and its associated seismic lines, wellpads and access roads, hectares of townsite expansion into adjacent boreal forest, new parks and new military projects, collectively explain the transformation and the suite of benefits and liabilities that impact CLFN peoples at a regional scale.

In setting a platform for discussion, it is also important to recognize that each of these land-uses currently exist in the Traditional Territory and are intended to increase in both area, intensity and productivity in the decades to come. This becomes clear when undertaking a cursory review of the business plans of the Government of Alberta (Alberta Agriculture, Alberta Energy, Alberta Transportation) and industrial associations (Canadian Association of Petroleum Producers, Alberta Beef Producers) which illustrate that management objectives are predicated on incremental growth in each of these sectors. As such, it is important to explore the consequences of these intended growth trajectories on a suite of social, economic, and environmental indicators.

The history of EIA’s in Canada and the current regulatory structure of ERCB emphasize and endorse a “project by project” approach to understanding land-use and its implications. This constrained view does not permit a full comprehension of historical, current and future land-use trajectories, or their risk/benefit ratios, and as such is not in the best public interest. The key conceptual differences between EIA’s and regional cumulative effects assessments are provided in Figure 21 and Figure 22. This report strives to adopt and implement the criteria of comprehensive cumulative effects assessments.

The consequences of adopting a project by project approach to land-use in the CLFN SA is illustrated for past (Figure 19) and a “potential” future (Figure 20) using the direct footprint of the energy sector. Because of analytical short-comings of EIAs with respect to comparative space and time, an EIA seldom concludes that any individual proposed project will have any significant effect at regional scales. Given that scientists generally adopt a confidence level of 5% when assessing the significance of a proposed project to be located on a regional landscape already populated with other projects, it becomes mathematically impossible to conclude that there will be a significant effect if the reference point is a contemporary one and not the pre-industrial conditions. Simply put, placing a few new land-use footprints on a large regional landscape already busy with activity, and then comparing the future condition to a reference point defined as today, cannot meaningfully reveal the true dynamics of land-use or their benefits and liabilities.

The next section (An Overview of Land-uses) chronicles the general history, pace, magnitude and distribution of land-uses within the CLFN SA. These materials are intended to assist the reader in understanding "meaningful" space and time when discussing issues relating to land-uses co-occurring on regional landscapes such as the CLFN SA.

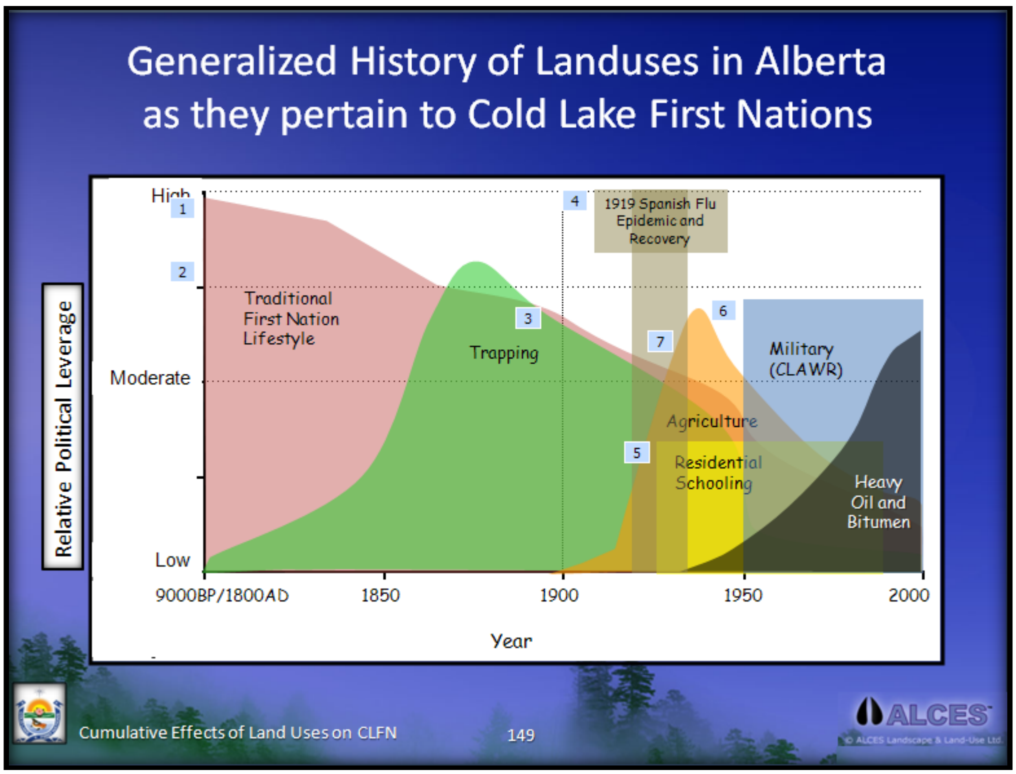


Figure 18. Generalized sequence of arrival and magnitude of land-uses in the CLFN SA.

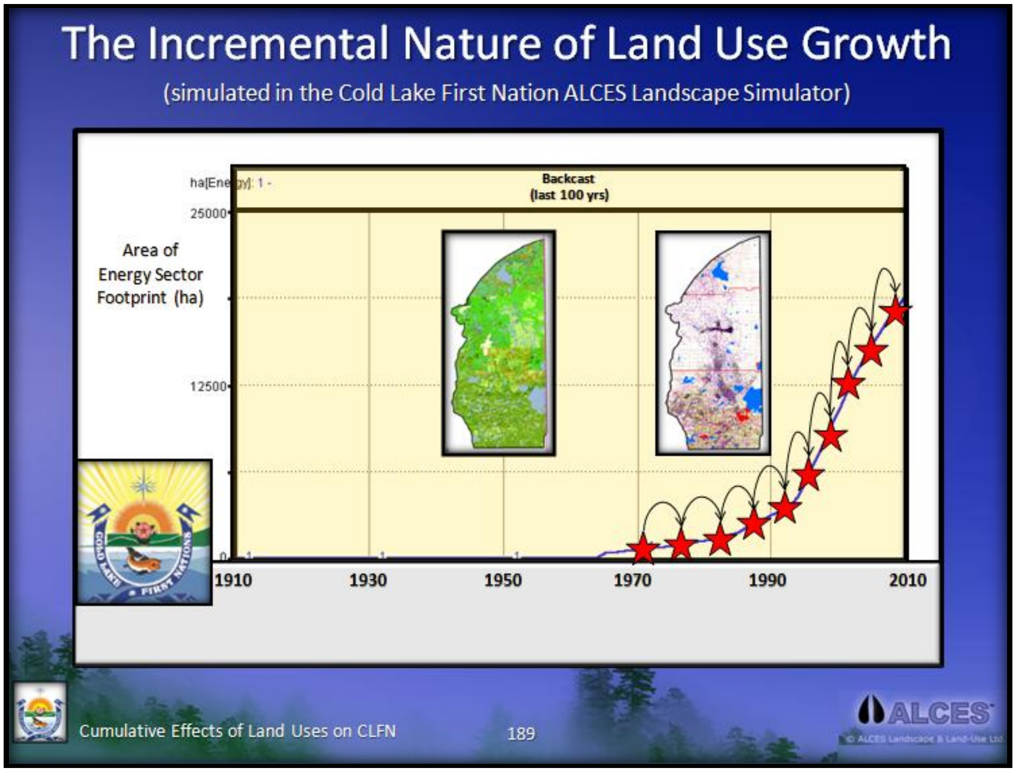


Figure 19. The simulated historical growth of the energy sector on CLFN using CLFN ALCES. Historical trend reveals the incremental and additive transformation of a landscape where projects are being considered one by one.

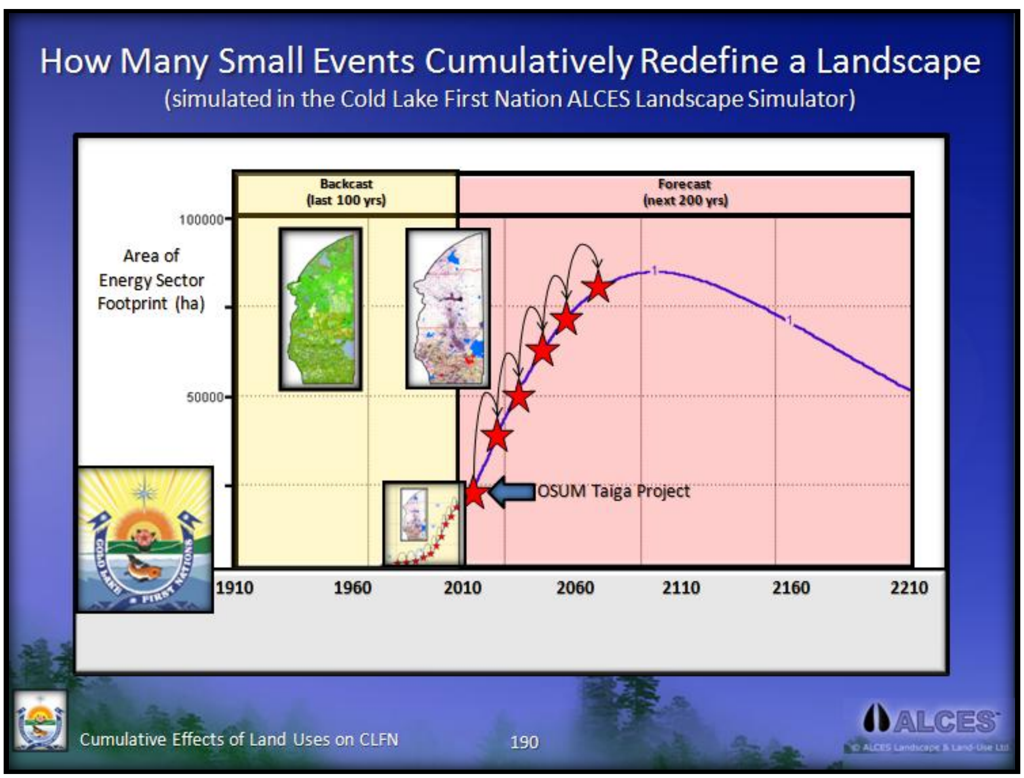
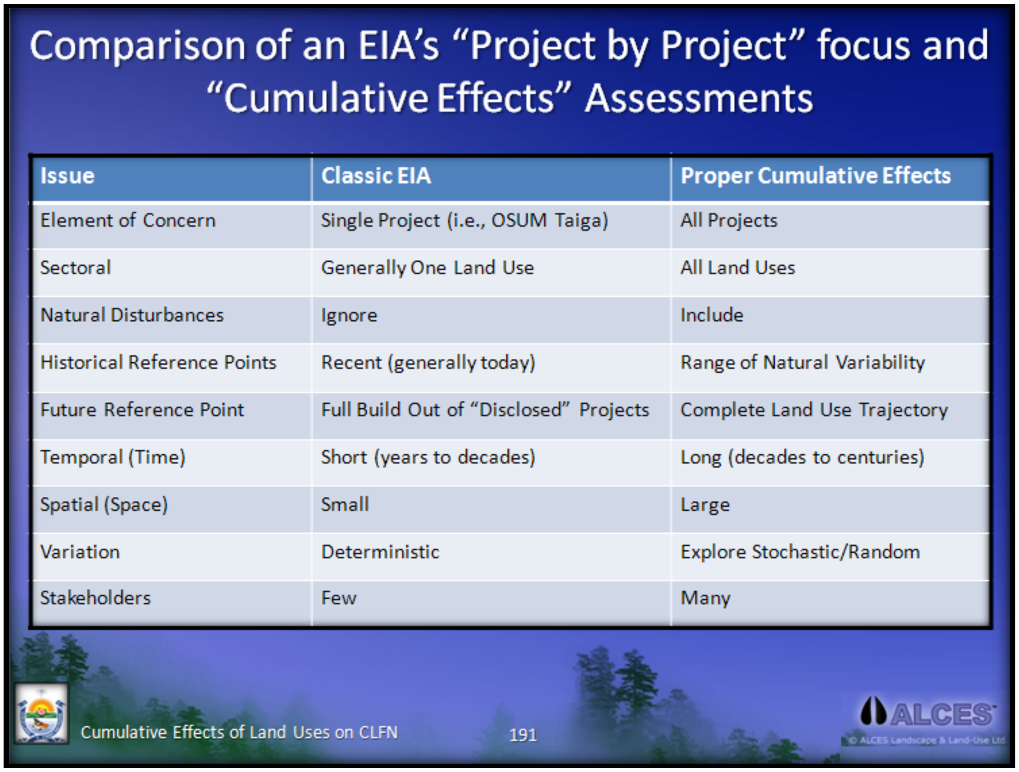


Figure 20. The cumulative effect of many consecutive small additions of land-use footprint lead invariably to a fundamentally transformed landscape.



Issue	Classic EIA	Proper Cumulative Effects
Element of Concern	Single Project (i.e., OSUM Taiga)	All Projects
Sectoral	Generally One Land Use	All Land Uses
Natural Disturbances	Ignore	Include
Historical Reference Points	Recent (generally today)	Range of Natural Variability
Future Reference Point	Full Build Out of "Disclosed" Projects	Complete Land Use Trajectory
Temporal (Time)	Short (years to decades)	Long (decades to centuries)
Spatial (Space)	Small	Large
Variation	Deterministic	Explore Stochastic/Random
Stakeholders	Few	Many

Figure 21. Key differences between the typical "project by project" EIA approach and a comprehensive cumulative effects assessment.

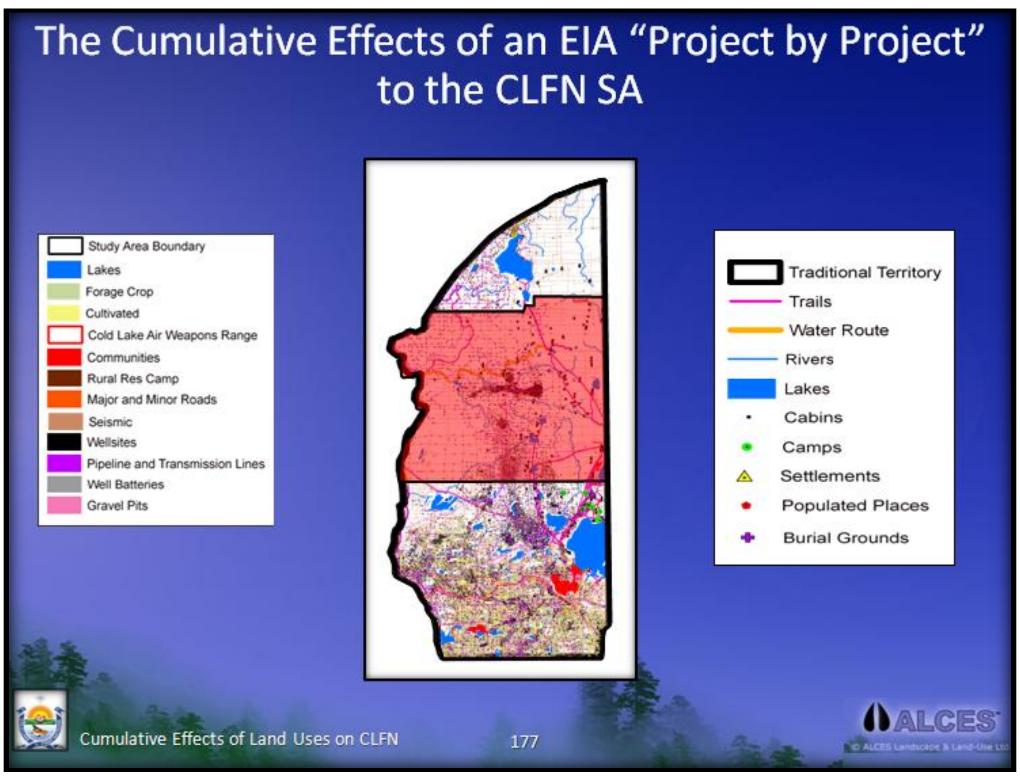


Figure 22. The conclusion of EIA's adopting a "project by project" approach is an incomplete conversation about both the benefits and liabilities that attend land-use.

4. OVERVIEW OF THE CLFN SA ALCES SIMULATORS

A detailed overview of the CLFN ALCES simulator and ALCES Mapper is provided in Appendix A. The descriptions which follow are general overviews of key components of these applications.

4.1 ALCES CLFN SIMULATOR

ALCES is a landscape cumulative effects model that simulates past, current and future landscape conditions, land-use footprints, reclamation and other indicators based on user-defined parameters. As noted above, ALCES is not a predictive model; it allows users to define land-use scenarios and project their potential outcomes into the future. The model enables users to explore and quantify dynamic landscapes affected by single or multiple human land-use practices and various natural processes such as fire, insects and flooding.

ALCES assists resource managers, planners and approval agencies by:

- Tracking land-use footprints created by, resources consumed by, and economic contributions of, different land-use practices,
- Identifying the response of ecological, social, and economic indicators to natural and land-use related change,
- Evaluating mitigation strategies to reduce or avoid undesirable effects on ecological (e.g. inferred water quality), social (e.g. population), and economic (e.g. employment and royalty revenues) indicators.

The architecture of the ALCES model is based on the following key concepts:

- The size of the study area can never change.
- The composition of the landscape can be highly dynamic, influencing all aspects of ecological, social, and economic performance of the study area.
- The dynamics of landscapes and key indicators are shaped by a suite of overlapping natural disturbance regimes (fire, insects, meteorology) and anthropogenic (human) land-uses (residential, transportation, cropland agriculture, livestock agriculture, forestry, energy, mining, tourism, hunting, fishing and trapping).
- Each of these natural disturbance regimes and land-uses is simulated separately in ALCES but can influence the behaviour of other land-uses through changes to landscape composition and related values such as natural resources (e.g., timber supply, wildlife, tourism potential).
- Effective landscape planning requires the active participation of all meaningful stakeholder groups (or disciplines) in the planning process.
- To be effective at assisting stakeholders in the development of sustainable land-use plans, ALCES must be able to report on a broad suite of indicators (social, economic, ecological).

- Although the precise future is unknowable, exploration of the logical consequences of a plausible land-use scenario allows managers and regulators to better identify management strategies that are consistent with societal objectives.

ALCES utilizes a spatially stratified approach to tracking land-use activities and natural disturbance regimes. The model stratifies landscapes based on up to 20 user-defined ‘landscape types’ and up to 15 user-defined ‘land-use footprints’. Although ALCES tracks footprints within each landscape type separately, it does not track the explicit geographic location of these features (e.g., latitude and longitude). This modelling approach greatly speeds up processing time (less than 1 second per simulation year) relative to a spatially explicit modelling approach, and makes it possible to simulate complex scenarios involving numerous overlapping land-uses and footprints.

A schematic showing the main types of ALCES inputs and outputs is provided in Figure 23.

The underlying structure of the ALCES model is depicted in Figure 24 and Figure 25. For each land-use operating in a region, the user defines past and future development rates, the portion of the landscape available for development, and management practices such as the intensity and lifespan of associated industrial footprints. Average rates and ranges of precipitation, temperature, fire, and insect outbreak must also be defined to simulate natural processes.
A hydrological model tracks the consequences of precipitation, runoff, evapotranspiration, infiltration, inflow, outflow and water use to standing water, flowing water, and groundwater. Forest succession is represented by changes in plant biomass, composition, and structure with time since disturbance. Climate change effects can be incorporated by defining temporal changes in natural disturbances rates, successional trajectories, land cover, meteorology, and hydrology.

The first-order effects tracked by ALCES are landscape composition and resource production/supply. Using an annual time-step (although monthly time steps can be used for the meteorology module) the model calculates changes in the area and length of each landscape and footprint type in response to natural processes and disturbances, landscape conversion, reclamation of footprints, and creation of new footprints associated with simulated land-use trajectories. ALCES also tracks resource production and supply using approaches that are typical of sector-specific models such as forestry timber supply models and the Hubbert-Naill life cycle approach for simulating exploitation of hydrocarbon deposits (Naill 1973). By tracking resource supply, ALCES can reduce or stop the expansion of a land-use if resource supply becomes inadequate. Changes to water quantity are also tracked by applying water use coefficients associated with each land-use.

Landscape condition and resource production attributes are translated into indicator variables using coefficients. A wide range of indicators are available so that trade-offs between diverse ecological and socio-economic objectives can be assessed. Types of indicators that can be tracked by ALCES include: water quality and quantity, employment, gross domestic product, biotic carbon storage, air emissions, wildlife habitat and populations, and social indicators such as family income and educational attainment.

Many variables act as ‘drivers’ of landscape change, with some potentially having a more significant effect than others. Through the evaluation of indicators, the relative influence of land-use activities and practices (e.g., residential, military, agricultural, energy, or recreation), natural disturbance regimes (e.g., fire or floods), and climatic effects (e.g., climate change) may be isolated and examined. In this manner, ALCES provides a framework for evaluating the significance of different natural and human land-use factors.

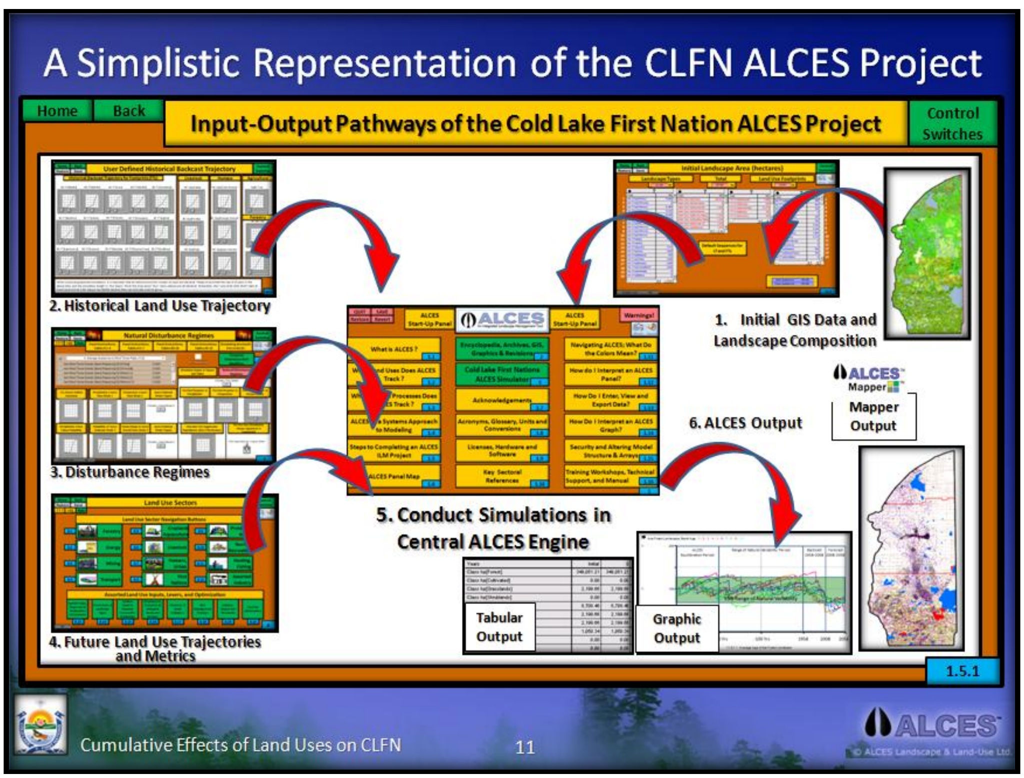


Figure 23. Schematic summarizing ALCES model inputs and outputs.

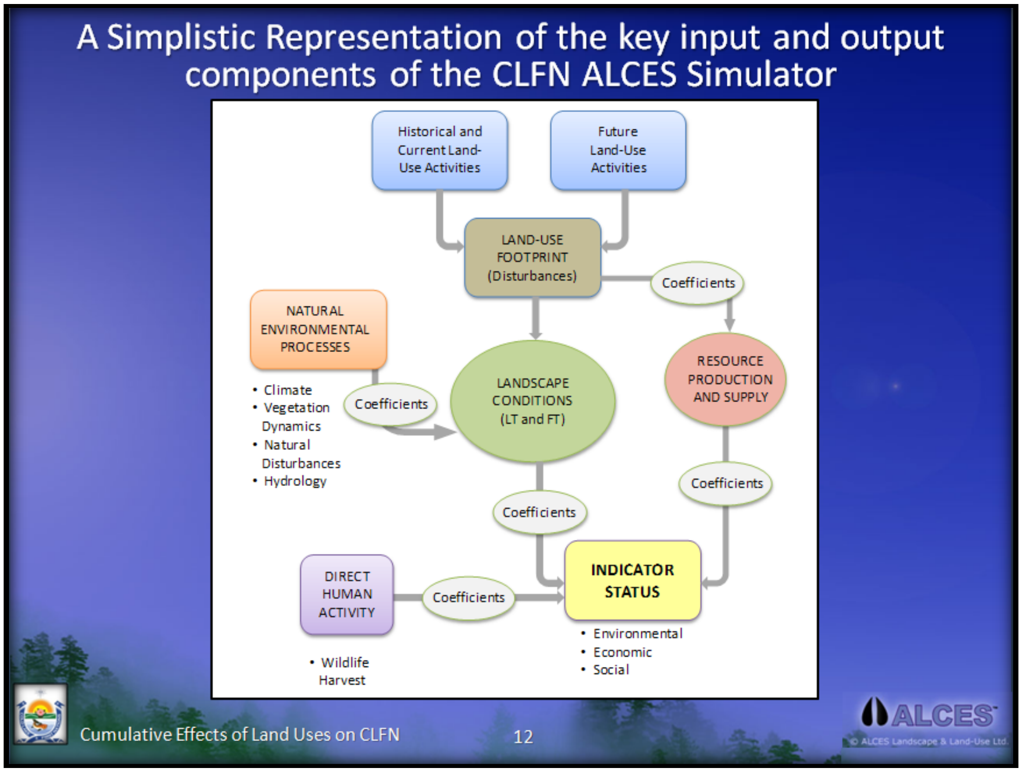


Figure 24. Underlying structure of the CLFN SA ALCES dynamic landscape model.

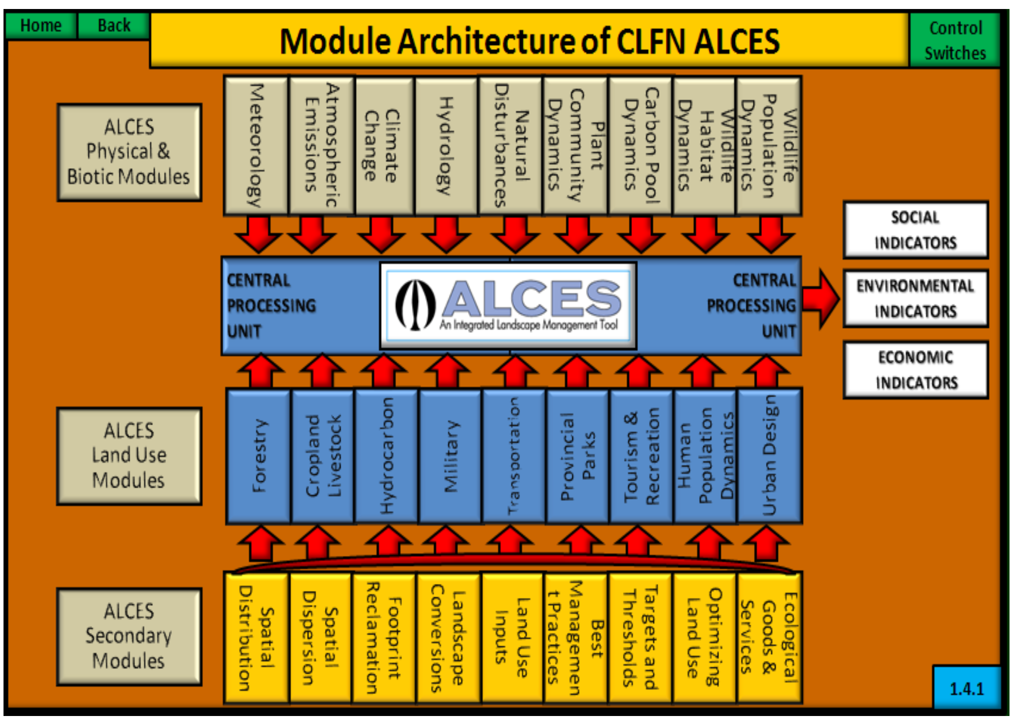


Figure 25. Modular structure of the CLFN ALCES simulator.

4.2 ALCES MAPPER

ALCES Mapper™ is the companion mapping application for the ALCES® model. As an ArcGIS extension, ALCES Mapper™ generates maps illustrating the plausible location and extent of future land-use features and landscape types based on ALCES® outputs. ALCES Mapper™ is capable of generating maps of landscape types, footprint types, forest age, disturbed area, and other derived indicators (e.g., caribou finite rate of population increase, oil and gas production, wildlife habitat quality, water demand, etc.) as in Figure 26.

ALCES Mapper™ requires two primary inputs: 1) geographic information system (GIS) data quantifying the study area landscape type and footprint type composition and spatial distribution, and 2) output data from the ALCES® model. The same GIS data that are summarized for the purpose of populating the ALCES® model are used by ALCES Mapper™. ALCES® output data is provided in the form of a structured input table with multiple worksheets. ALCES Mapper™ divides the study area into grid cells of user-defined size, and then calculates the landscape and footprint composition within each cell. The rates and proportions of land-use features, landscape types, natural disturbances, commodity production and other variables as reported by ALCES® are then applied to each cell, tracked, and displayed spatially by ALCES Mapper™.

The frequency and reporting interval of the ALCES Mapper™ outputs (i.e., time-steps) is user-defined. Additionally, ALCES Mapper™ allows users to specify the general location (i.e., where specified land-use footprints can or cannot occur) and the pattern of growth and reclamation of land-use features based on the rates and amounts generated by ALCES®. This feature provides flexibility to build landscapes with different ‘spatial rules’, and is useful for visualizing different zoning or resource utilization strategies. The ability to define logical land-use feature locations ensures that footprints like in-situ bitumen development are constrained to areas of economic deposits or areas with high potential. The spatial constraint masks used in the CLFN ALCES project are illustrated in Figure 27. Similarly, industrial footprints can be excluded from protected or culturally significant areas.

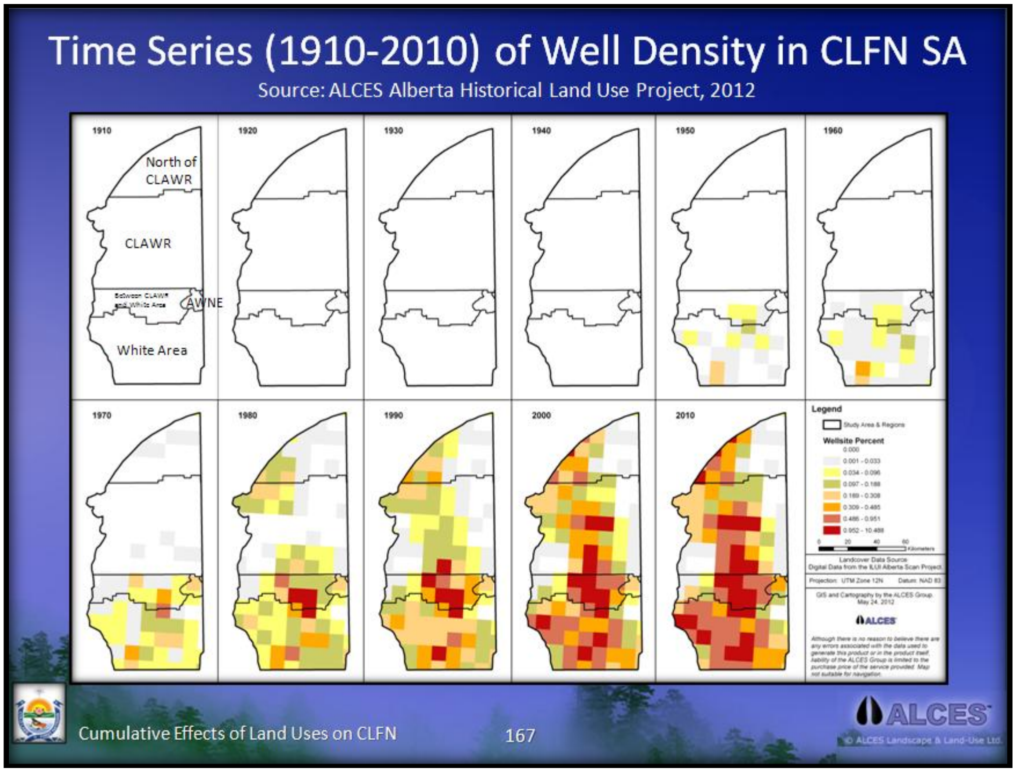


Figure 26. Example of ALCES Mapper output for time series of well density on CLFN SA.

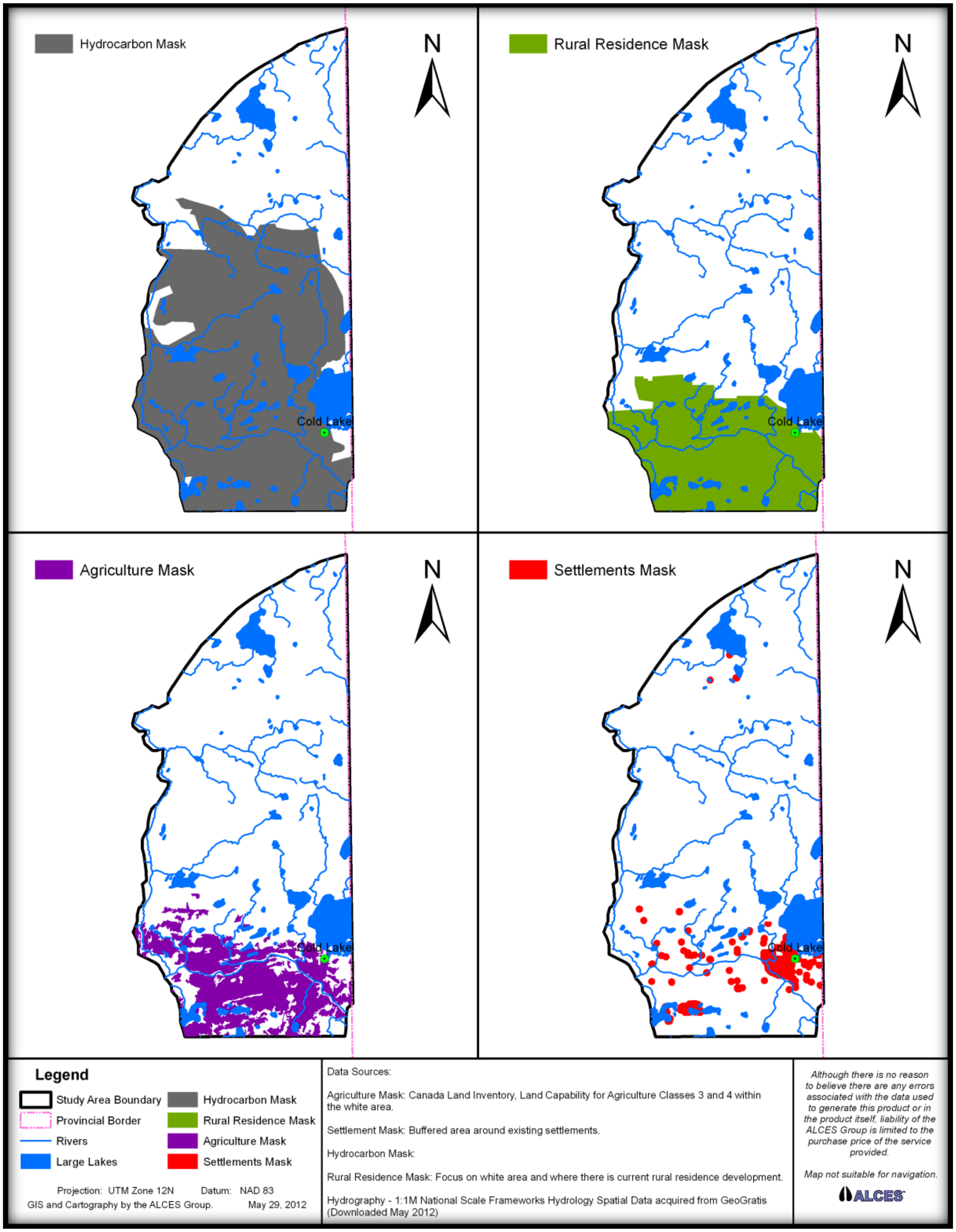


Figure 27. Spatial inclusionary masks used for expansion of agriculture, rural residential, settlements and hydrocarbon footprints in CLFN SA.

5. AN OVERVIEW OF LAND-USES

The land-uses that have collectively shaped the CLFN SA are First Nations, trapping, agriculture (both crops and livestock), the hydrocarbon sector, provincial parks, military, settlements and transportation (Figure 28).

Collectively, these land-uses have created ~152,000 ha (Figure 29) and 52,000 km (Figure 30) of direct footprints (croplands, roads, wellpads, seismic lines, settlements, rural residential, gravel pits) or have caused regulatory changes that have affected CLFN over very large area (Parks: 6,643 ha; CLAWR: 470,000 ha).

The following sections describe at a synoptic level the history and current status of each of these land-uses.

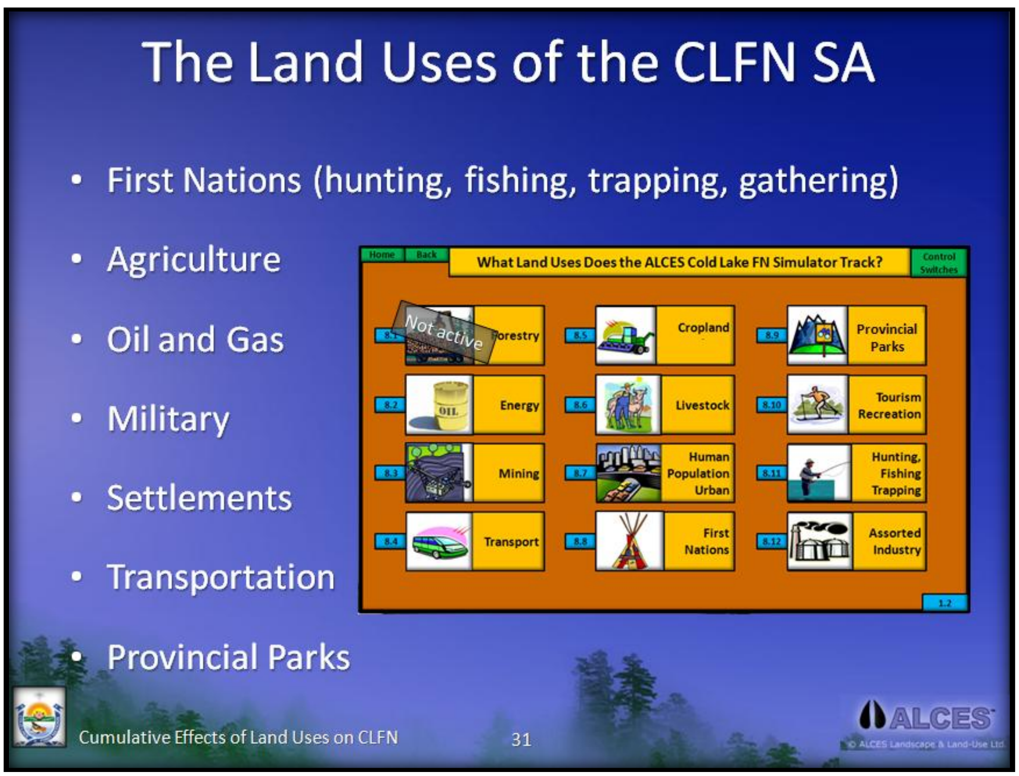


Figure 28. The overlapping land-uses that are collectively shaping the CLFN SA.

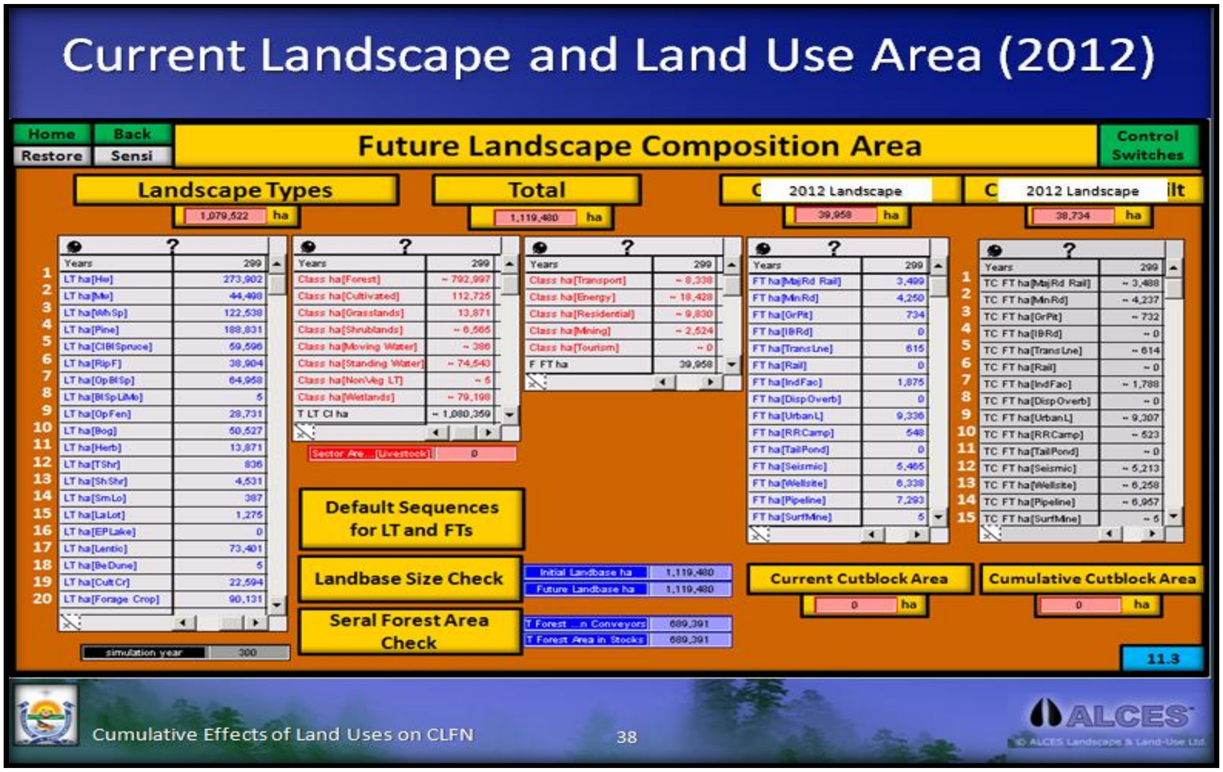


Figure 29. Current landscape composition of the CLFN SA.

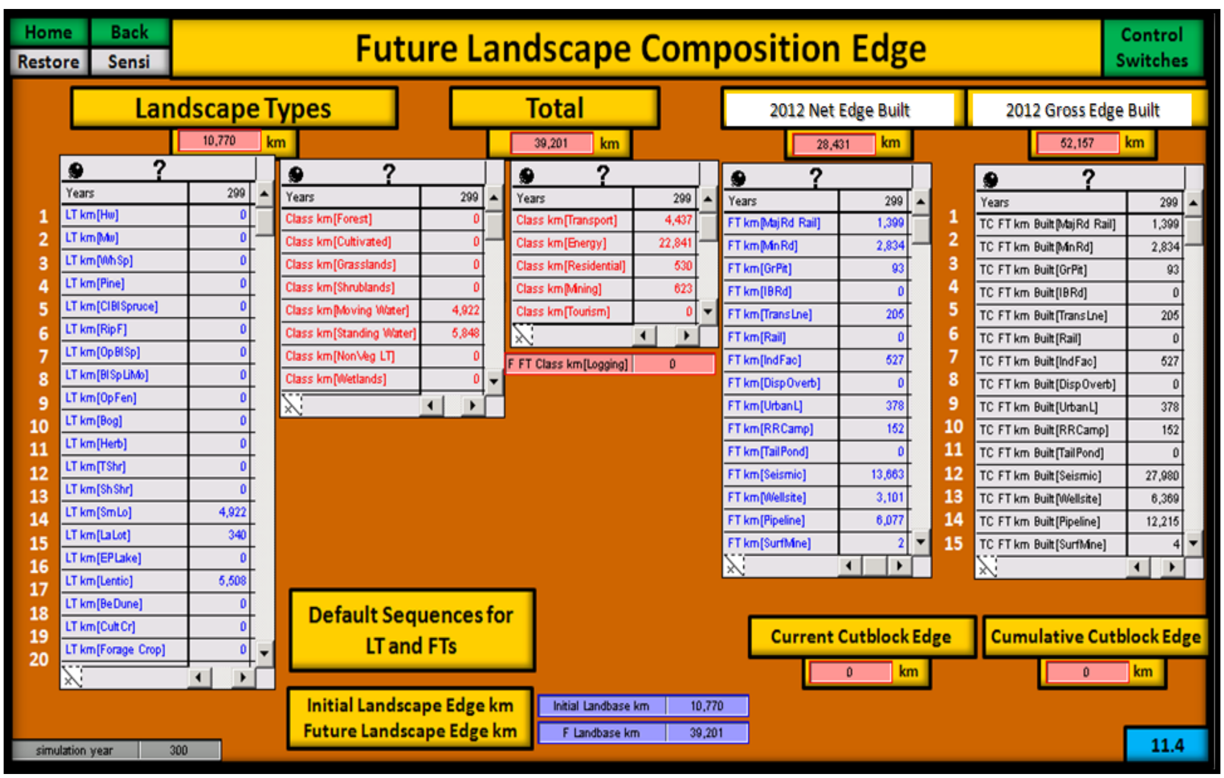


Figure 30. Current land-use edge of the CLFN SA.

5.1 FIRST NATIONS

The *Densuline* peoples of Cold Lake First Nations (Figure 31, Figure 32) have resided in the boreal mixed wood forests of east central Alberta for approximately 10,000 years. For 98% of this time, they existed as nomadic Hunter-Gatherers whose distribution and activities (Figure 33) were shaped by seasonal and inter-annual variation in climate, and the diversity of landforms that comprised this landscape. The CLFN/*Denesuline* community's pre-European era numbers likely fluctuated from a few hundred to a few thousand. Represented by a collection of nomadic family clans, their continuous movements (Figure 35) across a traditional network of trails and non-permanent settlements (Figure 37, Figure 40, Figure 41) reflected their need to find and harvest populations of moose, fish, and berries (among other foods, medicines and resources). As food resources would become locally depleted, these nomadic groups would continue their traditional movements, locating new food sources elsewhere, and allowing depleted areas to recover. The vast area of their Traditional Territory, and the low density of their numbers, allowed for a "spatial-temporal" system of movement and food harvest that was sustainable in time and space. Locations of important cultural activities in CLFN SA are shown in Figure 34 and more specifically in the Cold lake and Primrose Lake regions in Figure 38 and Figure 39.

Approximately 200 years ago the arrival of Europeans to the CLFN region catalyzed a series of incremental land-use changes that continues today. The inclusion of CLFN into the trapping industry substantively altered their economy and social fabric, but still allowed them to continue a dynamic lifestyle that was based on the land and the natural resources of the boreal forest. Both the CLFN and the wildlife upon which they depended relied heavily on the ability to migrate in poorer weather, and follow ancient migratory trails or seasonal indicators to seek better resources. The migration of people and animals are closely associated with the cultural milestones in traditional lifestyles and land management, and prompt cultural ceremonies or activities. The signing of Treaty Six in 1876 ushered in a new era that introduced CLFN to the concept of Treaty Reserve lands and would later lead to partial restrictions of movement. The arrival of permanent communities of Europeans and agriculture in the southern reaches of their Traditional Territory altered the southern portion of their landscape and its capacity to sustain traditional activities. During this period, some members of the CLFN community became active members of the farming and livestock industries.

In 1952, a land-use decision by the Governments of Canada and Alberta profoundly affected the peoples of CLFN. The establishment of the Cold Lake Air Weapons Range (CLAWR, also referred to as Primrose Air Weapons Range), ~470,000 ha (within CLFN on the Alberta side) and located in the middle of their Traditional Territory, prevented the CLFN from accessing the central portions of their traditional lands and made it logistically difficult to gain access to the northern regions. When the CLAWR was closed to the public in the late summer of 1954, "the economy of Cold Lake communities collapsed almost immediately." (Indian Claims Report, 1994, p. 75).

The advent of forced residential schooling starting in the 1920s caused a permanent discontinuity in community structure and inter-generational transfer of traditional knowledge. This discontinuity is reflected among differences expressed by elders and younger generations, whose aspirations for traditional lifestyles and participation in cash economies now sometimes clash.

Squeezed between expanding agriculture to the south and an exclusionary military land-use to the north (Figure 36), CLFN members struggled during the past 6 decades to maintain some semblance of traditional activities in a small sub-region that is currently undergoing a massive transformation caused by the hydrocarbon sector. The emergence of the heavy oil sector in the 1960s, and more recently a bitumen development play, has lead to a dense network of seismic lines, wellsites, access roads, processing plants, and pipelines across much of southern half of the CLFN SA (Figure 78, Figure 79, Figure 80). Collectively these energy sector footprints have fragmented the boreal forest landscape (Figure 78, Figure 79, Figure 80), creating an abundance of roads and other linear features, but also restricting access by CLFN to traditional lands through the establishment of gates and other obstructions.

The current network of reserves in CLFN (Figure 42, Figure 43) contains a level of land-use intensity that is visibly lower than the surrounding industrial (agricultural, energy, transportation, settlement) matrix.

Figure 31. A few key descriptions of the peoples of Cold Lake First Nations.

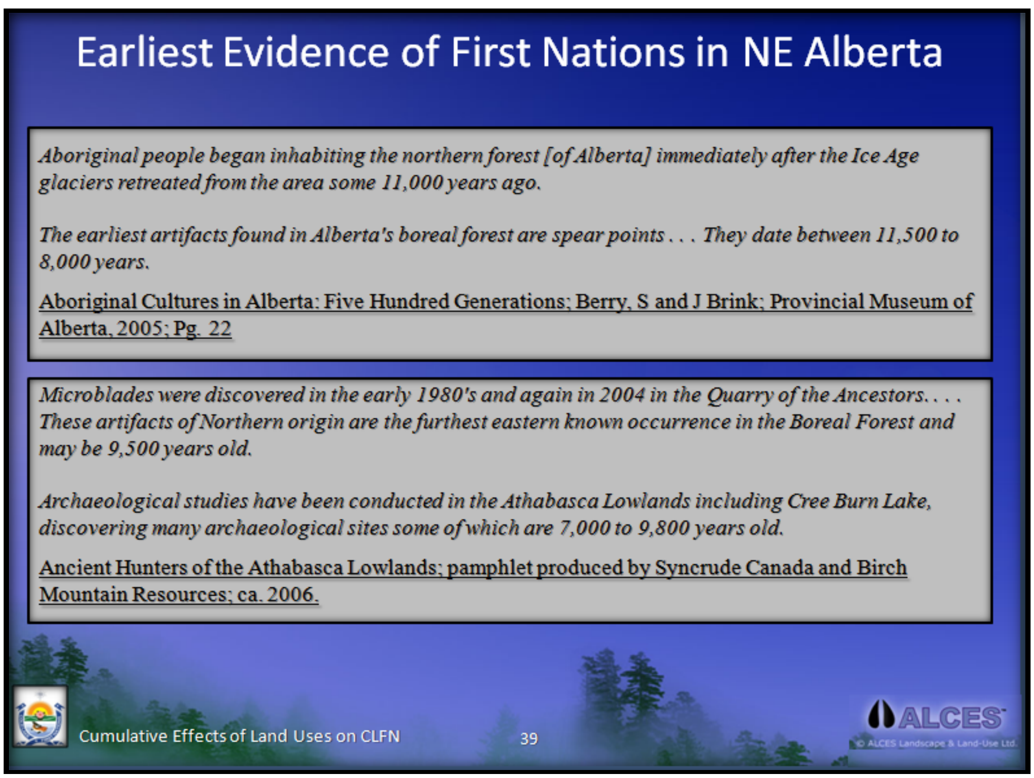


Figure 32. Earliest evidence of First Nations in northeast Alberta.

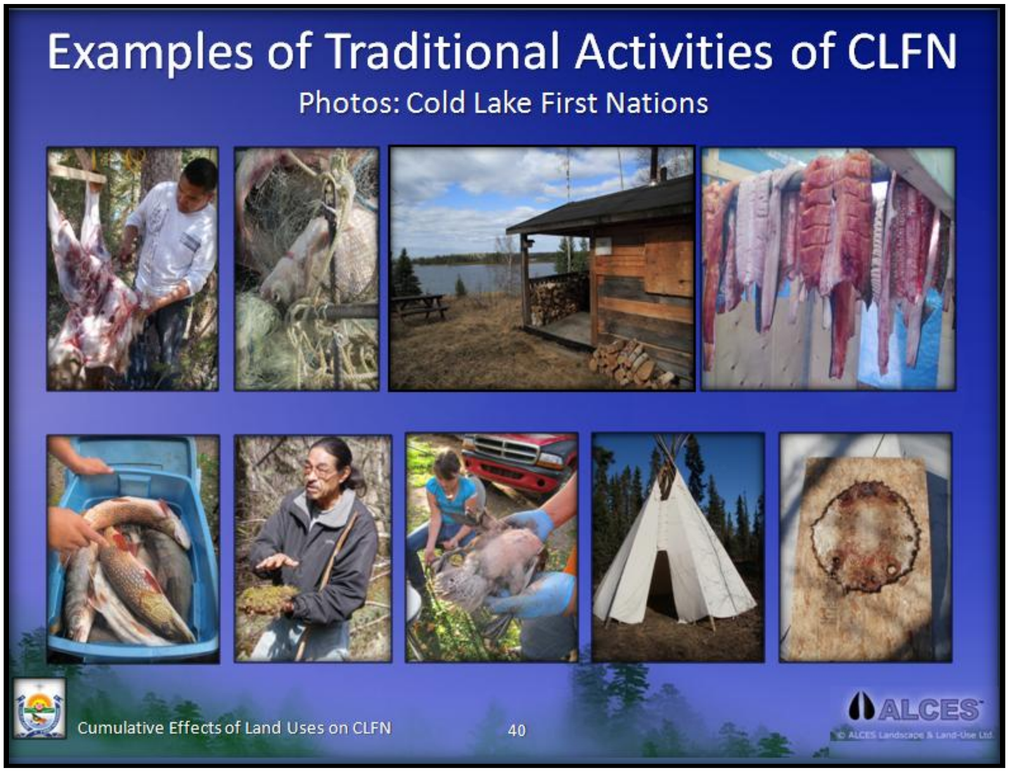


Figure 33. Examples of traditional activities of CLFN.

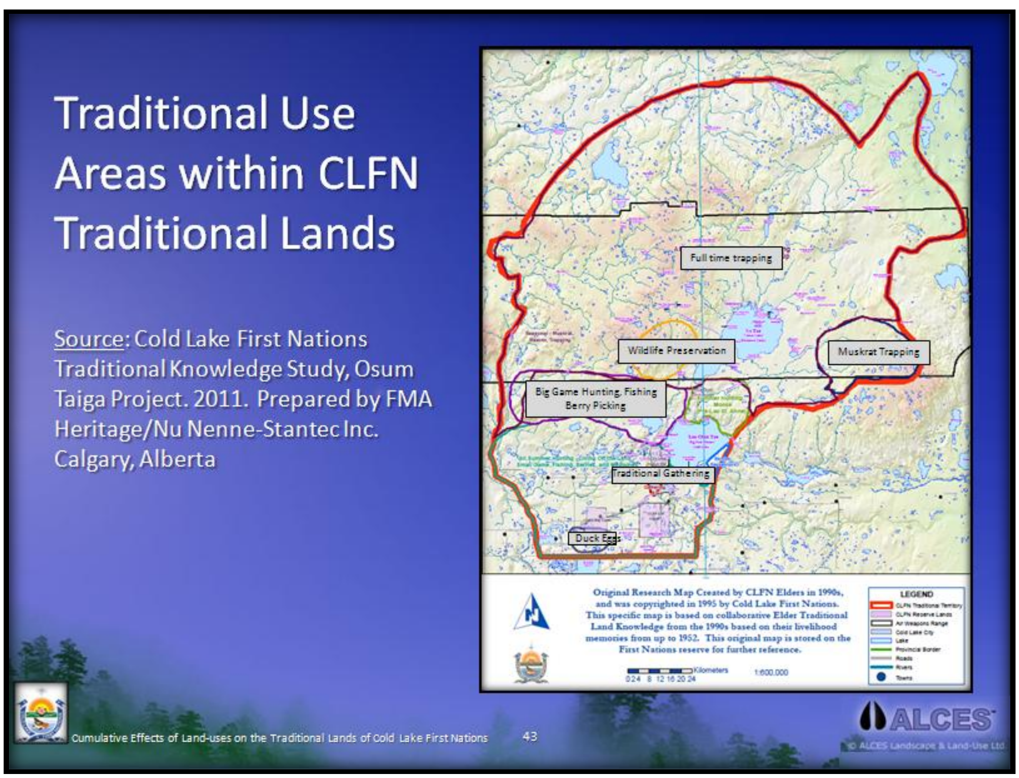


Figure 34. Examples of the geography of traditional activities of CLFN traditional lands. Source: Cold Lake First Nations Traditional Knowledge Study, 2011.

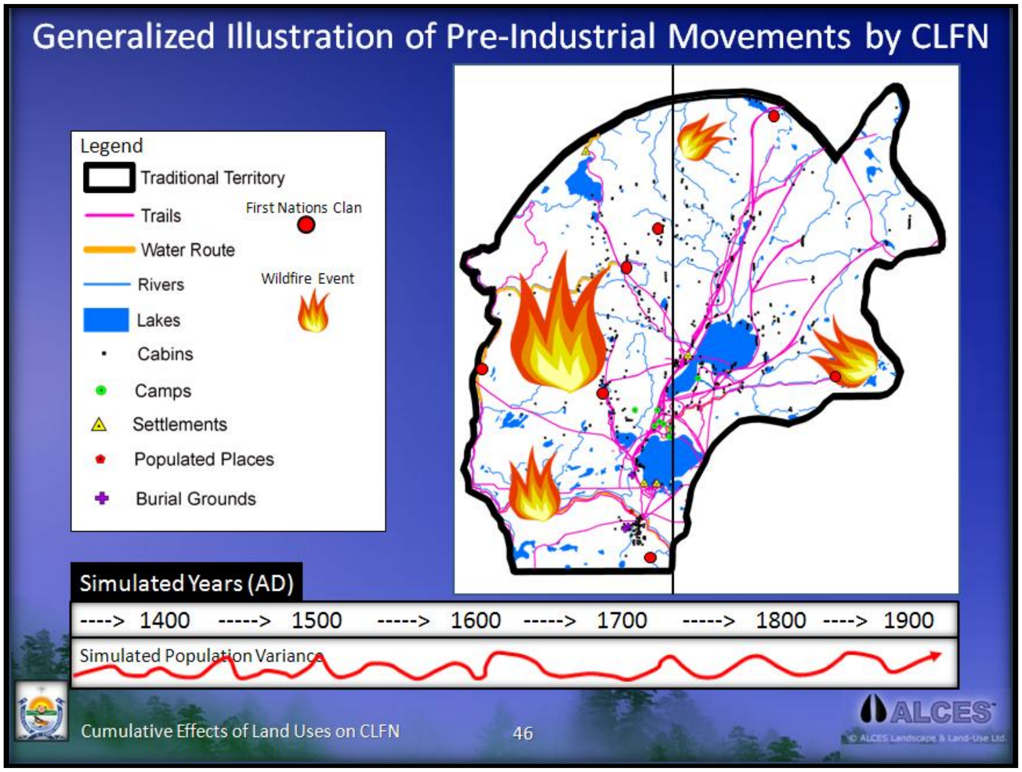


Figure 35. Generalized map, for illustration only, showing possible movements of CLFN bands in response to spatial-temporal variation in fires and food abundance.

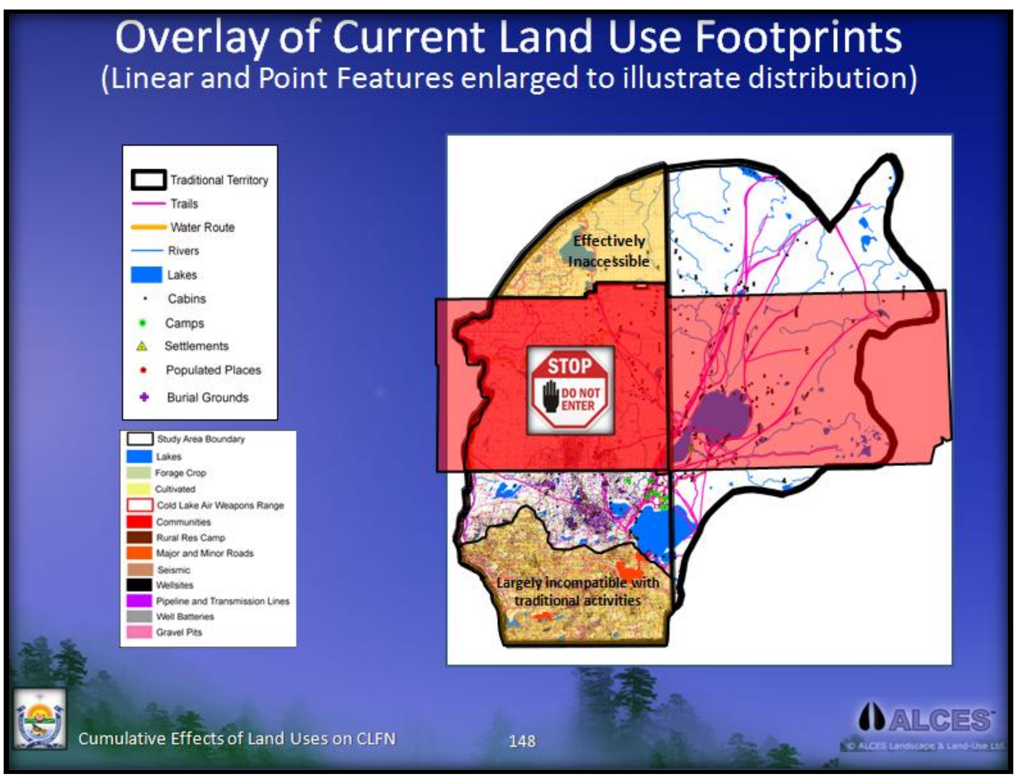


Figure 36. Spatial constraint of traditional activities of CLFN from CLAWR to the north and agriculture to the south.

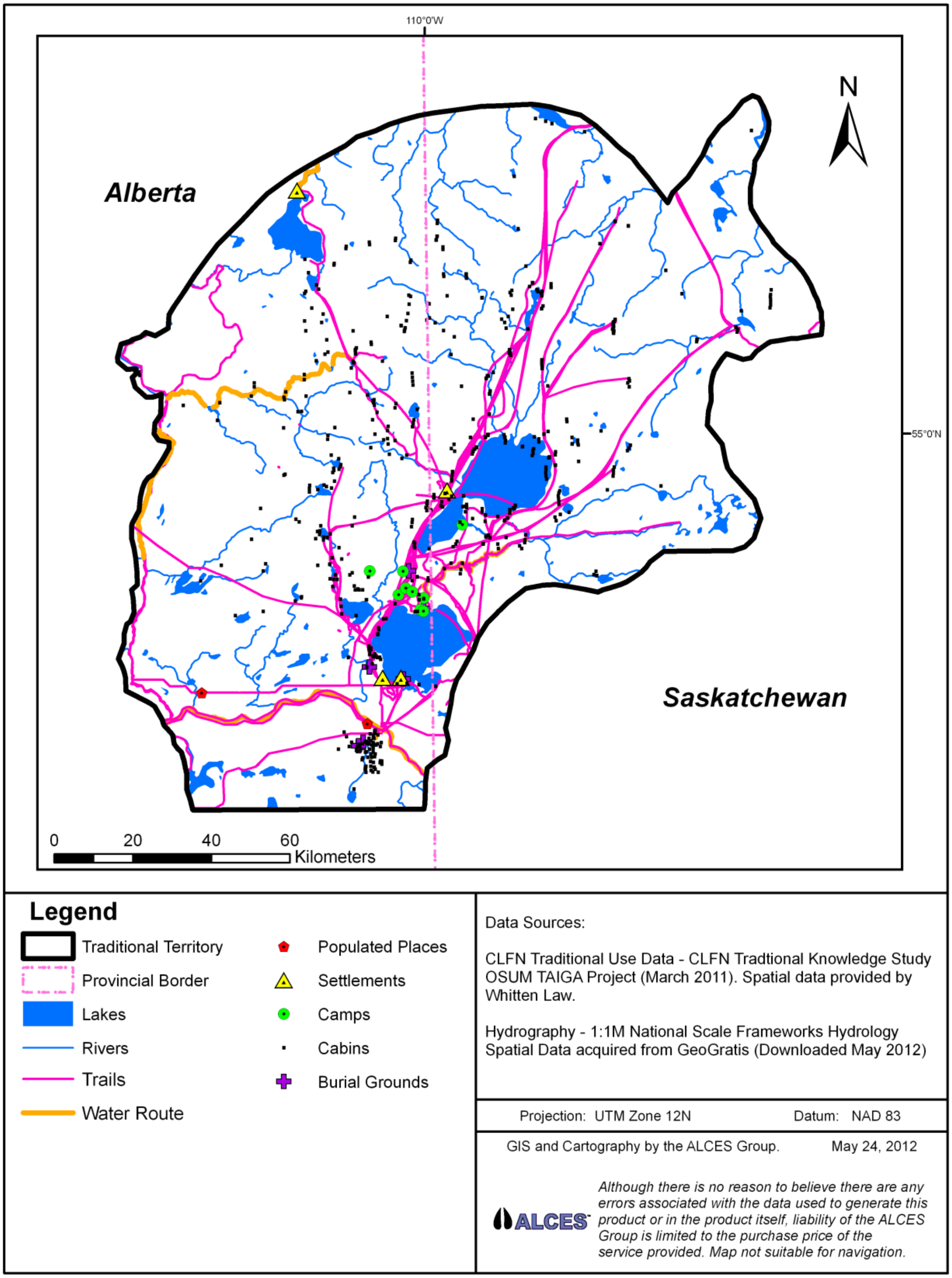


Figure 37. Historical network of traditional features and transportation networks of the traditional lands of CLFN. Source: Cold Lake First Nations Traditional Knowledge Study, 2011.

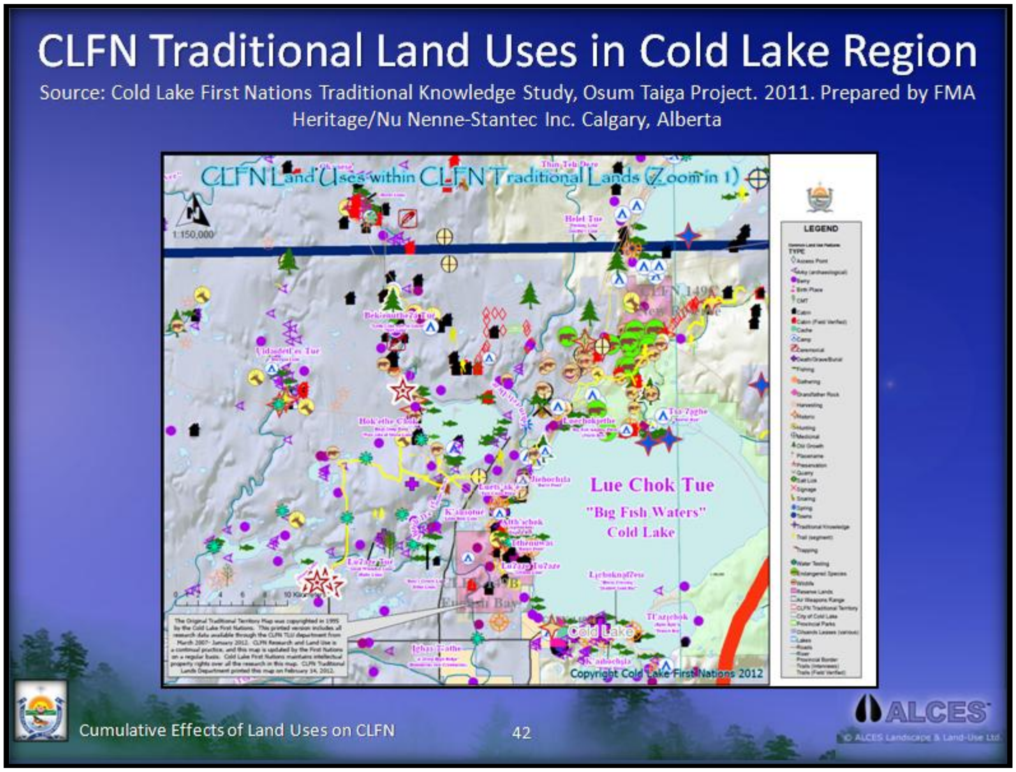


Figure 38. Distribution of traditional activities near Cold Lake. Source: Cold Lake First Nations Traditional Knowledge Study, 2011.

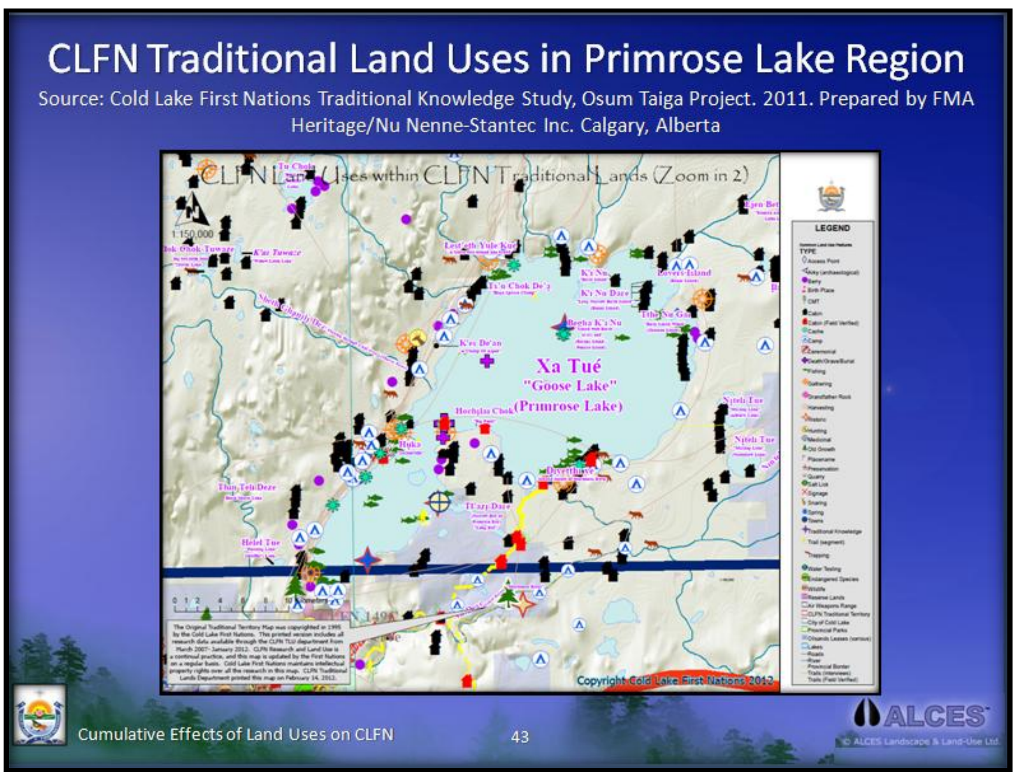


Figure 39. Distribution of traditional activities near Primrose Lake. Source: Cold Lake First Nations Traditional Knowledge Study, 2011.

Figure 40. Distribution and metrics of CLFN cultural features.

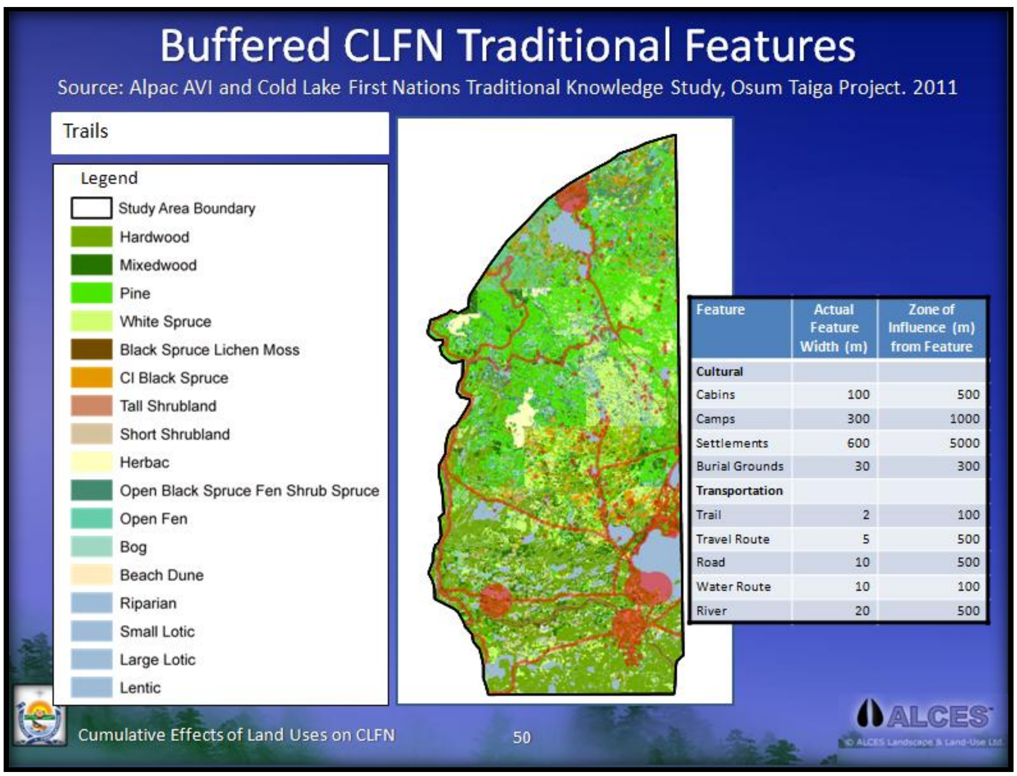


Figure 41. Buffered traditional features (cultural sites and transportation networks) illustrating locations of focus for traditional CLFN SA activities.

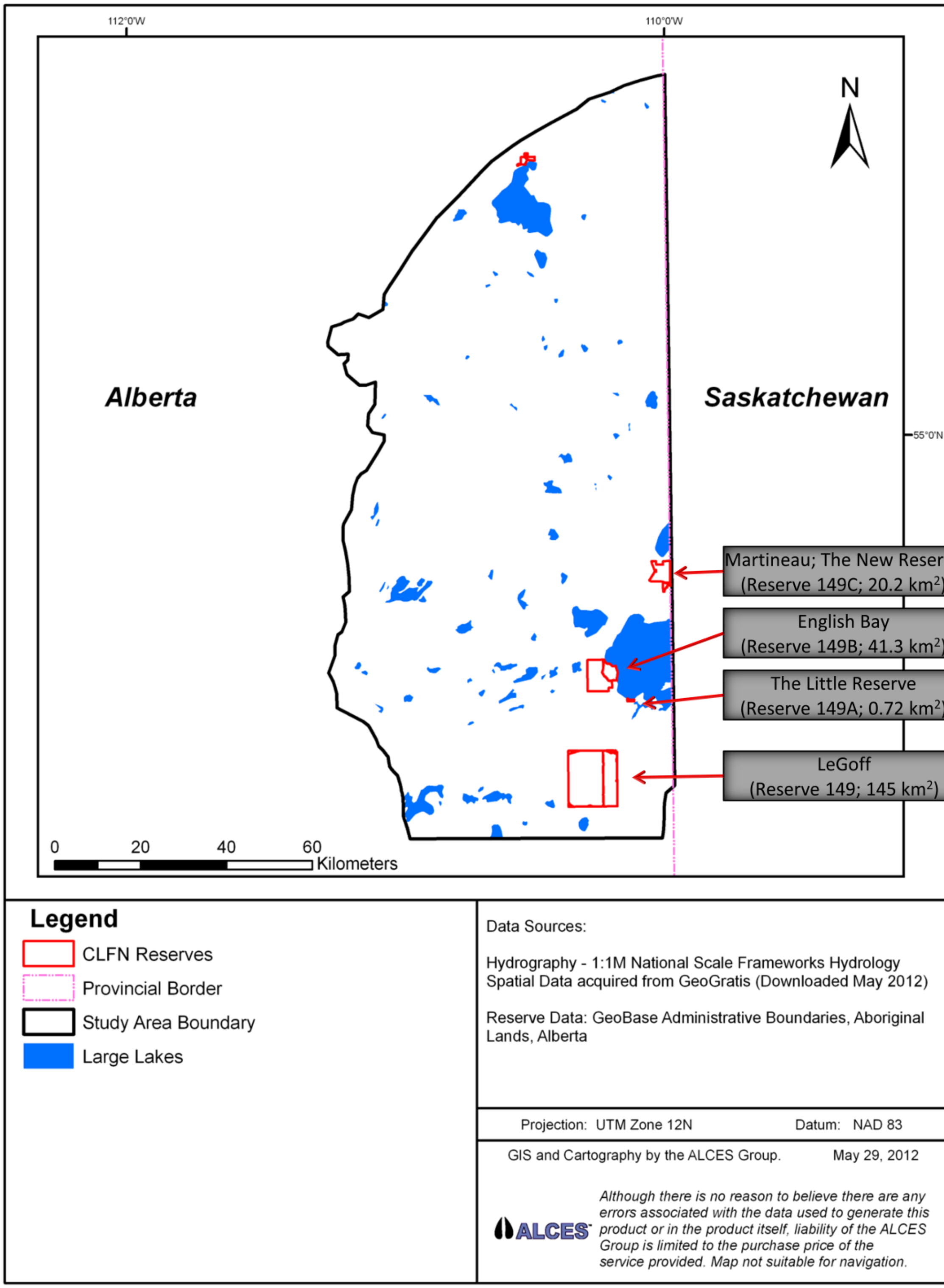


Figure 42. Network of existing reserves within the CLFN SA.

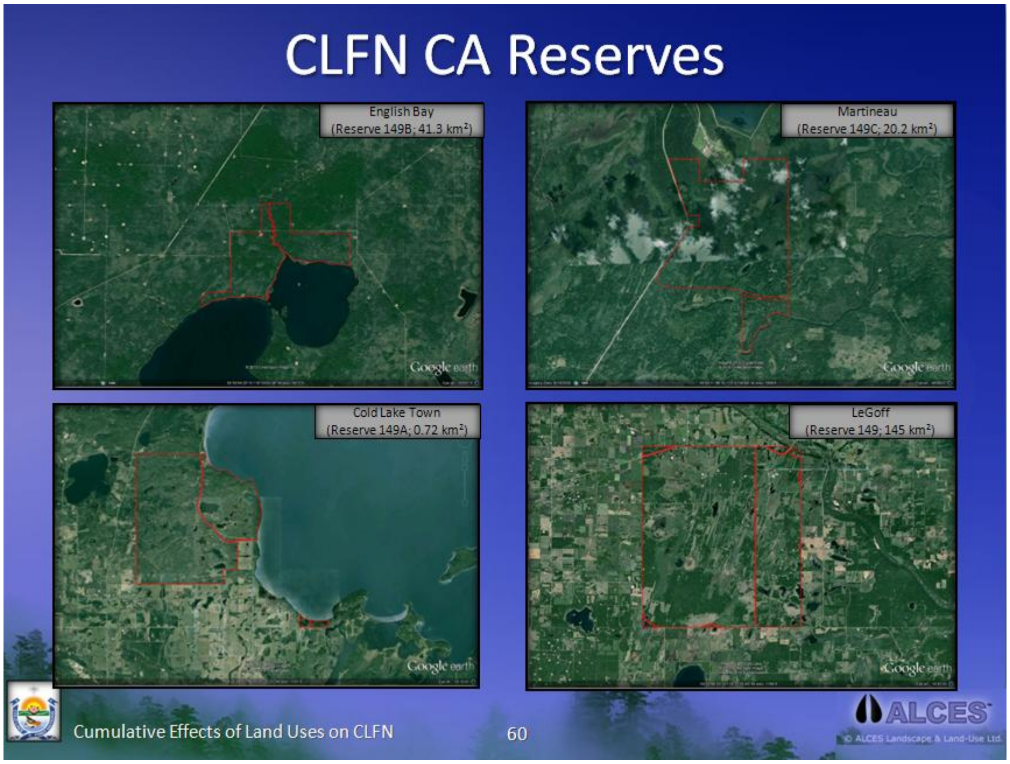


Figure 43. Google images of reserve network of CLFN SA.

5.2 NON-ABORIGINAL POPULATIONS

The non-aboriginal provincial population has numerous direct and indirect influences on the peoples of CLFN. The location of CLFN peoples relative to the overall human population in Alberta is illustrated in Figure 45. Density of rural residential populations is shown in Figure 46. It is generally understood that the census data of Statistics Canada does not accurately reflect populations of First Nation communities in Alberta. It is also recognized that censuses of populations in metropolitan centres will also incorporate CLFN individuals who are living off reserves.

Whereas human populations in the northern 2/3rd of the CLFN SA remains exceptionally low, the density of people in southern townships is higher and relates to the presence of settlements, reserves, rural residents, and energy sector work camps (Figure 47). The major communities of the CLFN SA are Cold Lake and Bonnyville. During the period of 2006 to 2011, Cold Lake grew by 15.4%, and Bonnyville grew by 6.6% (Figure 48). Historic and projected future growth of the urban footprint of Cold Lake and Bonnyville are shown in Figure 49 and Figure 50, respectively. These projections indicate the significant loss to natural and agricultural lands that occur as communities expand outward.

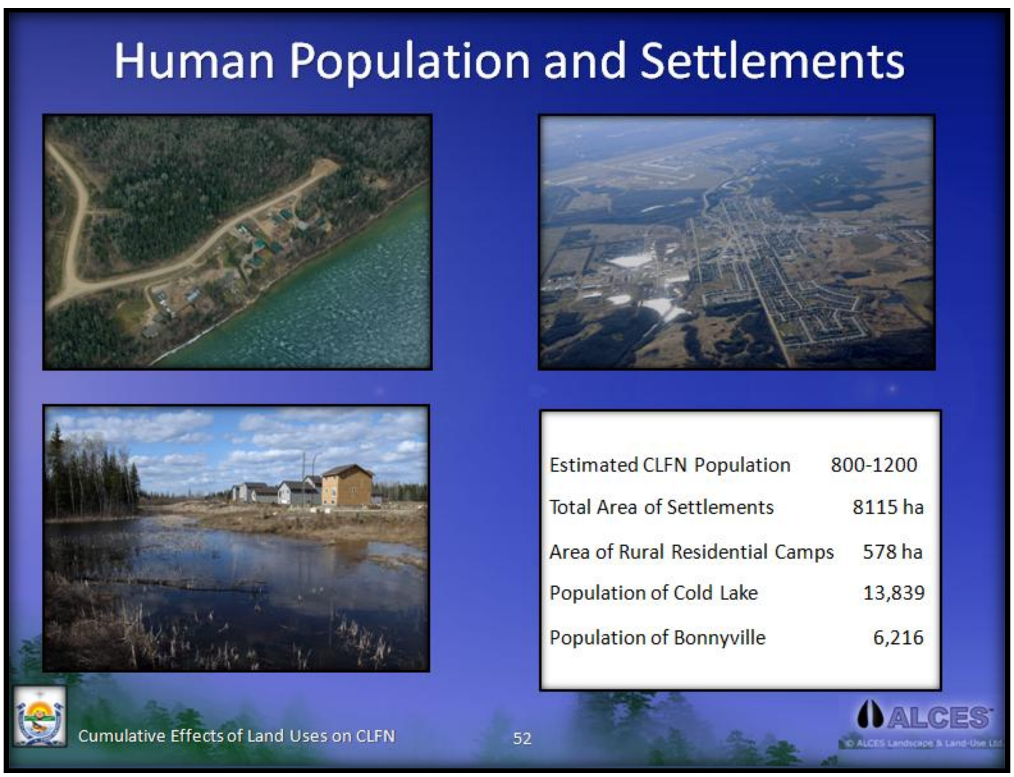


Figure 44. Settlements in CLFN and summary population values for CLFN SA.

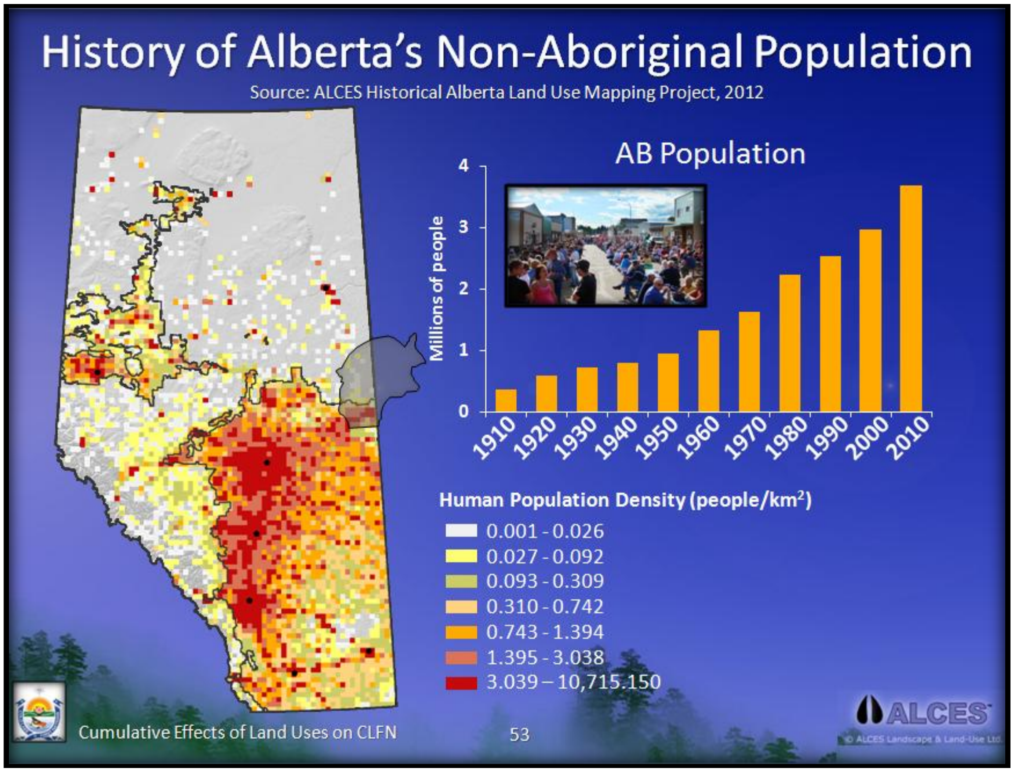


Figure 45. Population density of CLFN SA relative to Alberta. Source: ALCES Historic Alberta Land-use Reconstruction Project, 2012.

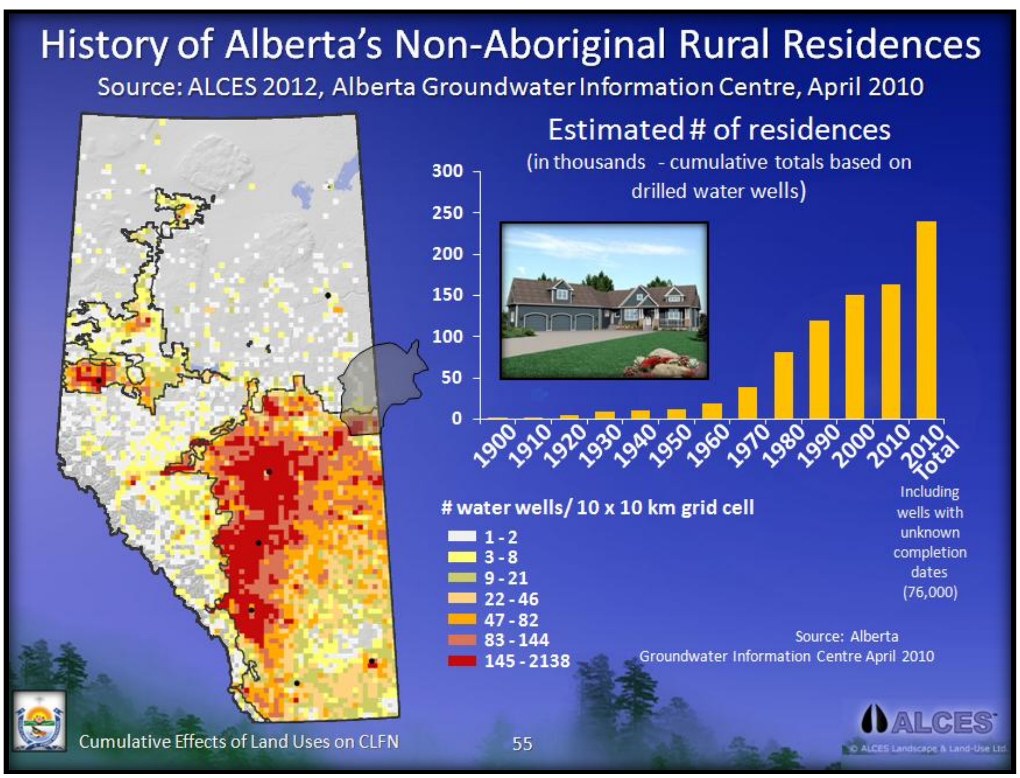


Figure 46. Rural residential density of CLFN SA relative to Alberta. Source: ALCES Historic Alberta Land-use Reconstruction Project, 2012.

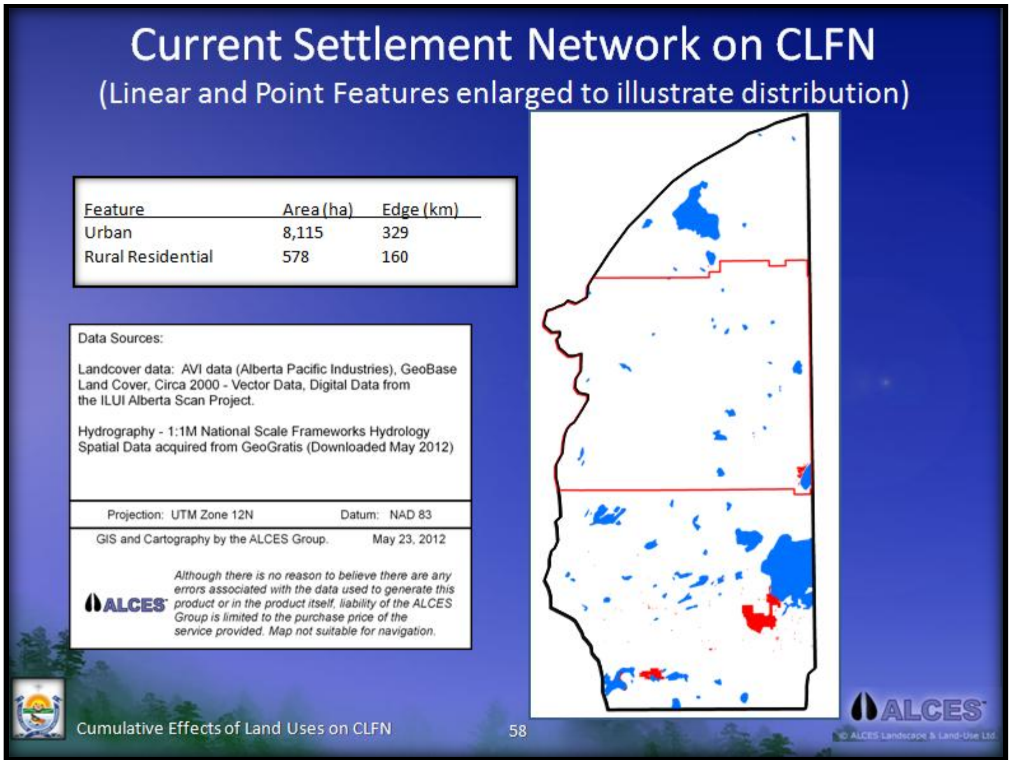


Figure 47. Major non-aboriginal settlements of CLFN SA.

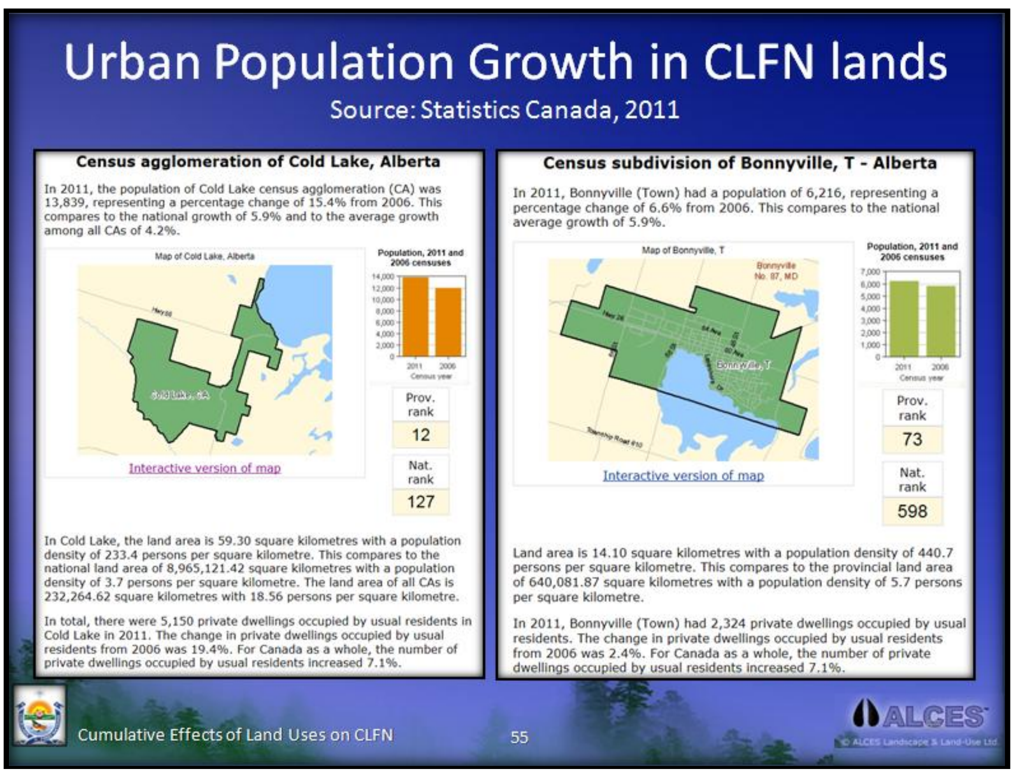


Figure 48. Population size and growth rates for Cold Lake and Bonnyville. Source: Statistics Canada, 2011.

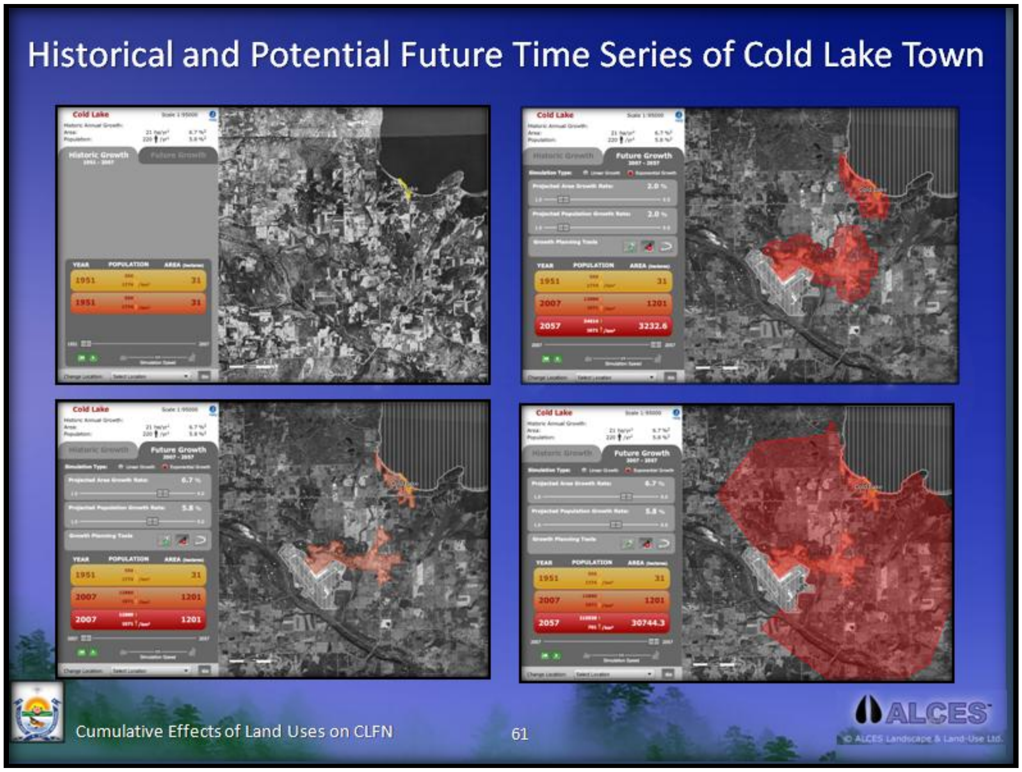


Figure 49. Historic and future time series of Cold Lake population and settlement growth. Future simulations are based on average historic area growth rates (lower right) and constant growth rate of 2% (upper right).

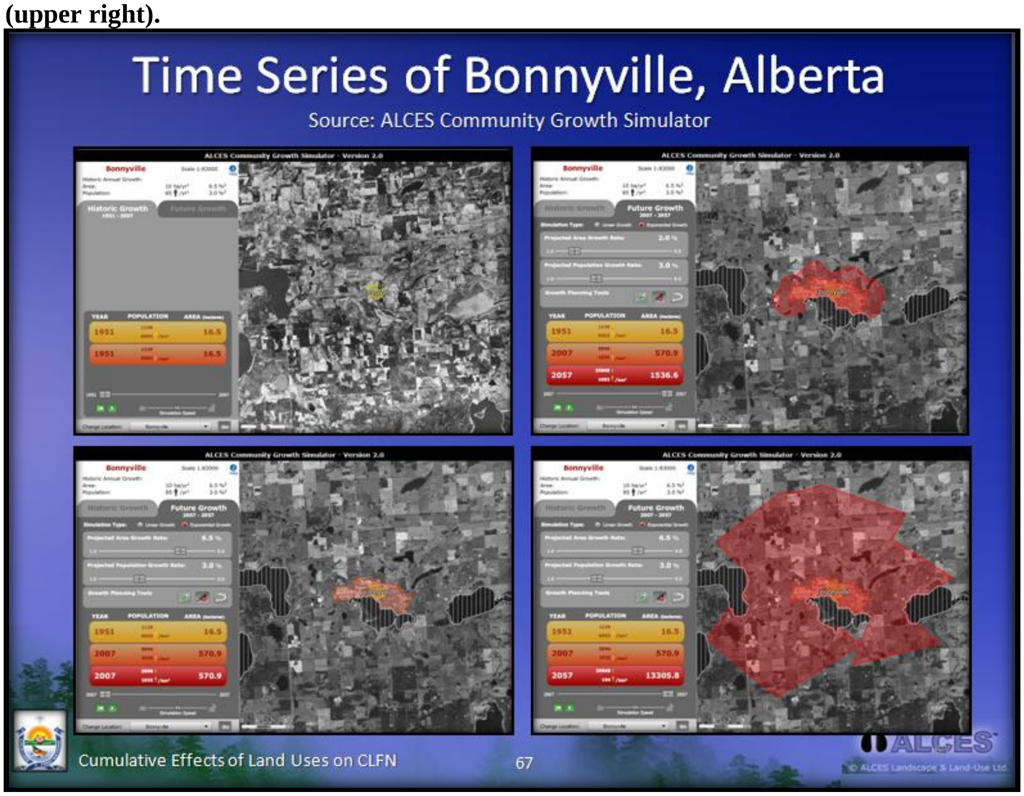


Figure 50. Historic and future time series of Bonnyville population and settlement growth. Future simulations are based on average historic area growth rates (lower right) and constant growth rate of 2% (upper right).

5.3 AGRICULTURE

The advent of agriculture in Alberta has drastically changed the landscape over the last 100 years (Figure 51). In 1910, less than 2% of Alberta's landscape was devoted to cropland, and by the year 2010, that percentage reached almost 20% (Figure 52). A similar growth in cattle population was seen as well, from less than a million head of cattle in 1910, to about 6 million in 2010 (Figure 58 and Figure 59). Part of this change was seen on the southern portion of the CLFN area as well. Today, agricultural croplands in the CLFN SA (total of 112,727 ha) include 22,594 ha of cultivated crops and 90,131 ha of forages (90,131 ha) (Figure 53).

Croplands in the CLFN region have been expanding at a rate 400 ha/yr during the past few decades and are projected to expand at a pace of 240 ha/yr until all remaining 25,000 ha of Class 4 soils are converted to agricultural production (Figure 54).

Deforestation of the White Area in and near the CLFN SA has occurred at a fast rate (Figure 55). Near Boyle, west of the CLFN SA, agricultural conversion of forests has occurred at a rate of 8.3 %/yr (Figure 56, Figure 57). The ongoing and incremental loss of natural landscapes to agriculture also reduces, bit by bit, the opportunity for CLFN peoples to participate in traditional activities in the southern portions of their traditional lands.

Based on an average area-weighted density of 12 cattle/km^2, the cattle population of CLFN SA is estimated at ~13,500.

Figure 51. Agricultural lands are now defining features of southern Alberta and the southern regions of the traditional lands of CLFN.

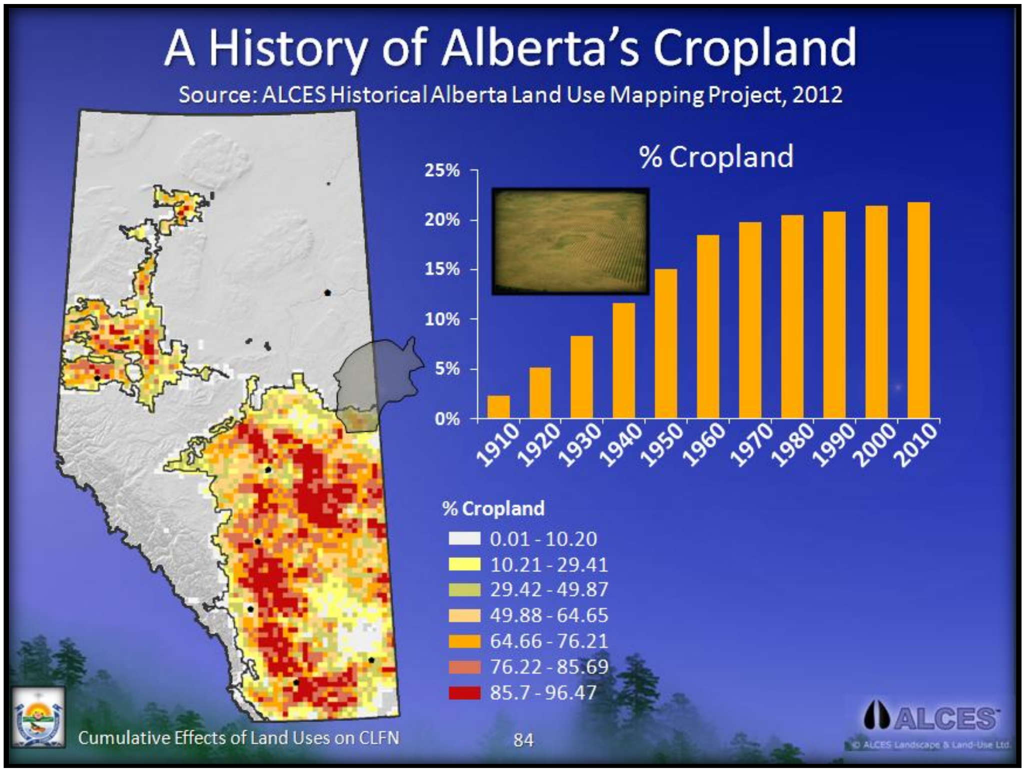


Figure 52. History of development of Alberta's cultivated crops in relation to traditional CLFN SA.

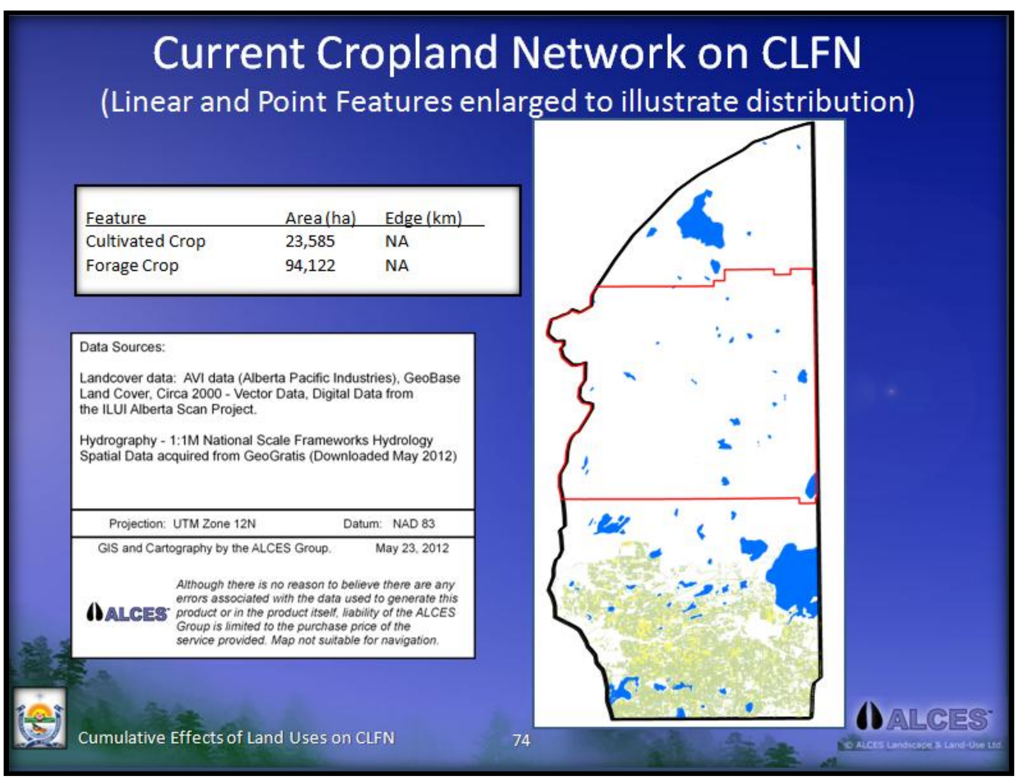


Figure 53. Current cultivated and forage cropland in CLFN SA.

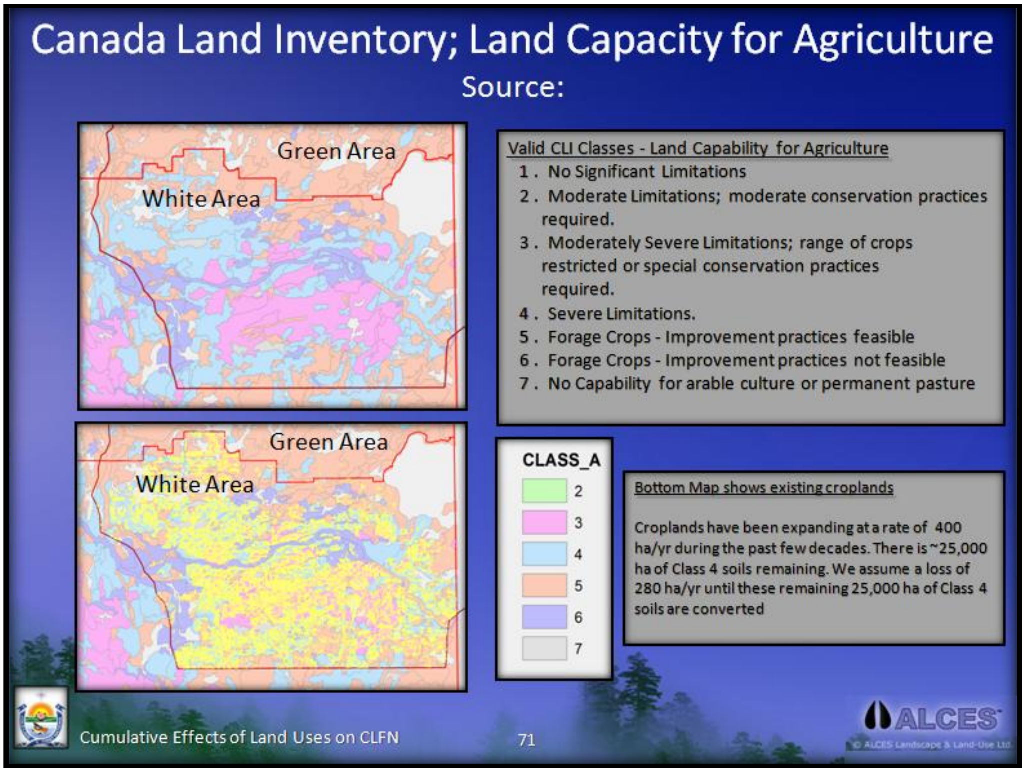


Figure 54. Spatial distribution of croplands (shown in yellow) in the southern portion (White Area) of the CLFN SA in relation to different soil types. Source: Canada Land Inventory; Soil Capacity Classification for Alberta; 1969; but digitized in 2000.

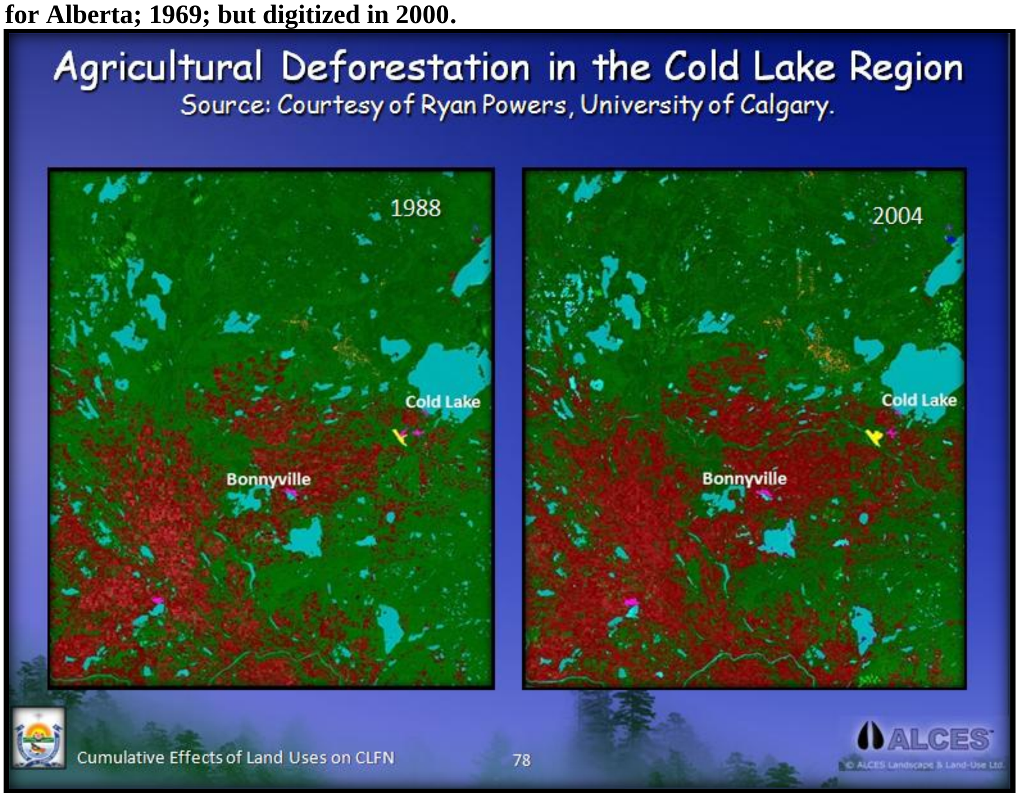


Figure 55. Expansion of croplands in the Cold Lake / Bonnyville region between 1988 and 2004. Source: Ryan Powers, University of Alberta.

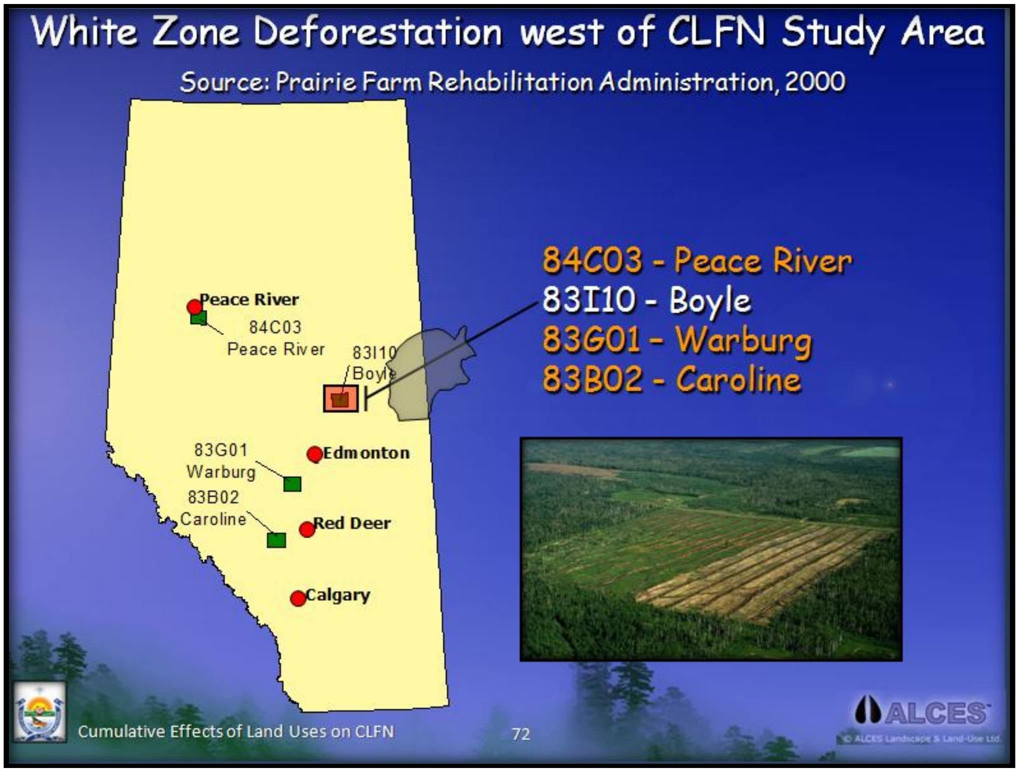


Figure 56. Agricultural deforestation in the White Area west of CLFN SA. Source: PFRA, 2000.

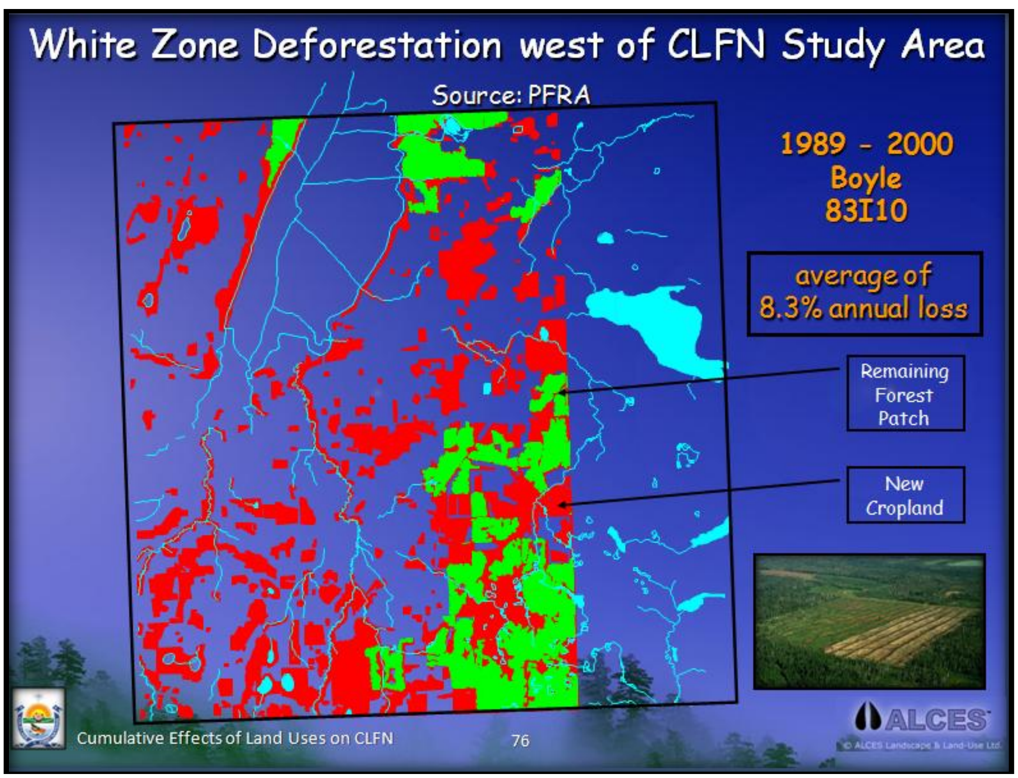


Figure 57. Example of agricultural deforestation in a township in the White Area west of CLFN SA. Areas in red reflect forest lands that were converted to agriculture during the period 1989 to 2000. Areas in green represent 1989 forest lands that were not converted. Source: PFRA, 2000.

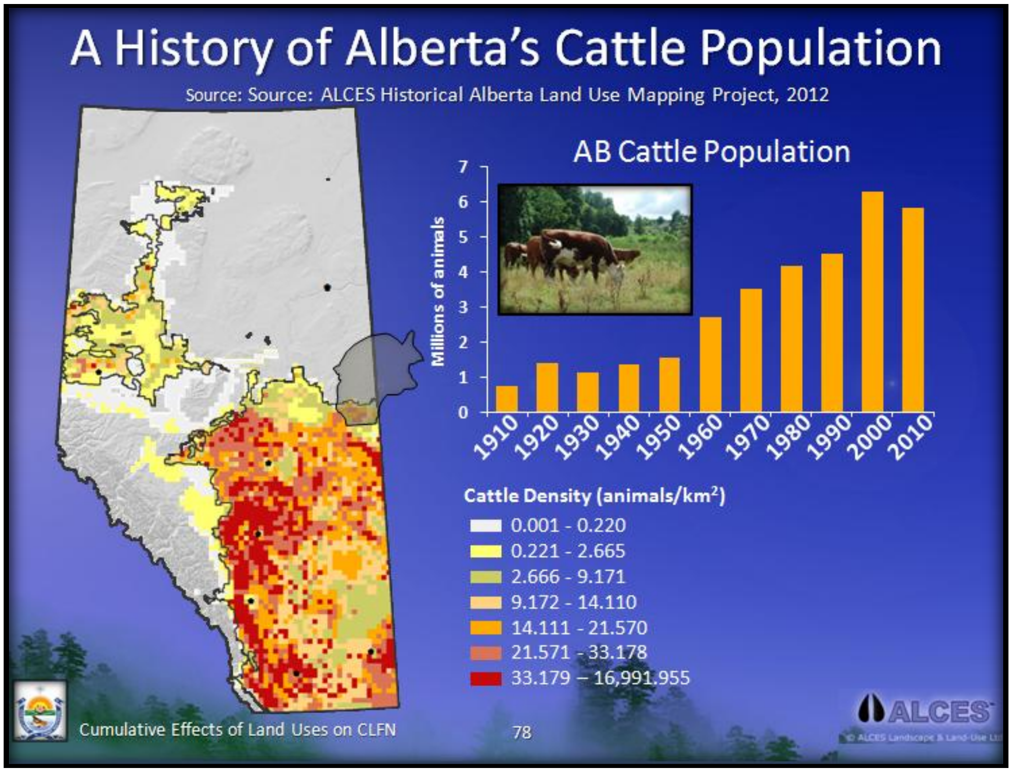


Figure 58. History of development of Alberta's cattle populations in relation to CLFN SA.

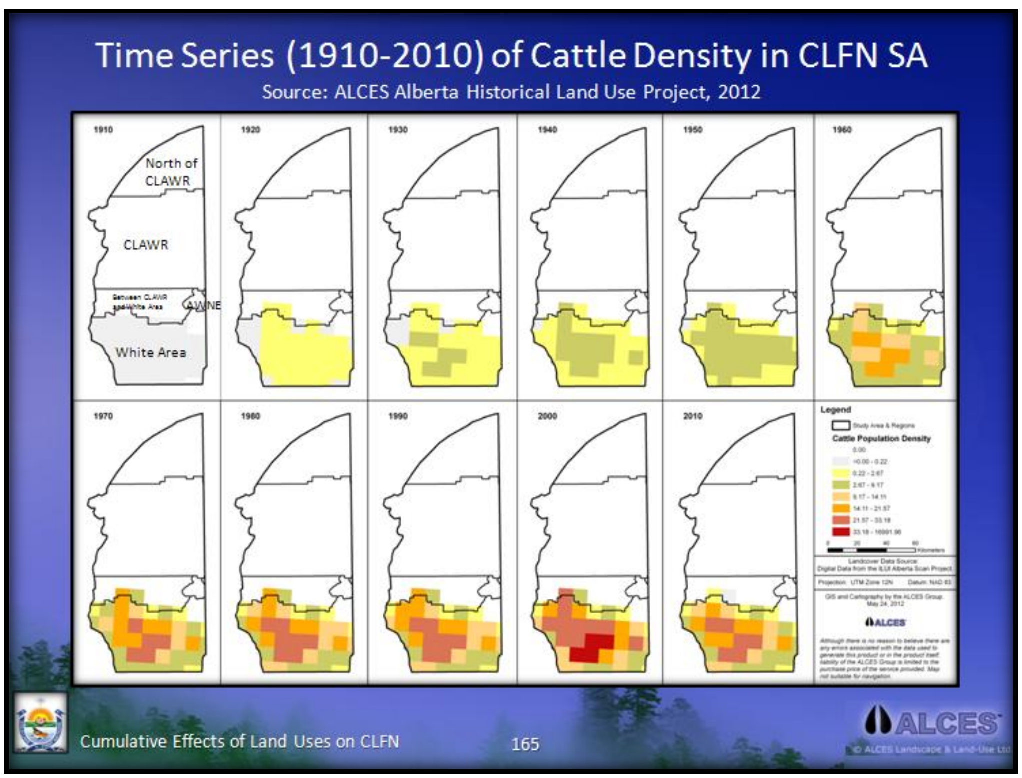


Figure 59. Historical time series (1910-2010) of cattle density in CLFN SA.

5.4 MILITARY

In 1952, a land-use decision by the Governments of Canada, Alberta, and Saskatchewan occurred that would profoundly affect CLFN. The establishment of the Cold Lake Air Weapons Range (CLAWR; also referred to as Primrose Air Weapons Range; (Figure 60 and Figure 61), ~470,000 ha (within CLFN Traditional Territory on the Alberta side) in size and located in the middle of their Traditional Territory, prevented the CLFN from accessing the central portions of their traditional lands, and made it logistically difficult to gain access to the northern regions. The Indian Claims Commission concluded

"*There can be no dispute that the exclusion of the people of Cold Lake from the air weapons range substantially impaired their livelihoods and their access to food and other resources. The results of that event continue as a sense of loss and a source of grievance in the community and the results are still painfully evident. The damage to the community was not only financial, it was psychological and spiritual.*" (p. 118)

During the period of full exclusion of CLFN from their Traditional Territory in CLAWR, extensive access to CLAWR was granted to oil and gas companies for purposes of constructing and operating hydrocarbon infrastructure. Following the Indian Claims Commission and subsequent intense negotiations, in 2002, ~50 years following the abolishment of CLFN peoples from CLAWR, Canada, Alberta, and CLFN entered into a Settlement and Access Agreement whereby some level of access to CLAWR was restored to CLFN for traditional purposes. An attempt to quantify the current level of access by CLFN peoples to CLAWR is provided in Figure 62. The major constraint categories influencing limitations to access include lack of night visitation rights, weekday restrictions, military activities that render some areas unsafe, access restrictions by gates, and inconvenience/incompatibility of current paperwork and notification protocols.

The legacy of a historical restriction to access in the CLAWR has led to a discontinuity of cultural connection to their Traditional Territory, and the degeneration of significant cultural sites. Consequently, access to the CLAWR is currently estimated at only 3.8% of the pre-CLAWR era (Figure 62). Current constraints categories that collectively reduce access of CLFN to CLAWR include:

- Access not permitted at night
- Access largely restricted to weekends
- Access not permitted in locations of active military or energy sector activity
- Access restricted to entrance through gates
- Access restricted to those not capable to follow paperwork protocols

The network of cultural features that have been developed by CLFN during their occupation of the landscape prior to the establishment of the CLAWR is largely unused and in the process of decomposition. As indicated in Figure 63, this includes many dozens of cabins scattered throughout the CLAWR.

Figure 60. The Cold Lake Air Weapons Range is now the largest and most extensive land-use occurring on CLFN SA.

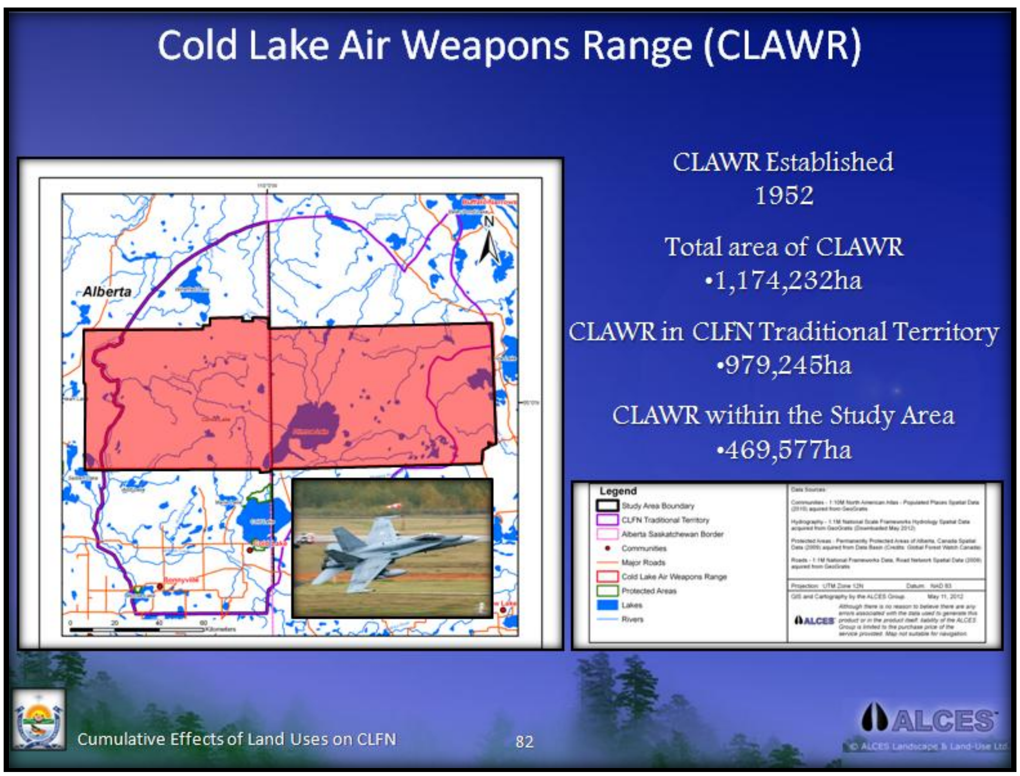


Figure 61. Location and size of the Cold Lake Air Weapons Range relative to the CLFN Traditional Territory.

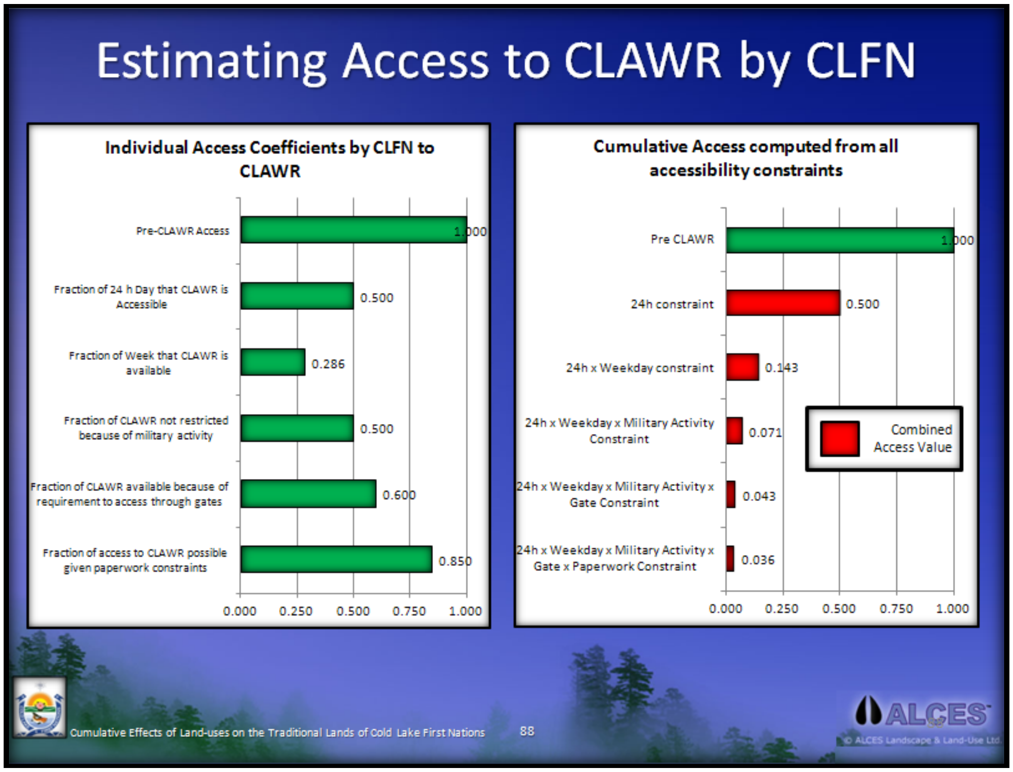


Figure 62. Estimating combined access constraints of Cold Lake Air Weapons Range by CLFN.

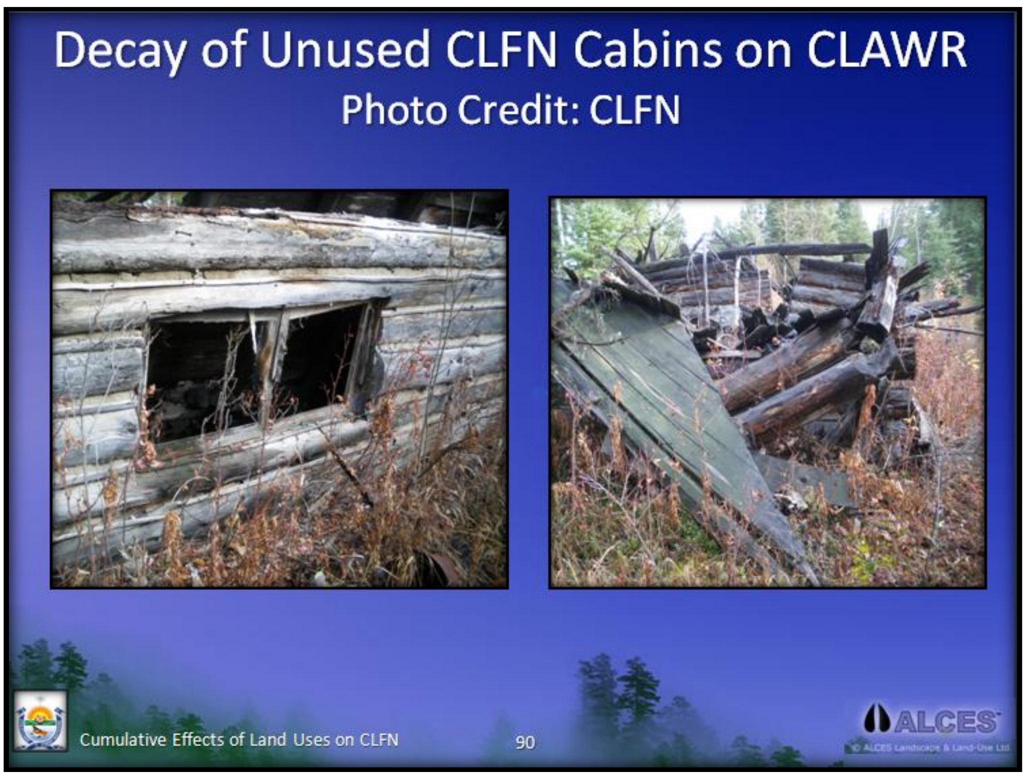


Figure 63. The pre-CLAWR network of many dozens of cabins are unused, not maintained, and are in the process of decay.

5.5 PROVINCIAL PARKS AND RECREATION AREAS

The provincial park network comprises 6,643 ha of the CLFN SA. There is controversy among the CLFN people concerning the establishment of provincial parks and recreation areas around Cold Lake which are situated on the Nation's longstanding important cultural and traditional use sites. Generally, CLFN members are unable to exercise many of their traditional activities within park boundaries (Figure 64, Figure 65, Figure 66).

There is no known proposed expansion of provincial parks within the CLFN. As such, no additions to the Provincial Park network were simulated during this project. For the purposes of this report, provincial parks and recreation were considered to be largely incompatible with consumptive activities (hunting, trapping, fishing, medicine and plant gathering) of the CLFN due to regulatory restrictions and concerns over conflict with recreational users.

Figure 64. The provincial parks and recreation areas network in CLFN SA is intended to contribute to ecological integrity in the region but this mandate is not necessarily compatible with maintaining traditional activities of CLFN peoples.

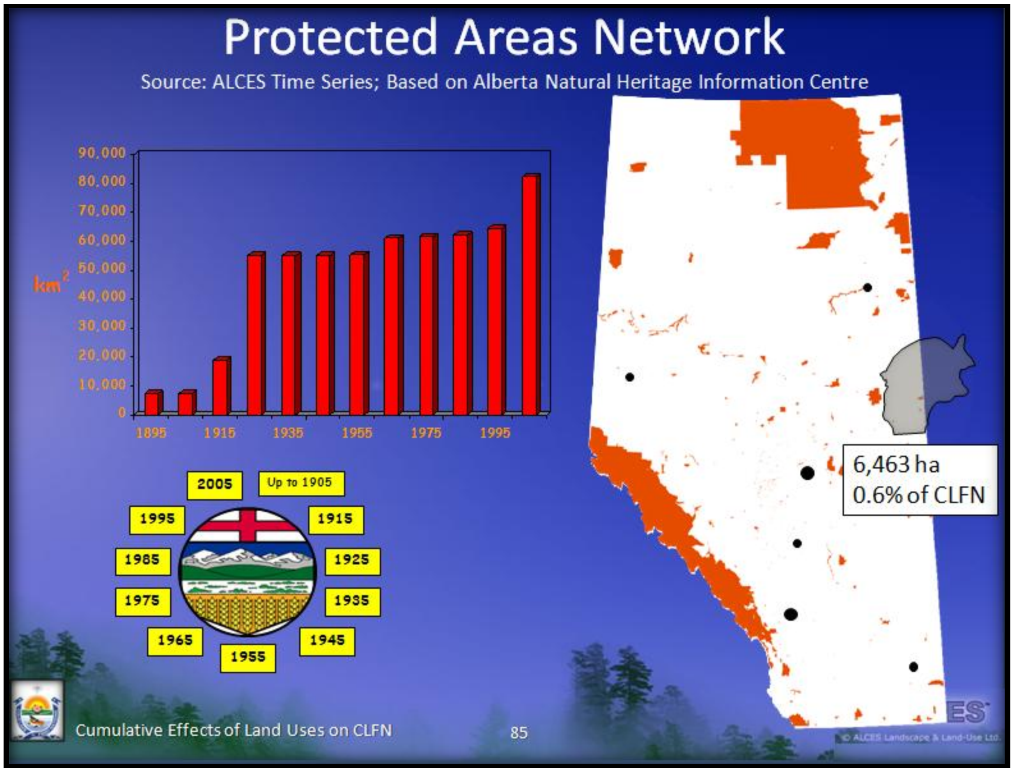
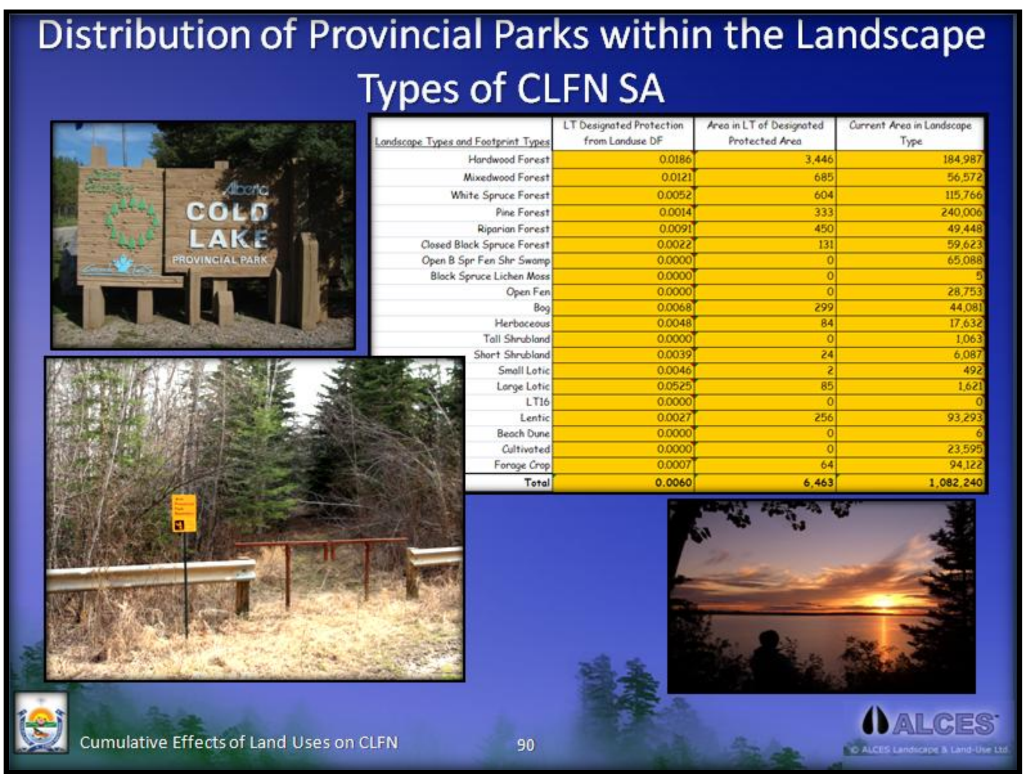


Figure 65. Historical changes in the area of protected areas (provincial, federal) in Alberta relative to CLFN SA.



Landscape Types and Footprint Types	LT Designated Protection from Landuse DF	Area in LT of Designated Protected Area	Current Area in Landscape Type
Hardwood Forest	0.0186	3,446	184,987
Mixedwood Forest	0.0121	685	56,572
White Spruce Forest	0.0052	604	115,766
Pine Forest	0.0014	333	240,006
Riparian Forest	0.0091	450	49,448
Closed Black Spruce Forest	0.0022	131	59,623
Open B Spr Fen Shr Swamp	0.0000	0	65,088
Black Spruce Lichen Moss	0.0000	0	5
Open Fen	0.0000	0	28,753
Bog	0.0068	299	44,081
Herbaceous	0.0048	84	17,632
Tall Shrubland	0.0000	0	1,063
Short Shrubland	0.0039	24	6,087
Small Lotic	0.0046	2	492
Large Lotic	0.0525	85	1,621
LT16	0.0000	0	0
Lentic	0.0027	256	93,293
Beach Dune	0.0000	0	6
Cultivated	0.0000	0	23,595
Forage Crop	0.0007	64	94,122
Total	**0.0060**	**6,463**	**1,082,240**

Figure 66. Distribution of provincial parks of CLFN SA relative to landscape types.

5.6 FORESTRY

Although forestry is the largest and most extensive land-use within the boreal forests of Alberta (Figure 67 and Figure 68), it is not a significant land-use within CLFN SA. The southern extent of the Forest Management Agreement (FMA) of Alberta-Pacific Forest Industries does extend into the northern portion of the CLFN SA, but the intended future harvest of wood is considered to be insignificant. There is, however, a minor level of wood harvest within the study area, and that volume is accounted for by small scale companies within the CLFN itself.

Significant logging does occur immediately to the east of CLFN SA and within the Traditional Territories of CLFN in Saskatchewan. An example of the regional cutblock network is illustrated using Google imagery in Figure 69.

Figure 67. The forest sector is the largest land-use practice in the boreal forest of Alberta.

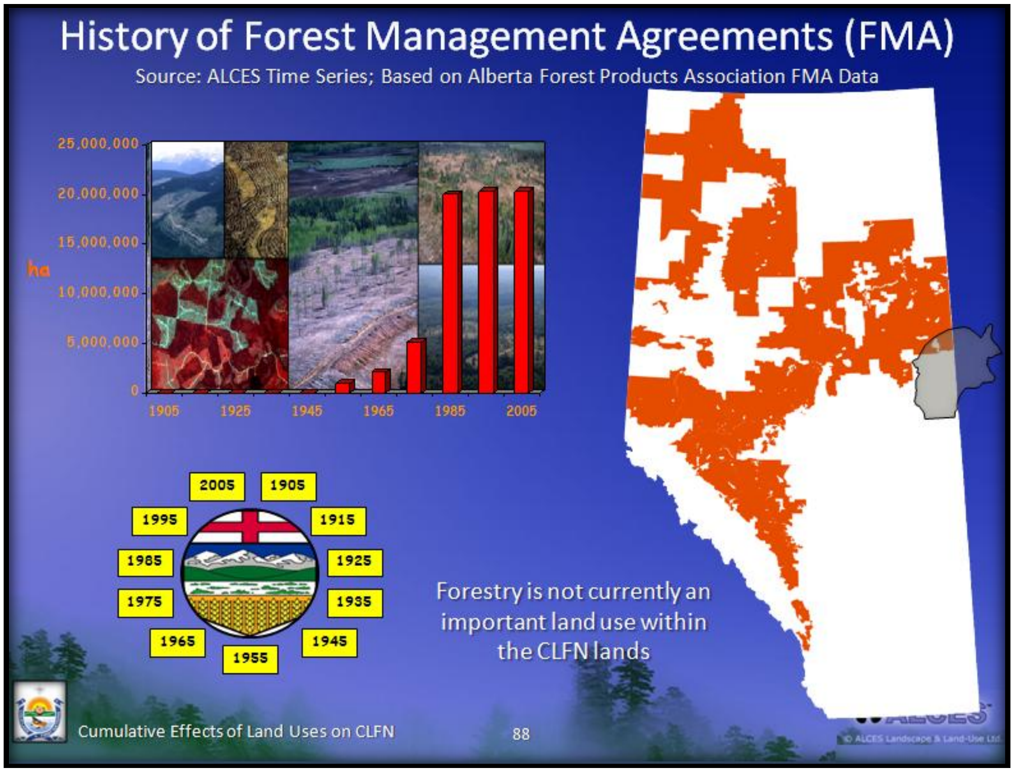


Figure 68. History and location of Forest Management Agreement Areas (FMA) within Alberta relative to CLFN SA.

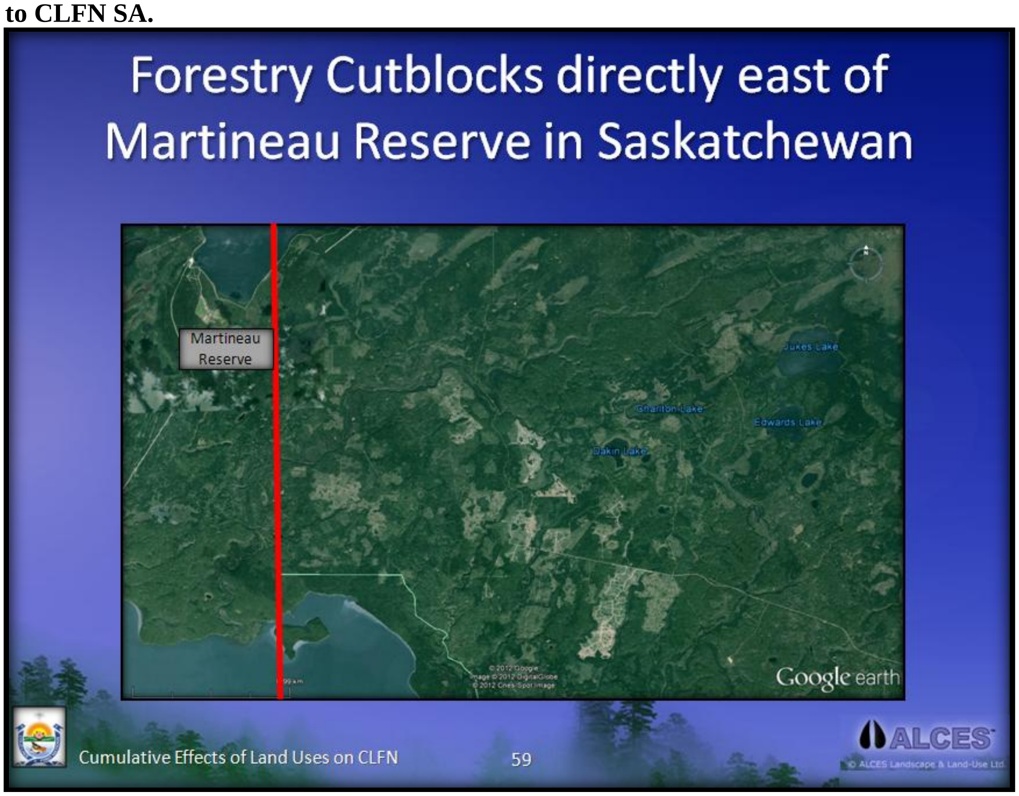


Figure 69 Google imagery illustrating cutblock network in the Traditional Territory of CLFN immediately east of the Martineau Reserve in Saskatchewan.

5.7 OIL AND GAS

The hydrocarbon reserves beneath the surface of CLFN are immense (Figure 70 and Figure 71), span the Ft. McMurray and Cold Lake oilsand regions (Figure 72), and have played a key role in the history of oil production in Alberta (Figure 73). Estimates by the ERCB (2011) suggest ~28.7 B m^3 of heavy oil and bitumen are “in place” in the Cold Lake region (Figure 71) and of these reserves ~6.3B m^3 are recoverable using current technology (Lemmens, Birchwood Resources, 2012). Only 0.297 B m^3 have been recovered to date, emphasizing how much more development is yet to occur. The major deposits comprising the heavy oils and bitumen reserves of the region are located within the Upper and Lower Grand Rapids, the Cold Lake Coldwater, and the Wabiskaw/Ft. McMurray (Figure 74).

In terms of jobs, royalties, revenues, and landscape transformation, no land-use during the past several decades in the CLFN region has delivered higher numbers and more change than the hydrocarbon sector.

The CLFN SA is placed into context of the historical provincial trajectory of natural gas, conventional oil, and unconventional oil development in Figure 75, Figure 76, and Figure 77, respectively. The combined historical energy sector footprint, shown for each township, has grown exponentially (Figure 81 and Figure 82) at both provincial and CLFN scales. However, it is clear that conventional oil has not been an important contributor in the CLFN region. Although some significant volumes of natural gas have been historically produced, primary natural gas production is not permitted from much of the region because of its adverse effects on production of unconventional oil (Figure 83, Figure 84). The hydrocarbon focus of this region is to extract unconventional oil (heavy oil, bitumen), and the Government of Alberta has developed policies and regulations intended to encourage the exploration, extraction and translocation of these valued hydrocarbons to provincial, national and international markets.

Historical hydrocarbon extraction has generated a substantial footprint of 21,000 ha and ~24,000 km of edge on CLFN SA, comprised of seismic lines (5,761 ha, 14,402 km; Figure 78), wellsites (5,391 ha, 2,716 km; Figure 79), pipelines (5,688 ha, 6,406 km), and access roads (3,694 ha, 2,463 km; Figure 80).

This ALCES project was triggered by one of dozens of forecasted bitumen and heavy oil projects that will affect the landscape and peoples of CLFN during the next several decades. Although the individual footprint of individual projects could be viewed by some as minor (if seen in isolation and expressed at the regional scale) (**Error! Reference source not found.**), when considered in combination with other oil projects required to extract the remaining 5 B m^3 of bitumen and heavy oil, a series of proposed project will contribute to a massive landscape transformation not seen since the retreat of glacial ice sheets 10,000 years ago. At the local scale, the footprint of an individual project will have a significant and adverse effect on ecological and cultural indicators for a minimum of several decades.

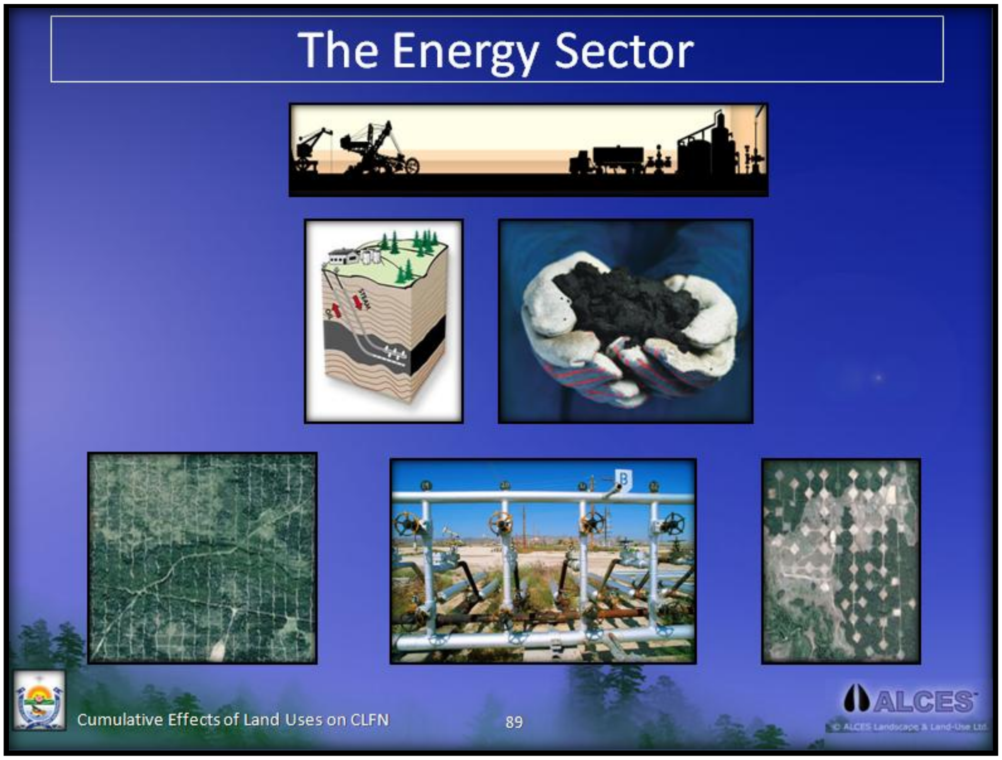


Figure 70. The hydrocarbon sector is an important land-use in the CLFN SA, and one whose benefits and liabilities are immense.

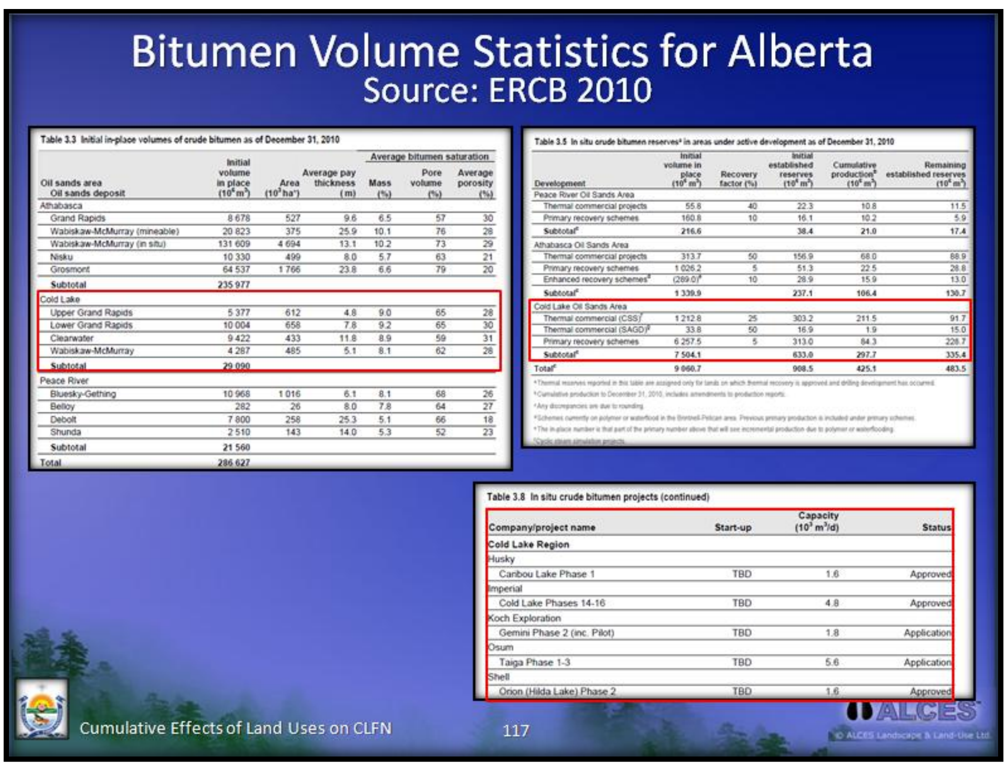


Table 3.3 Initial in-place volumes of crude bitumen as of December 31, 2010

Oil sands area / Oil sands deposit	Initial volume in place ($10^6 m^3$)	Area ($10^3 ha^a$)	Average pay thickness (m)	Average bitumen saturation: Mass (%)	Pore volume (%)	Average porosity (%)
Athabasca						
Grand Rapids	8 678	527	9.6	6.5	57	30
Wabiskaw-McMurray (mineable)	20 823	375	25.9	10.1	76	28
Wabiskaw-McMurray (in situ)	131 609	4 694	13.1	10.2	73	29
Nisku	10 330	499	8.0	5.7	63	21
Grosmont	64 537	1 766	23.8	6.6	79	20
Subtotal	235 977					
Cold Lake						
Upper Grand Rapids	5 377	612	4.8	9.0	65	28
Lower Grand Rapids	10 004	658	7.8	9.2	65	30
Clearwater	9 422	433	11.8	8.9	59	31
Wabiskaw-McMurray	4 287	485	5.1	8.1	62	28
Subtotal	29 090					
Peace River						
Bluesky-Gething	10 968	1 016	6.1	8.1	68	26
Belloy	282	26	8.0	7.8	64	27
Debolt	7 800	258	25.3	5.1	66	18
Shunda	2 510	143	14.0	5.3	52	23
Subtotal	21 560					
Total	286 627					

Table 3.5 In situ crude bitumen reserves[a] in areas under active development as of December 31, 2010

Development	Initial volume in place ($10^6 m^3$)	Recovery factor (%)	Initial established reserves ($10^6 m^3$)	Cumulative production[b] ($10^6 m^3$)	Remaining established reserves ($10^6 m^3$)
Peace River Oil Sands Area					
Thermal commercial projects	55.8	40	22.3	10.8	11.5
Primary recovery schemes	160.8	10	16.1	10.2	5.9
Subtotal[c]	**216.6**		**38.4**	**21.0**	**17.4**
Athabasca Oil Sands Area					
Thermal commercial projects	313.7	50	156.9	68.0	88.9
Primary recovery schemes	1 026.2	5	51.3	22.5	28.8
Enhanced recovery schemes[d]	(289.0)[e]	10	28.9	15.9	13.0
Subtotal[c]	**1 339.9**		**237.1**	**106.4**	**130.7**
Cold Lake Oil Sands Area					
Thermal commercial (CSS)[f]	1 212.8	25	303.2	211.5	91.7
Thermal commercial (SAGD)[g]	33.8	50	16.9	1.9	15.0
Primary recovery schemes	6 257.5	5	313.0	84.3	228.7
Subtotal[c]	**7 504.1**		**633.0**	**297.7**	**335.4**
Total[c]	**9 060.7**		**908.5**	**425.1**	**483.5**

[a] Thermal reserves reported in this table are assigned only for lands on which thermal recovery is approved and drilling development has occurred.
[b] Cumulative production to December 31, 2010, includes amendments to production reports.
[c] Any discrepancies are due to rounding.
[d] Schemes currently on polymer or waterflood in the Brintnell-Pelican area. Previous primary production is included under primary schemes.
[e] The in-place number is that part of the primary number above that will see incremental production due to polymer or waterflooding.
[f] Cyclic steam simulation projects.

Table 3.8 In situ crude bitumen projects (continued)

Company/project name	Start-up	Capacity ($10^3 m^3/d$)	Status
Cold Lake Region			
Husky			
Caribou Lake Phase 1	TBD	1.6	Approved
Imperial			
Cold Lake Phases 14-16	TBD	4.8	Approved
Koch Exploration			
Gemini Phase 2 (inc. Pilot)	TBD	1.8	Application
Osum			
Taiga Phase 1-3	TBD	5.6	Application
Shell			
Orion (Hilda Lake) Phase 2	TBD	1.6	Approved

Figure 71. Key oil and bitumen statistics for CLFN SA and Alberta. Source: ERCB 2010.

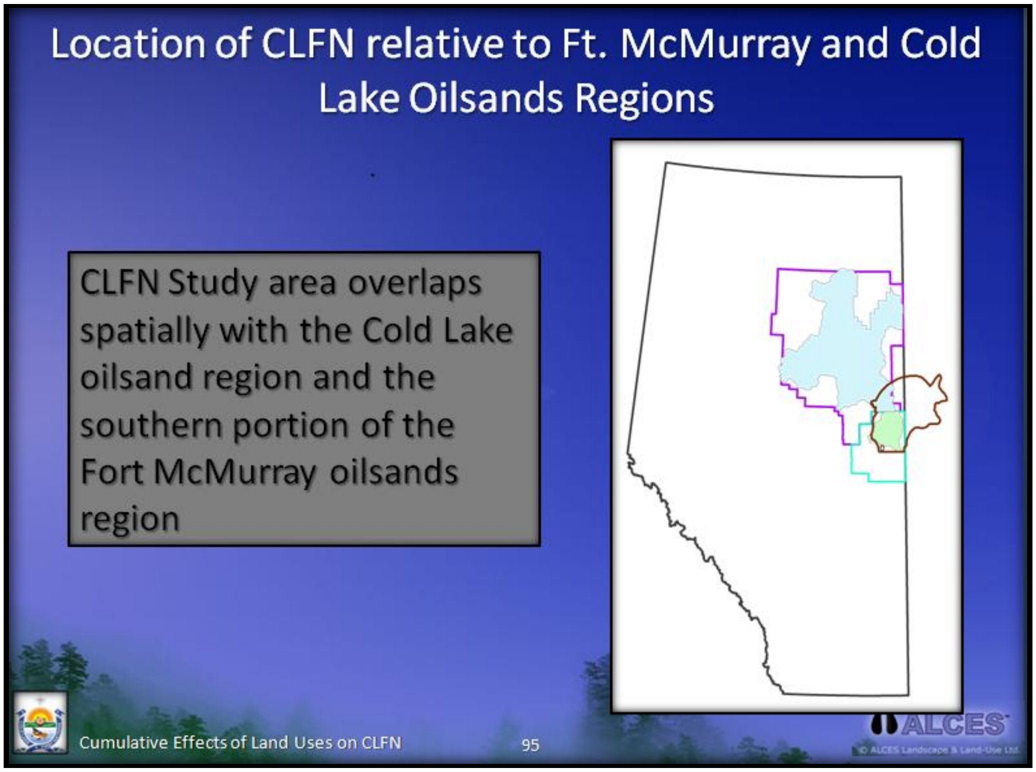


Figure 72. The traditional lands of CLFN span both the Ft. McMurray and Cold Lake oilsand regions of Alberta.

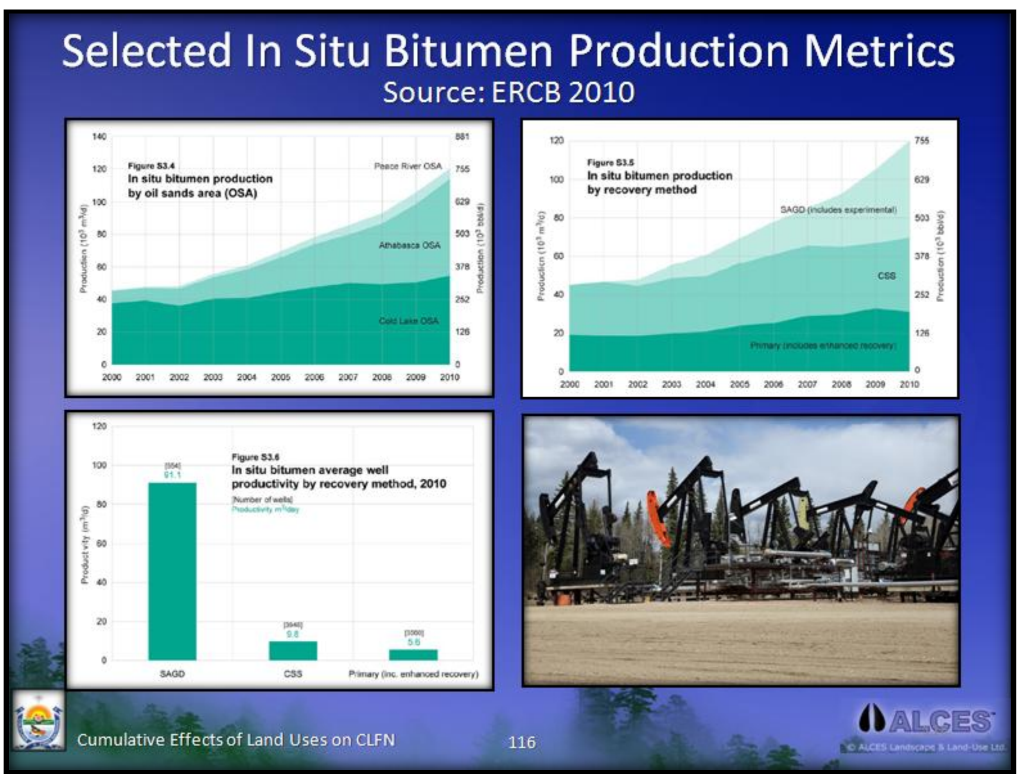


Figure 73. Historical production of heavy oil and bitumen in Alberta in relation to the Cold Lake reserves. Source: ERCB, 2010.

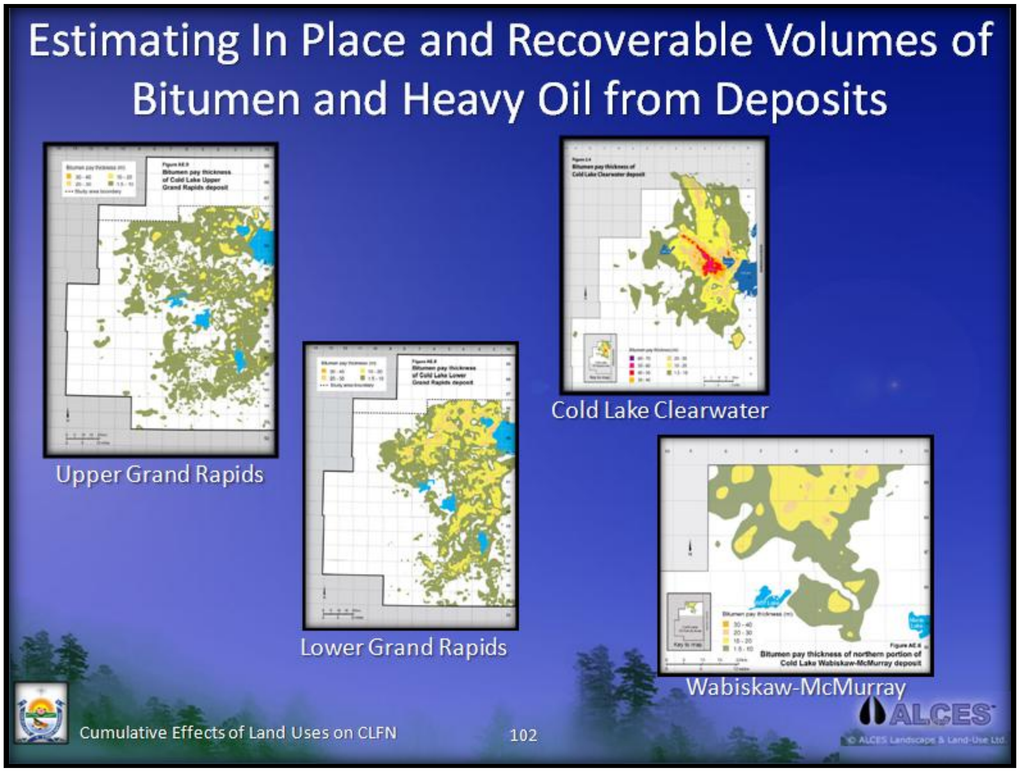


Figure 74. Major heavy oil and bitumen deposits in the Cold Lake region. Source: ERCB, 2011.

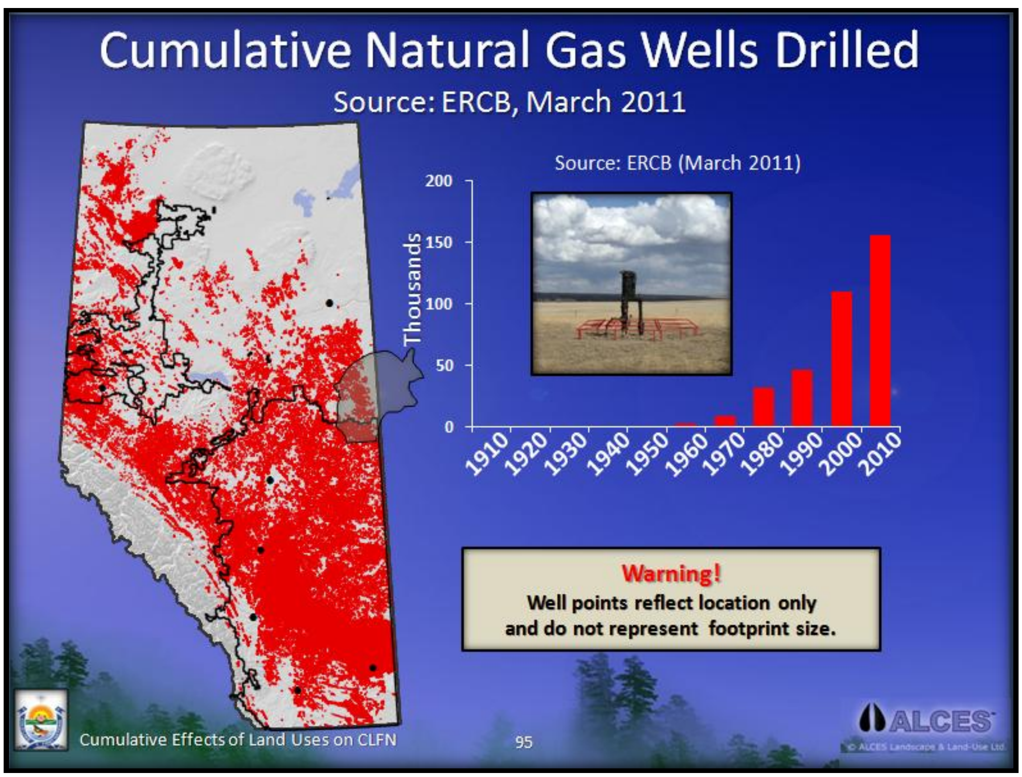


Figure 75. CLFN SA in context of historical natural gas production in Alberta. Source: ERCB, 2011.

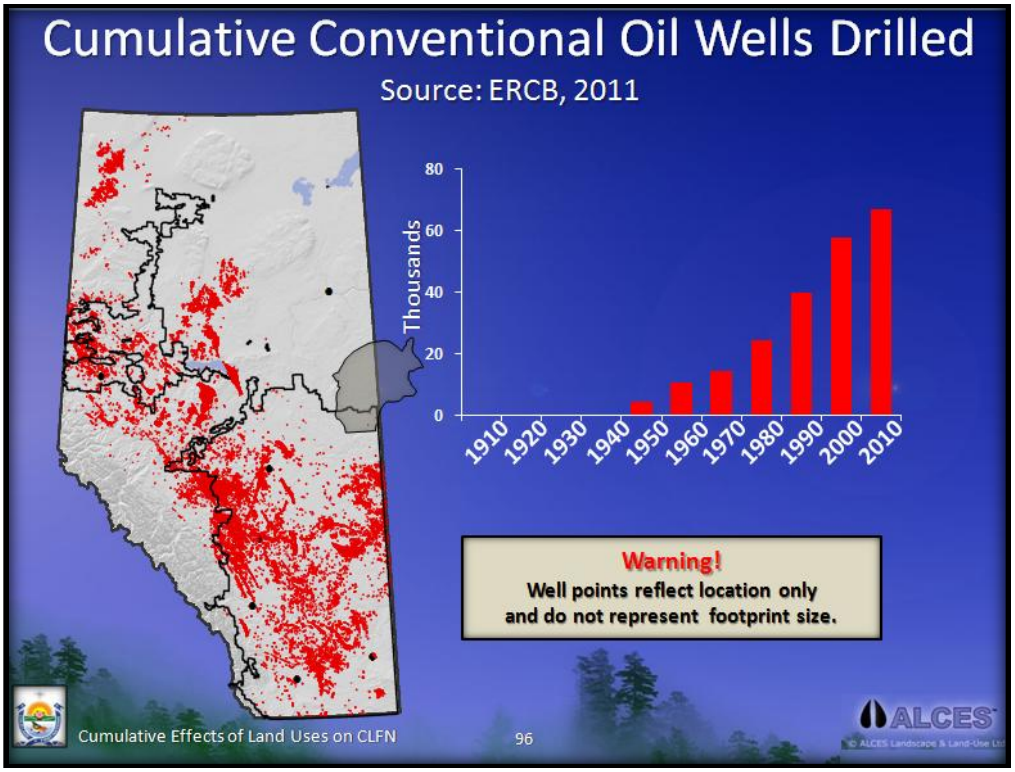


Figure 76. CLFN SA in context of historical conventional oil production in Alberta. Source: ERCB, 2011.

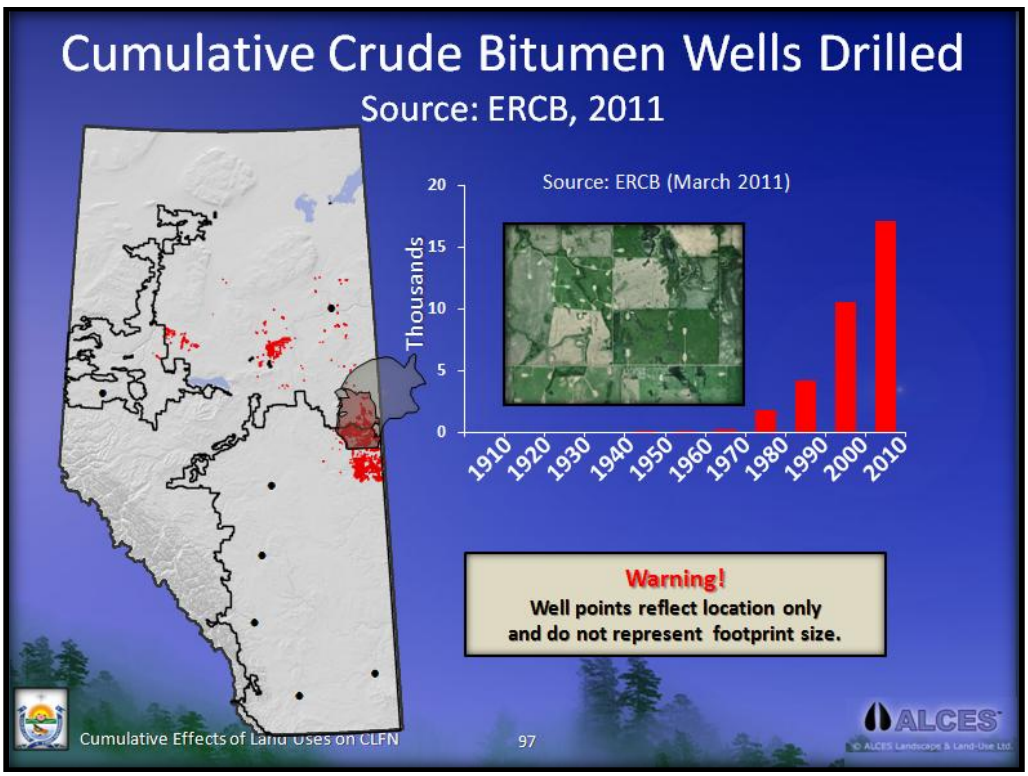


Figure 77. CLFN SA in context of historical unconventional oil (heavy, bitumen) production in Alberta. Source: ERCB, 2011.

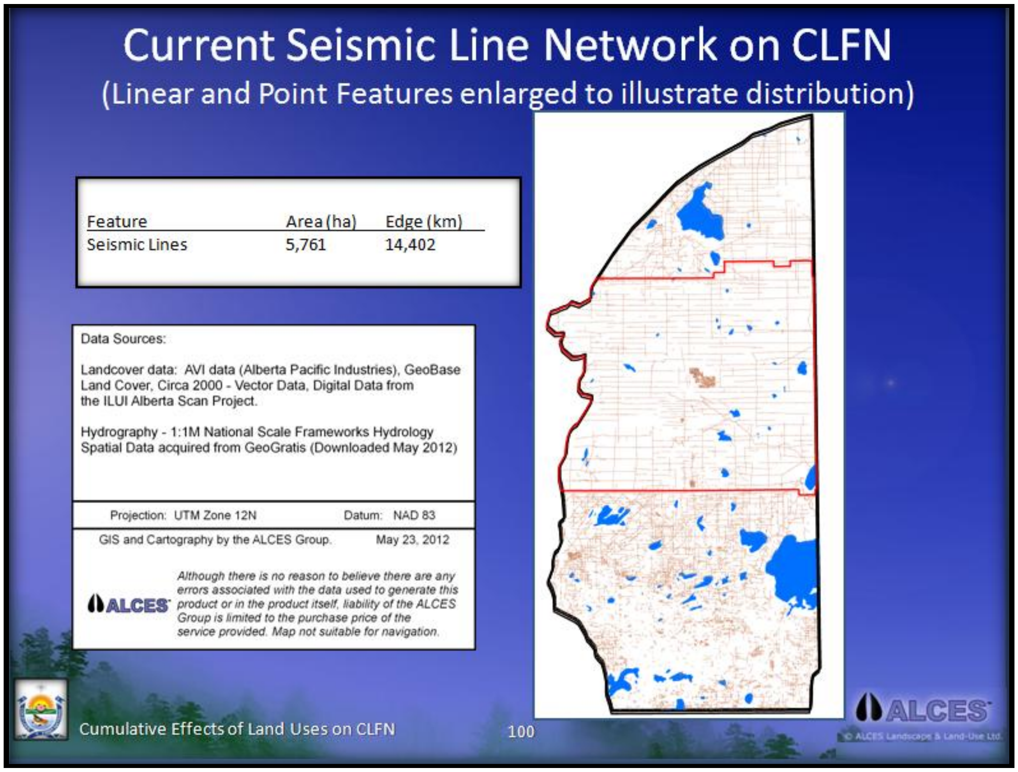


Figure 78. Current seismic line network on CLFN SA.

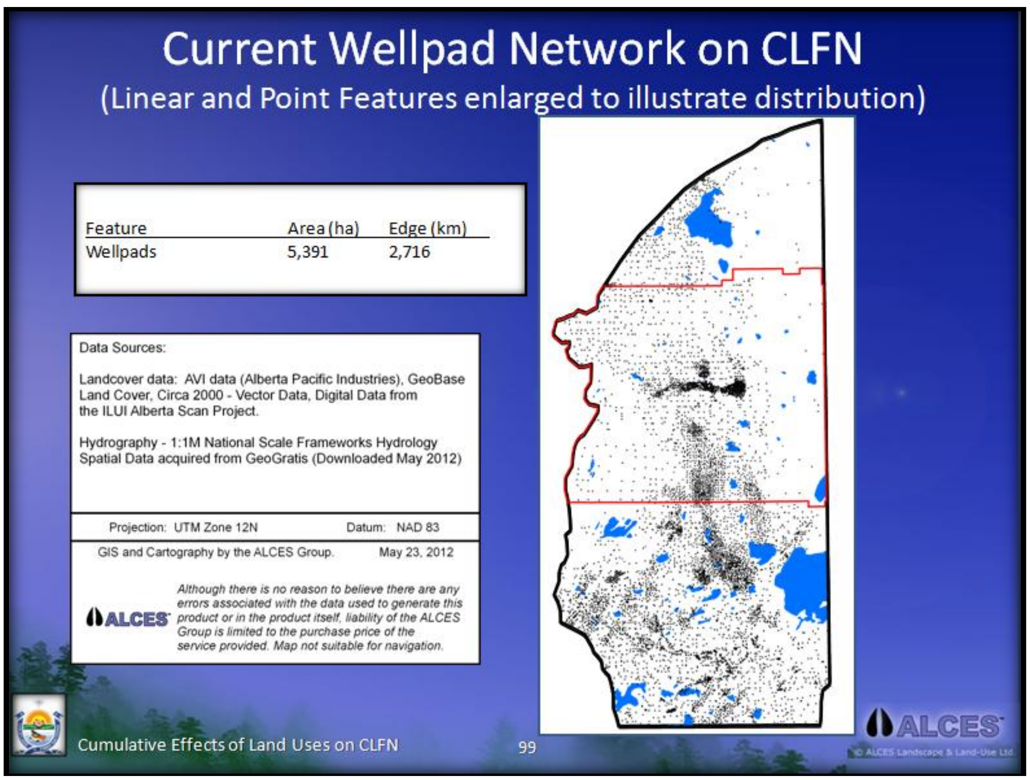


Figure 79. Current wellpad network on CLFN SA.

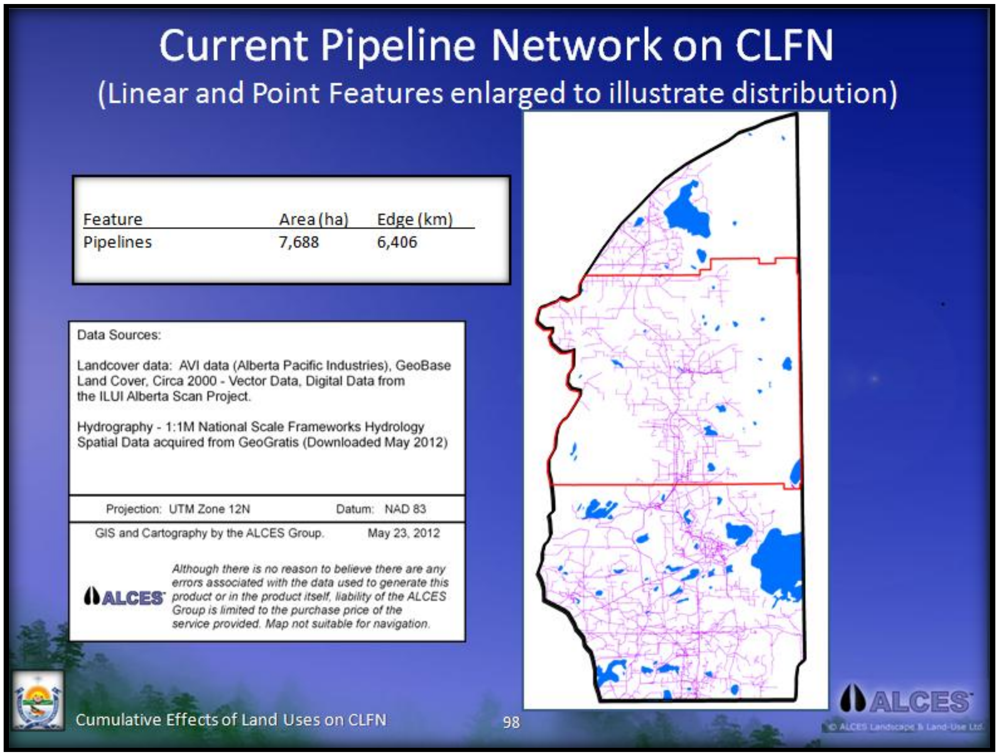


Figure 80. Current pipeline network on CLFN SA.

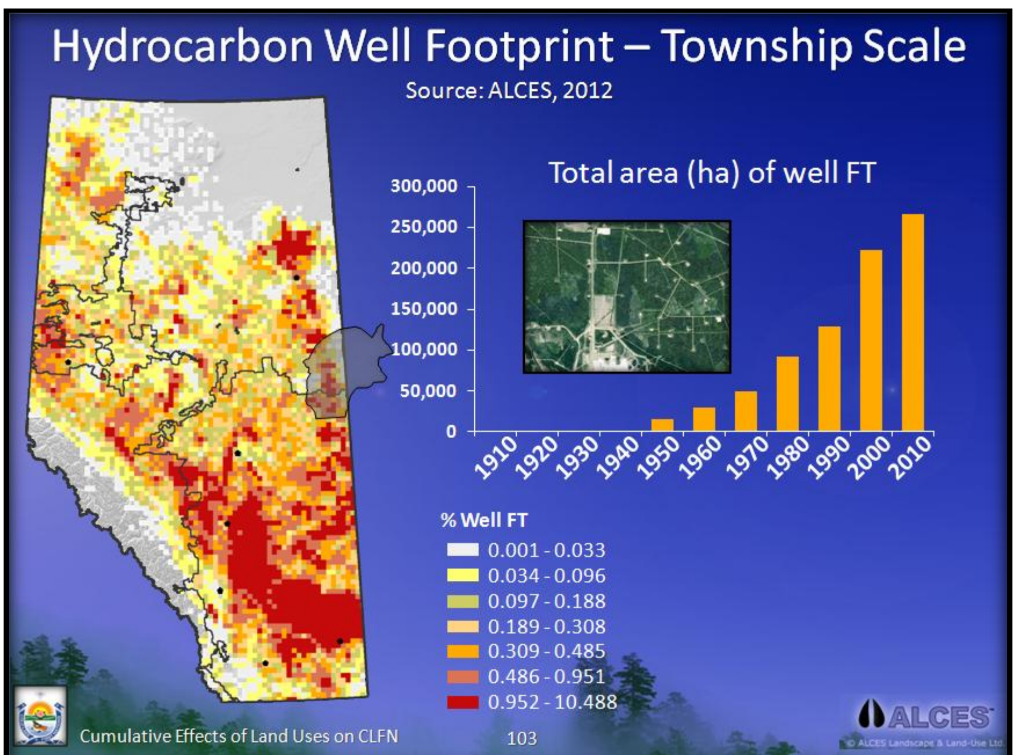


Figure 81. CLFN SA in context of historical well footprint in Alberta. Source: ERCB, 2011.

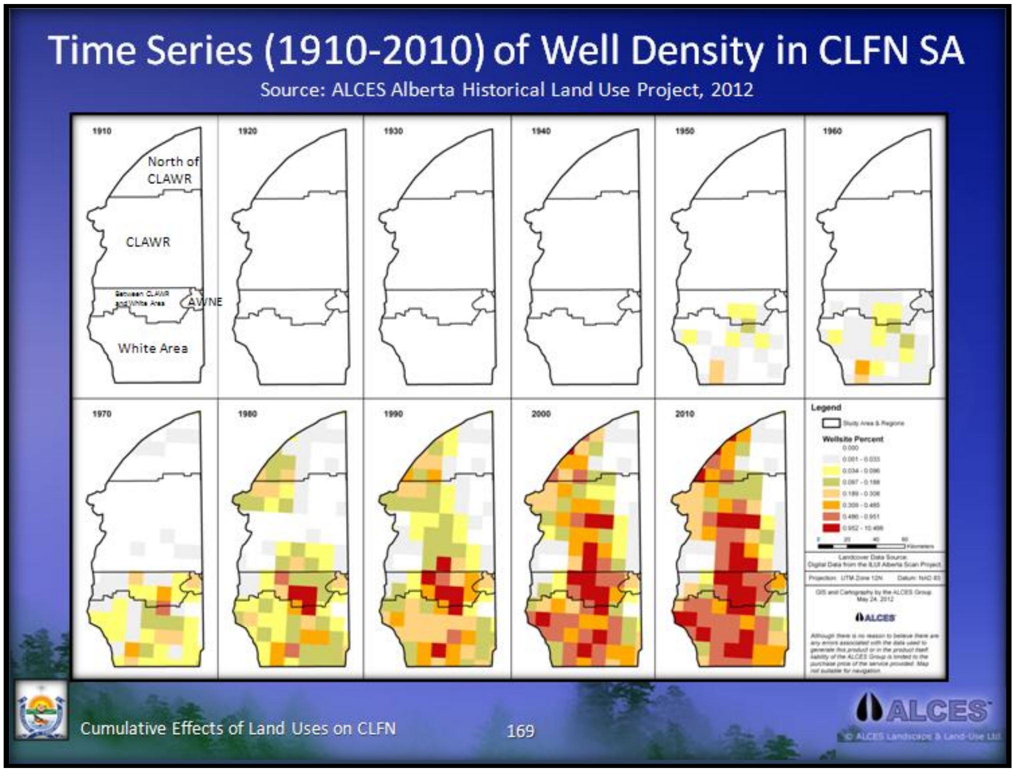


Figure 82. Time series (1910-2010) of well density in CLFN SA.

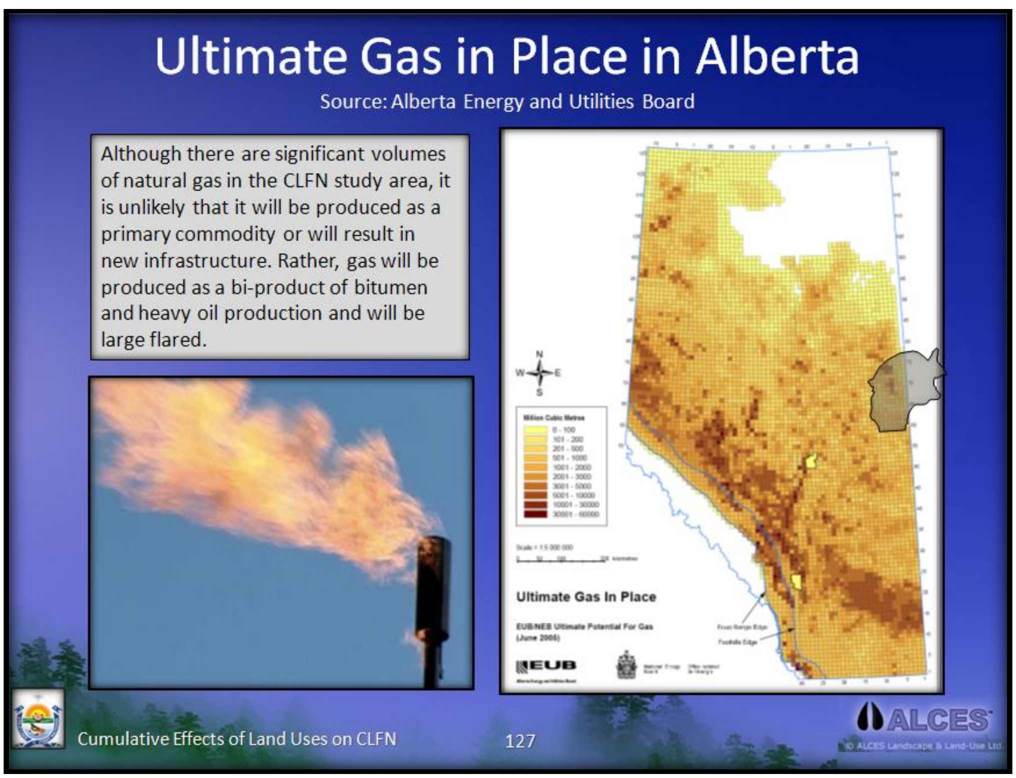


Figure 83. Ultimate Gas in Place in Alberta and in relation to the CLFN SA. Source: Alberta Energy and Utilities Board.

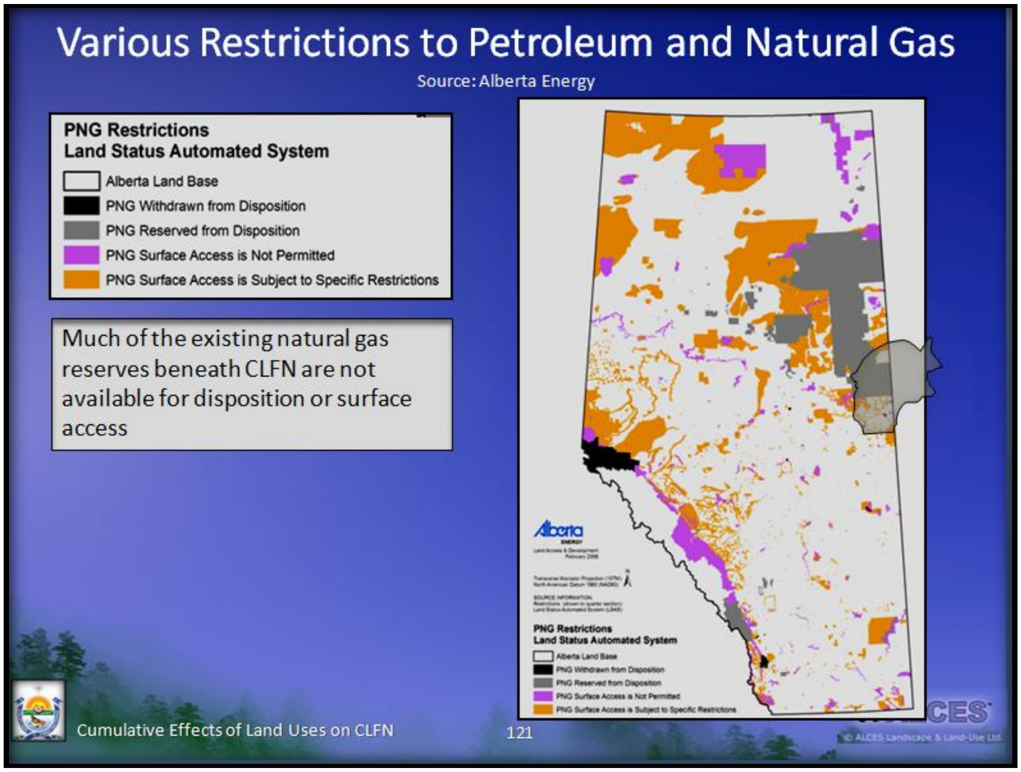


Figure 84. Various restrictions to natural gas production in region of CLFN SA. Source: Alberta Energy.

5.8 TRANSPORTATION

Transportation has changed much for the peoples of CLFN during the past 200 years. In the pre-European era, common modes of travel included walking, snowshoeing, and canoeing. The rivers and lake shorelines would have been as important as movement corridors 200 years ago as roads are today. Horses were not commonly used or owned by CLFN until the 1930s. With the arrival of European settlements and agriculture came the conversion of major trail routes into roads, and eventually the construction of a 2 x 1 mile road grid in the White Area. This network was further expanded by private and public roads to accommodate the land-uses of parks, military, and rural residential.

During the first several decades following the arrival of Europeans, transportation networks and general “access” to the landscape would have increased by orders of magnitude. Distances that would have taken multiple days or weeks to transverse on foot, by dog sled, or by canoe eventually became accessible in a matter of hours by truck, car, snowmobile, and quad for those CLFN members who had access to vehicles. Although the amount of time that CLFN were actually “living on the land” was slowly declining by the mid-1900s, the community gained increased access efficiency by using vehicles on a rapidly expanding network of roads (Figure 85) until the establishment of CLAWR abruptly terminated the people’s ability to access traditional trails and water routes throughout the Traditional Territory. In the decades that followed, physical access to areas outside CLAWR generally increased with construction of seismic lines, access roads and pipelines.

The changes to land accessibility have profoundly affected the mindset of the CLFN community. To the younger generation, who has been raised with limited access to Traditional Territory, recent changes to land access have been incremental. To the elders however, who hold a collective memory and a strong cultural connection to previously accessible land, the changes they observed seemingly occurred overnight.

The current road network of CLFN (6,600 ha, 3,600 km) is well established in the White Area, and is sparse in the central and northern reaches (Figure 86). Roads within CLAWR provide access to the infrastructure of the military community and hydrocarbon sector, but remain largely inaccessible to CLFN. The history of road construction in the CLFN SA is placed within context of the Province of Alberta in Figure 87.

Transportation networks and access are inextricably linked. The more abundant linear features (roads, trails, transmission lines, pipelines) are on the landscape, the easier it becomes for people with vehicles (aboriginal, non-aboriginal) to move across the landscape and gain access to wildlife that can be hunted, trapped, or fished. It is not surprising, therefore, that research projects repeatedly demonstrate the negative relationship between access density (km/km^2) and abundance of harvested ungulate (moose), fish (grayling, walleye), and furbearer(fisher, marten) species. Avid outdoorsmen relish opportunities to travel along newly created roads, seismic lines, or pipelines, as these new features provide entrance into wildlife habitat that is relatively unexploited, and provides wonderful, if not short-lived, experiences of hunting, fishing, and trapping (Figure 88).

What is clear to all contemporary and traditional wildlife stewards is that fish and wildlife populations cannot be sustained where transportation features are abundant and harvest is not carefully regulated. Lots of roads and unhindered hunting and trapping are clearly a recipe for collapse of local and regional populations of species that that attract hunters, fishers, and trappers. Where fish and wildlife resources are inadequate to sustain both aboriginal and non-aboriginal stakeholders, the statutes are clear and First Nations are to be given priority. That said, an abundance of harvesters, roads, and unlimited and unregulated harvest, has also lead to the undesired conclusion of resource collapse. It is therefore clear that the conversation about access management is a critical one for both aboriginal and non-aboriginal communities alike.

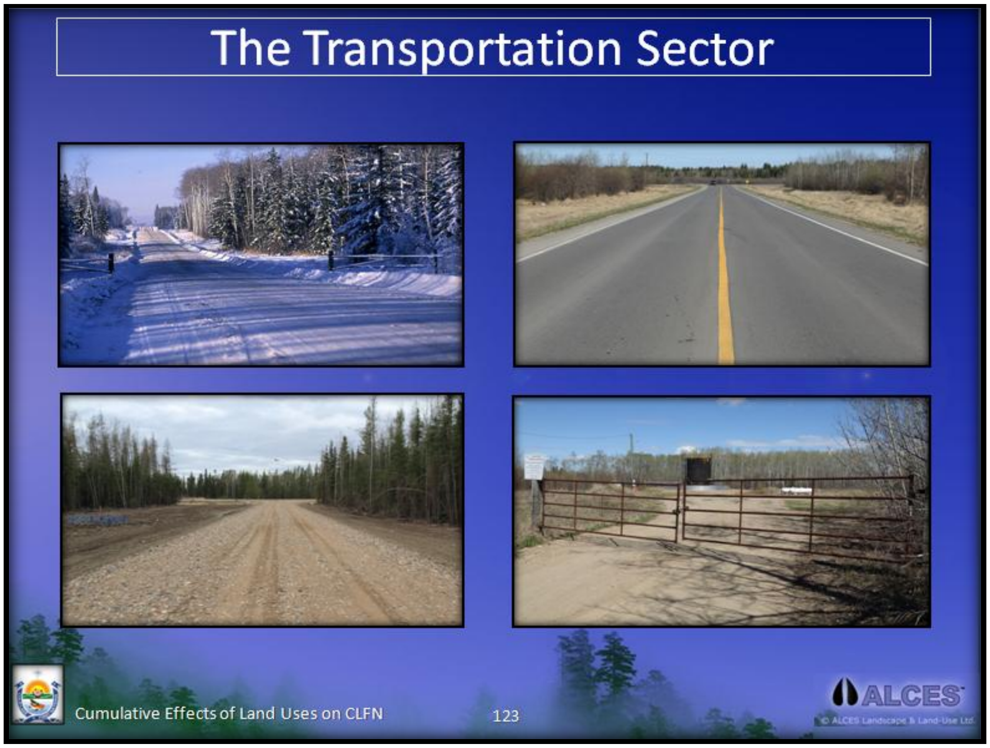


Figure 85. Roads provide access to the landscape but also provide challenges to sustainable management of wildlife resources.

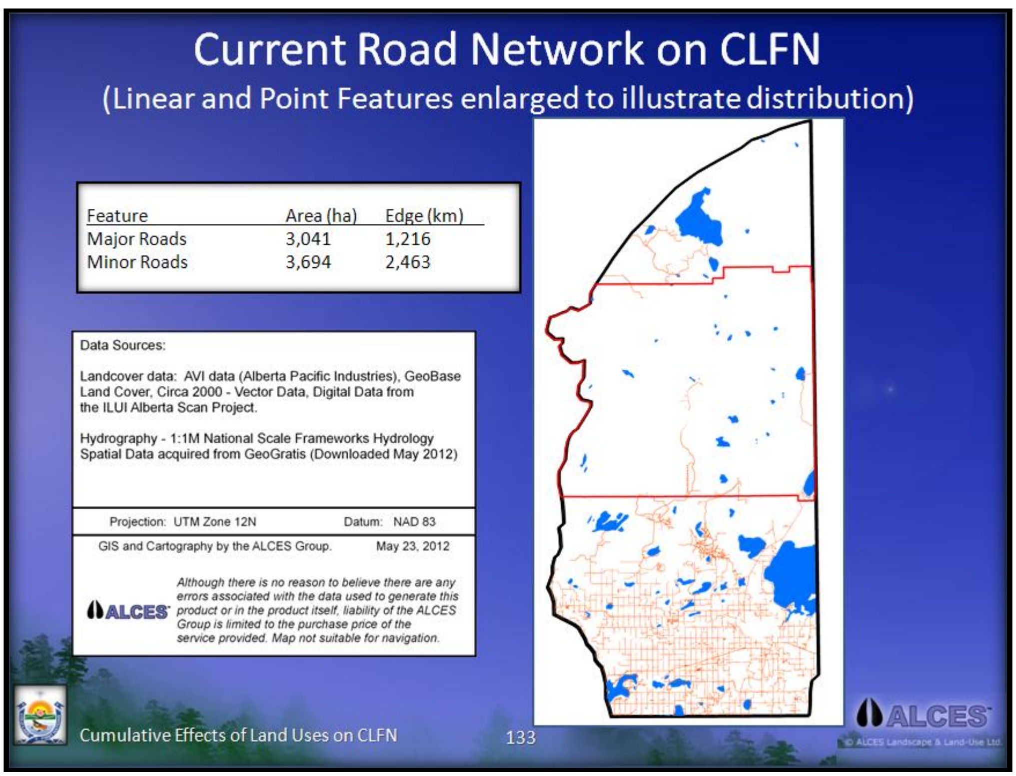


Figure 86. Current road network on CLFN SA.

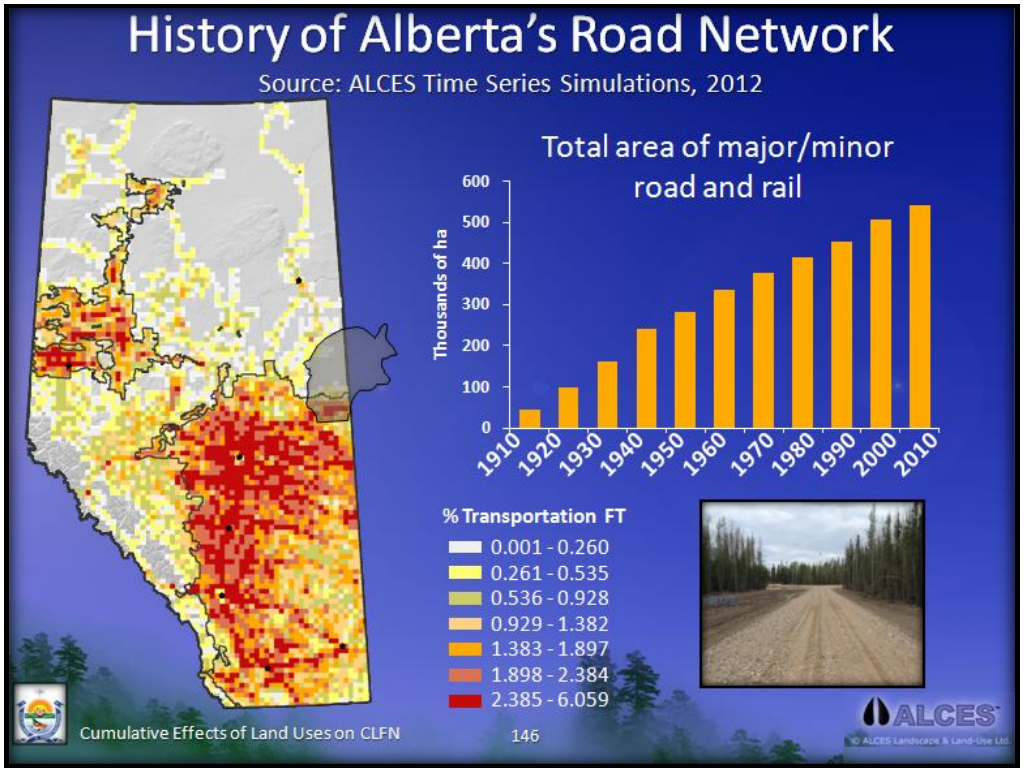


Figure 87. Road network of CLFN SA in context of Alberta.

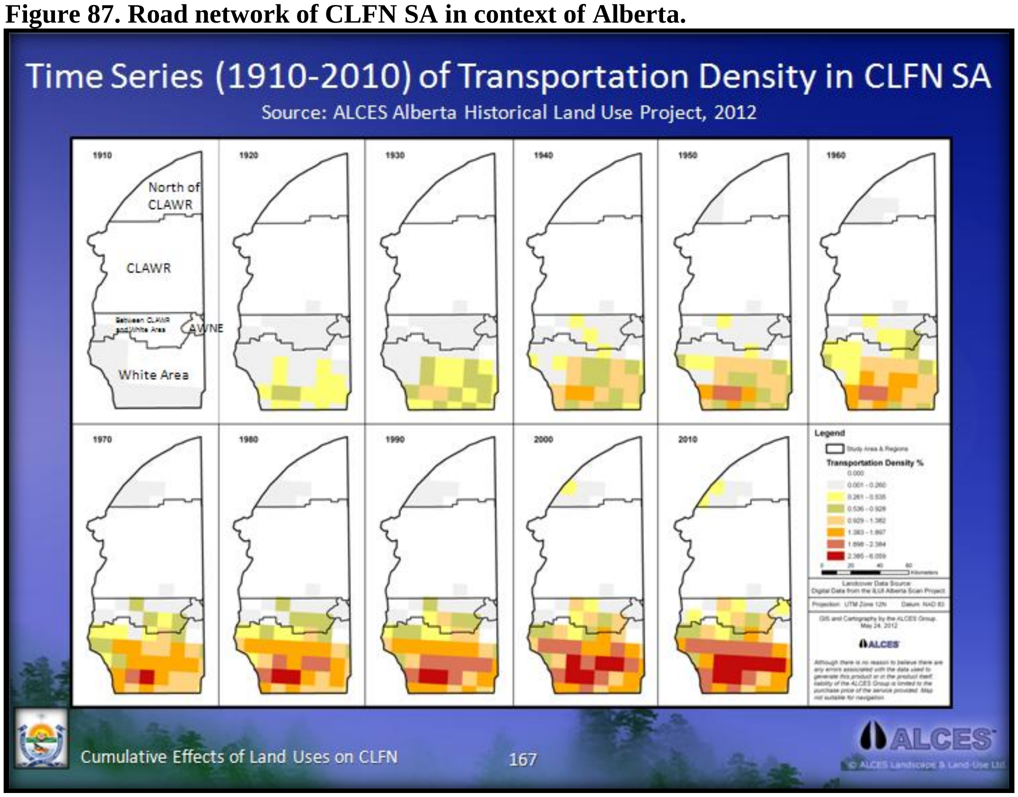


Figure 88. Time series (1910-2010) of transportation density in CLFN SA.

5.9 CURRENT STATUS OF MULTIPLE OVERLAPPING LAND-USES

Assessing the direct and indirect footprints of all overlapping land-uses is a key step to completing a comprehensive cumulative effects assessment. As such, the next logical step is to combine the anthropogenic footprints from the land-use sectors of croplands, transportation, energy sector, residential, military, and parks. Collectively, the direct footprints of each land-use, and their indirect buffers, largely determine the amount and quality of habitat available for harvested species (moose, fish, furbearers, berries) and ecological processes. These land-use footprints also determine the production of such important commodities as crops, livestock, and hydrocarbons (Figure 89).

When adopting a broad historical perspective, it is easy to see that not all land-uses arrived on the CLFN SA at the same time, nor did they have the same level of effect on key indicators. Very broadly, the history of land-uses is displayed in Figure 18. The general order of land-use histories is:

1. First Nations
2. Trapping
3. Agriculture (crops and livestock)
4. Settlements
5. Residential Schooling
6. Military
7. Oil and Gas

While some might find it confusing, possibly offensive, to refer to First Nations as a land-use, that is precisely what they were and are. This aboriginal community was the defining use of the landscape prior to the 1900s in space and time from the perspective of people and their activities. Whatever anthropogenic footprints existed (camps, trails, waste dumps, burial sites) would have been theirs and not altered by European cultures that had yet to arrive. Their spatial and temporal pattern of land-use would change radically with the arrival of trapping and subsequent land-uses associated with non-aboriginal cultures.

It may also be confusing to describe “residential schooling” as a land-use, but from the perspective of cultural movement patterns, the government decision to school CLFN children away from their parents and homes inevitably caused a major shift in the way CLFN people used the land.

At a simplistic level, Figure 90, Figure 91, and Figure 92 reveal the extent to which all land-uses have transformed the CLFN landscape since pre-industrial times. Approximately 113,000 ha has been converted from native forests and grassland into crops (Figure 100) and another ~40,000 ha is currently in the footprint of transportation (9,000 ha), energy sector (21,000 ha) and residential (10,000 ha). Combined, 13.6% of the landscape is in the direct footprint of land-use. Highest increases in direct land-use footprint occur in the southern portions of CLFN SA and are attributed to agricultural conversions (Figure 93 and Figure 94). In contrast, highest land-use edge density in CLFN SA is associated with the footprints of the energy sector in the area south of CLAWR and north of the White Area (Figure 95,

Figure 96, Figure 97). Temporal changes to the natural landscape are illustrated in Figure 98 and Figure 102, and are shown as a time series in Figure 99.

At the scale of the CLFN SA, it is difficult to discern narrow land-use features such as roads, seismic lines and pipelines, so linear features were buffered by 100 m to allow viewers to visualize their locations (Figure 101).

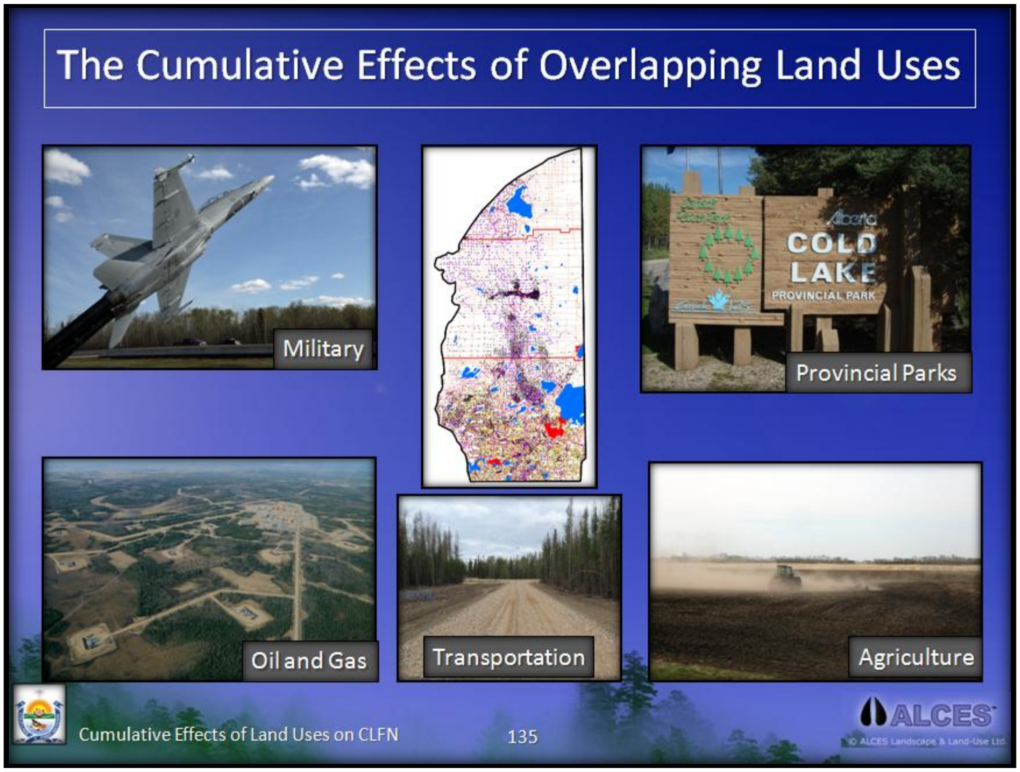


Figure 89. The CLFN landscape is being collectively transformed by a suite of overlapping land-uses.

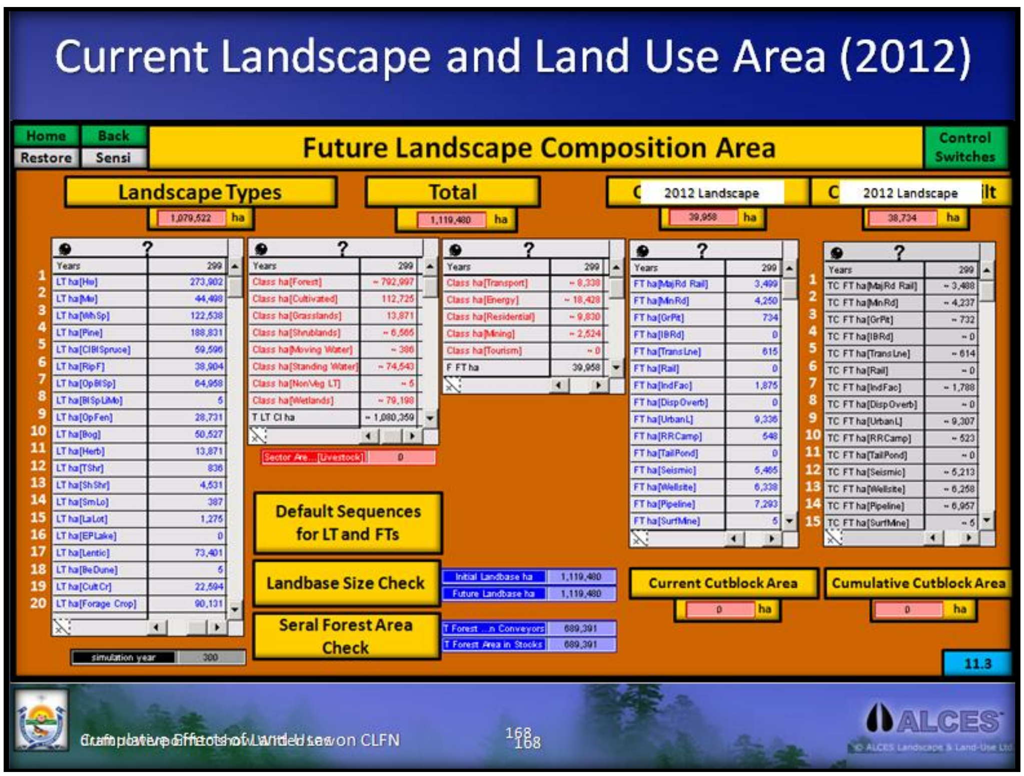


Figure 90. Current (2012) area in landscape and footprint types on CLFN SA.

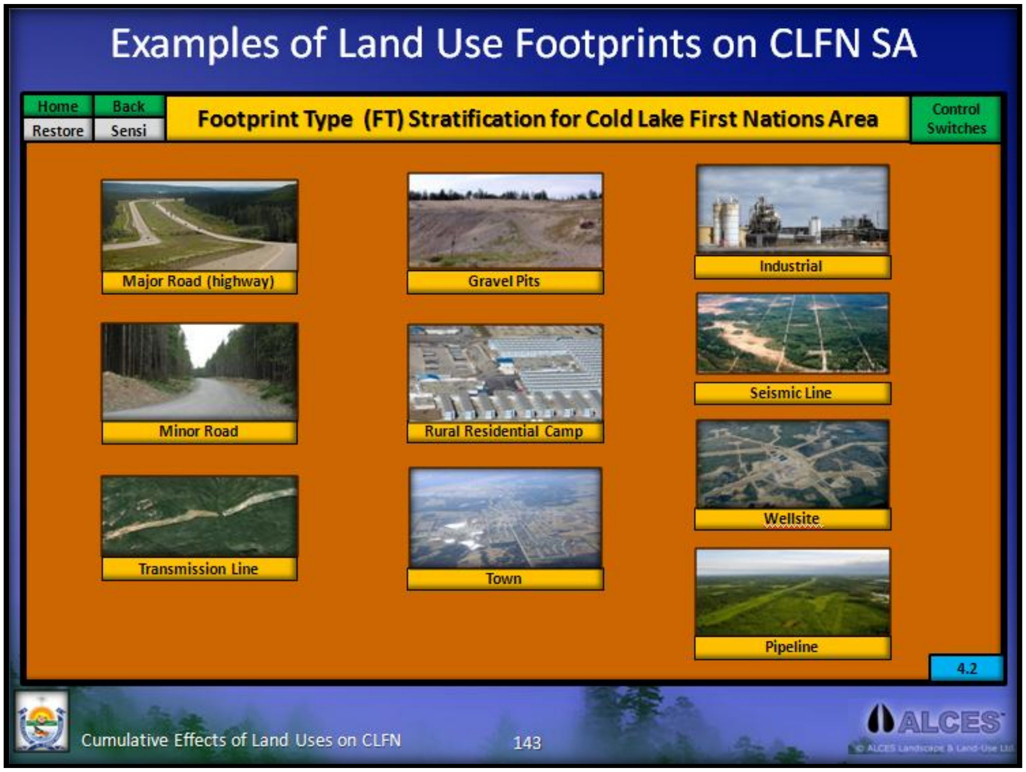


Figure 91. Examples of key land-use footprints on CLFN SA.

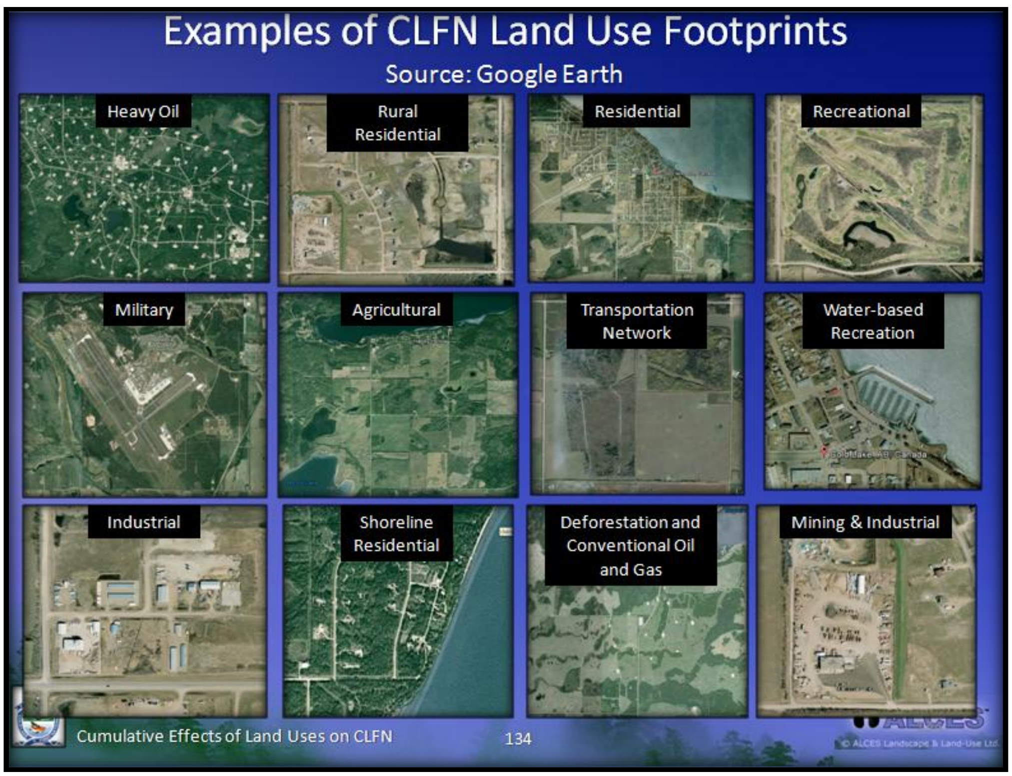


Figure 92. Examples of land-use footprints on CLFN SA as clipped from Google Earth (www.earth.google.com).

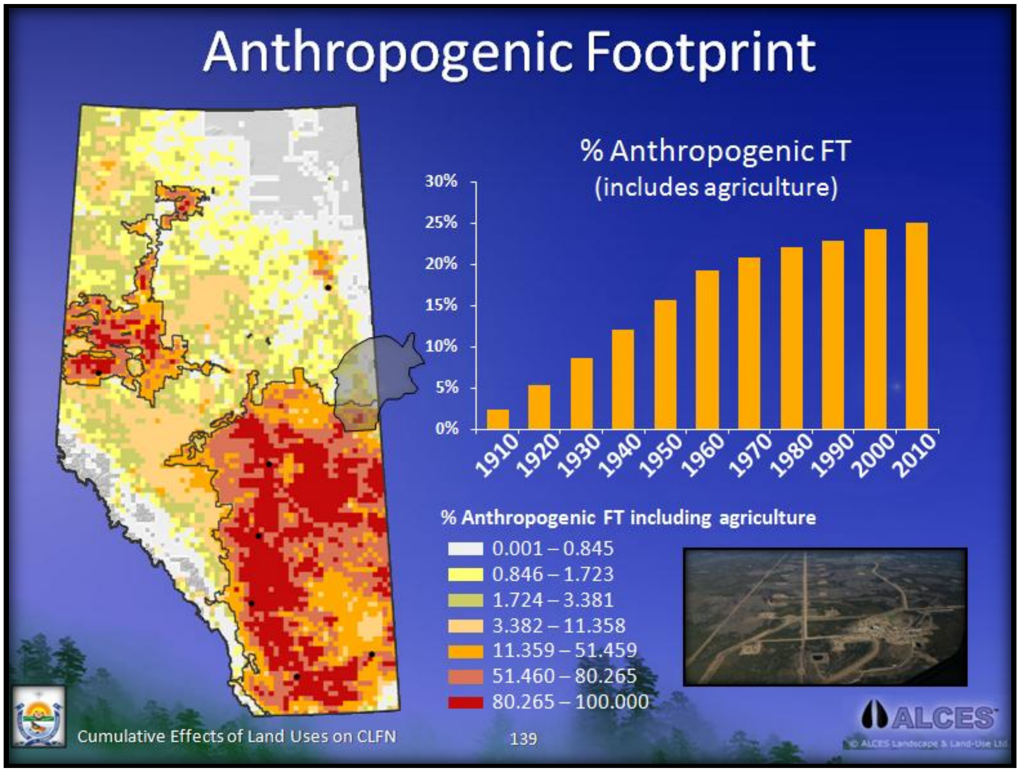


Figure 93. Temporal changes in anthropogenic area in Alberta and CLFN SA.

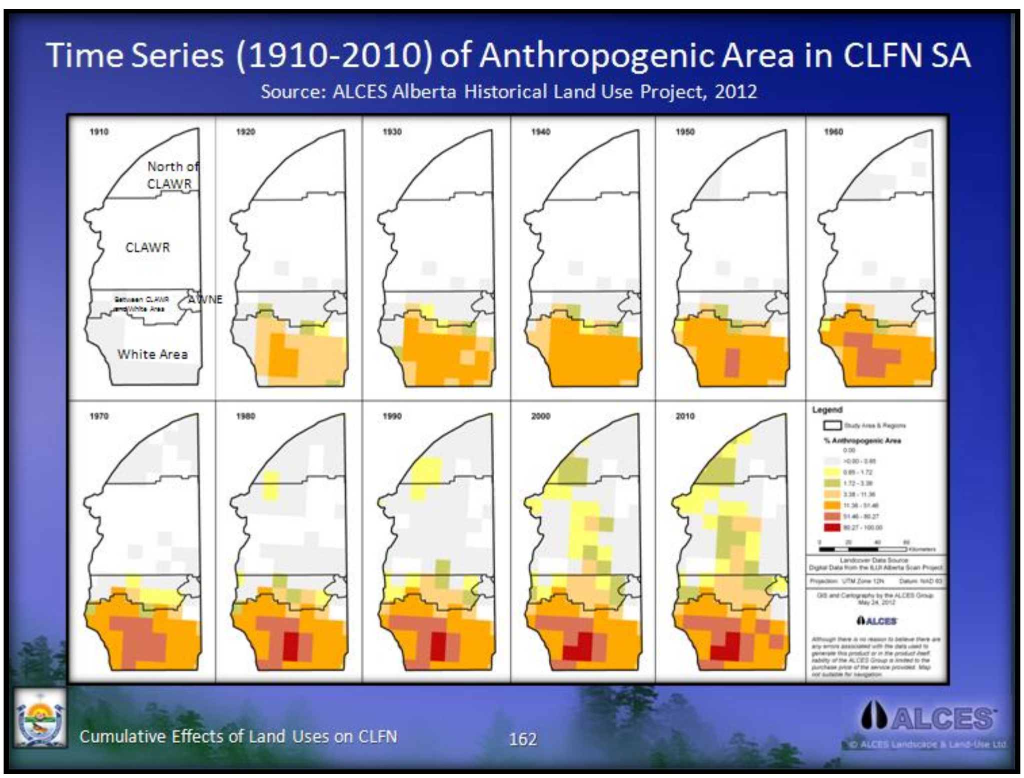


Figure 94. Historical time series (1910 - 2010) of anthropogenic area in CLFN SA.

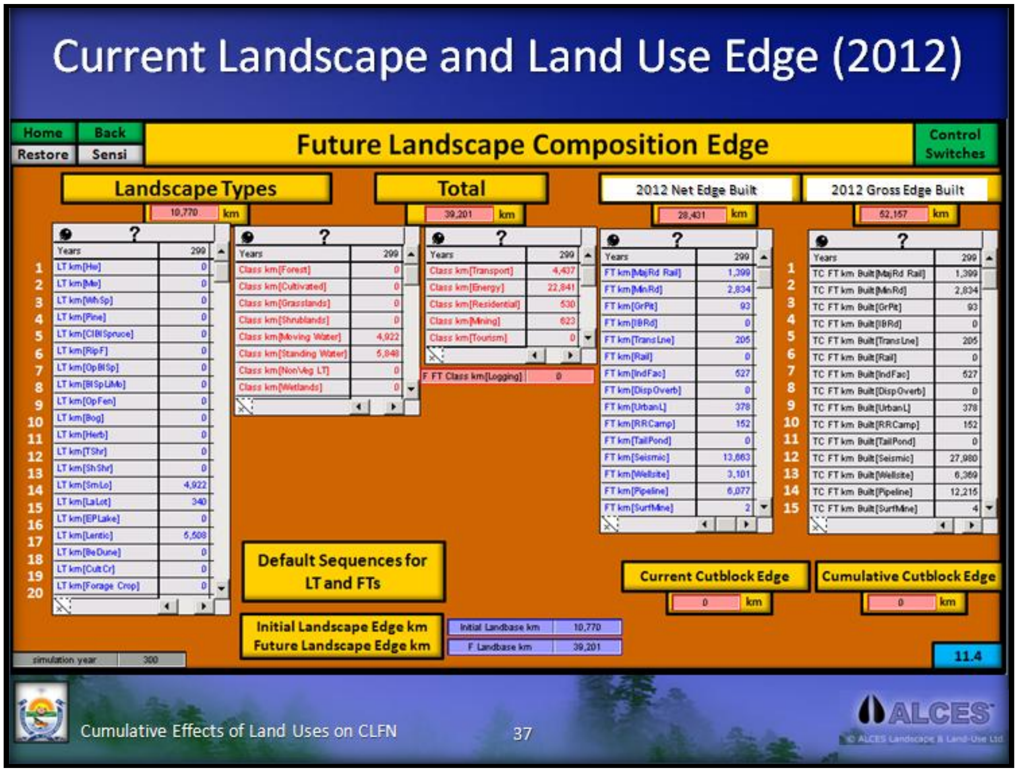


Figure 95. Current and Cumulative Land-use Edge on CLFN SA as of 2012.

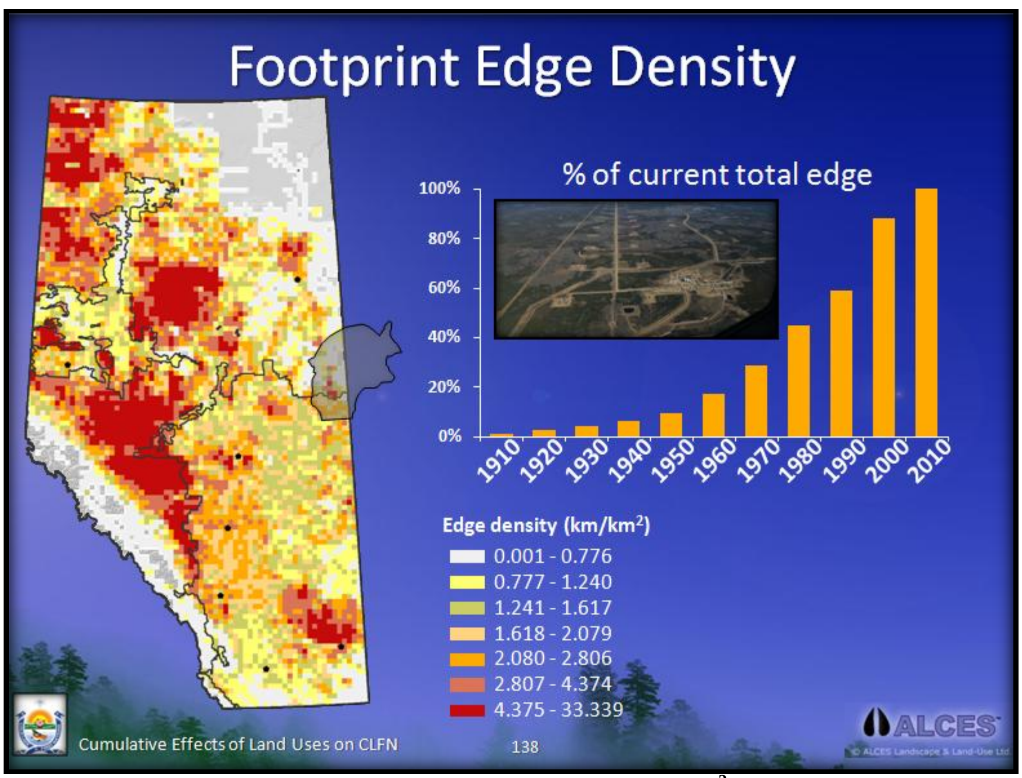


Figure 96. Temporal changes in footprint edge density (km/km^2) in Alberta and CLFN SA.

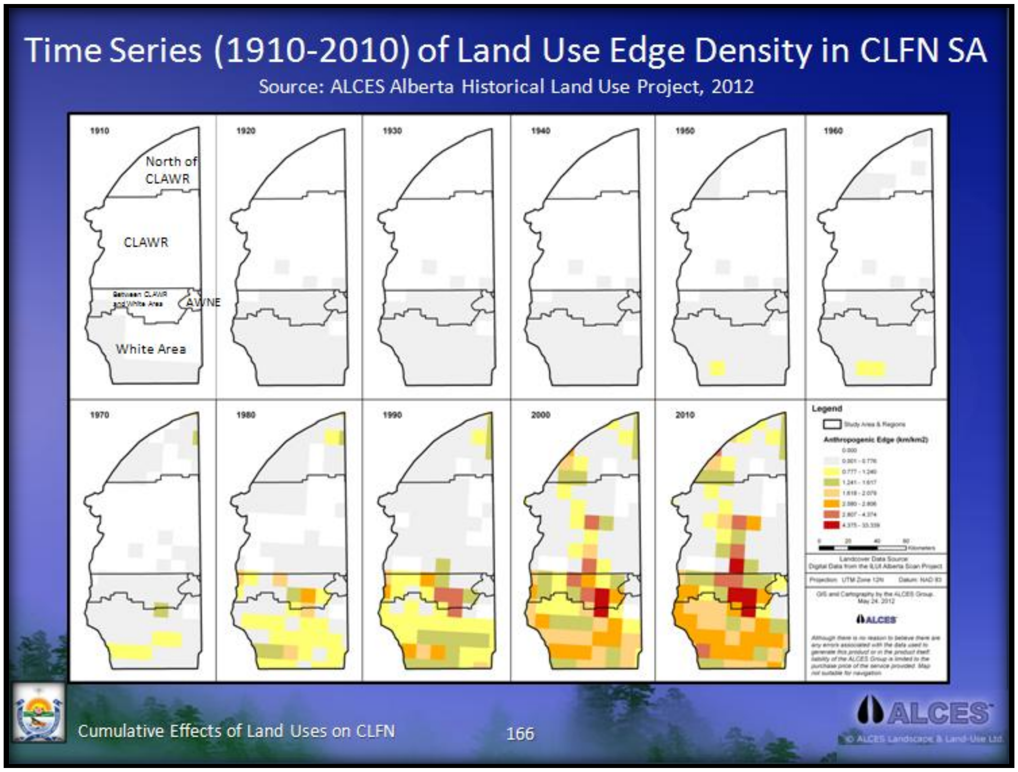


Figure 97. Historical time series (1910-2010) of land-use edge density in CLFN SA.

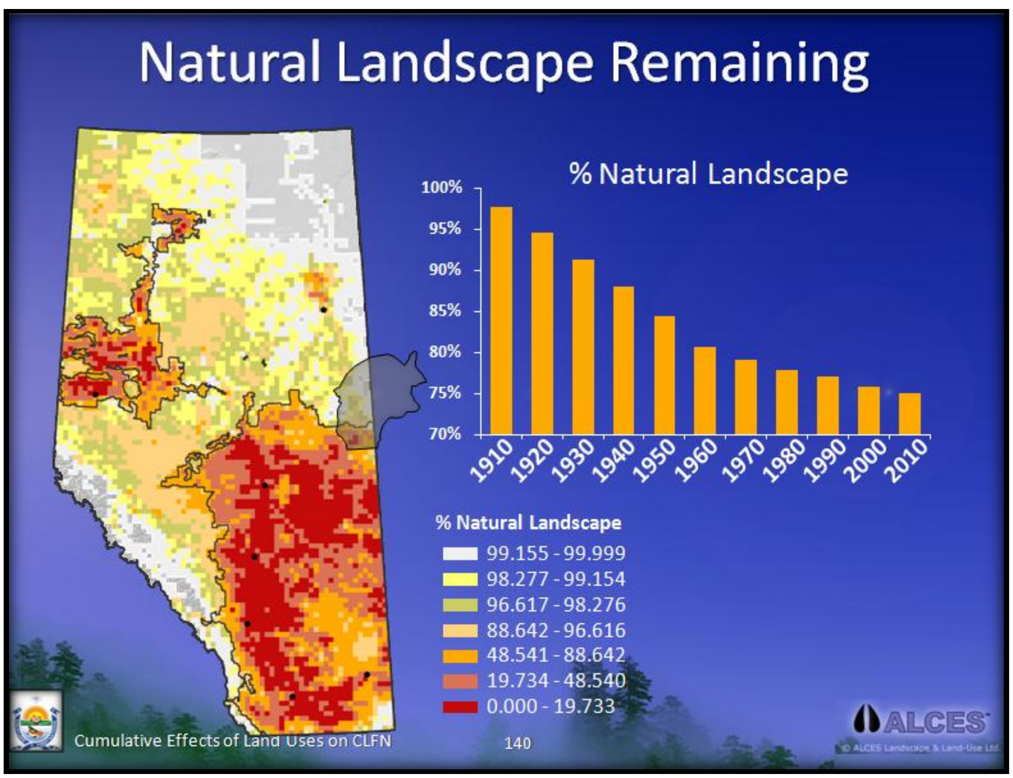


Figure 98. Temporal changes in natural landscapes in Alberta and CLFN SA.

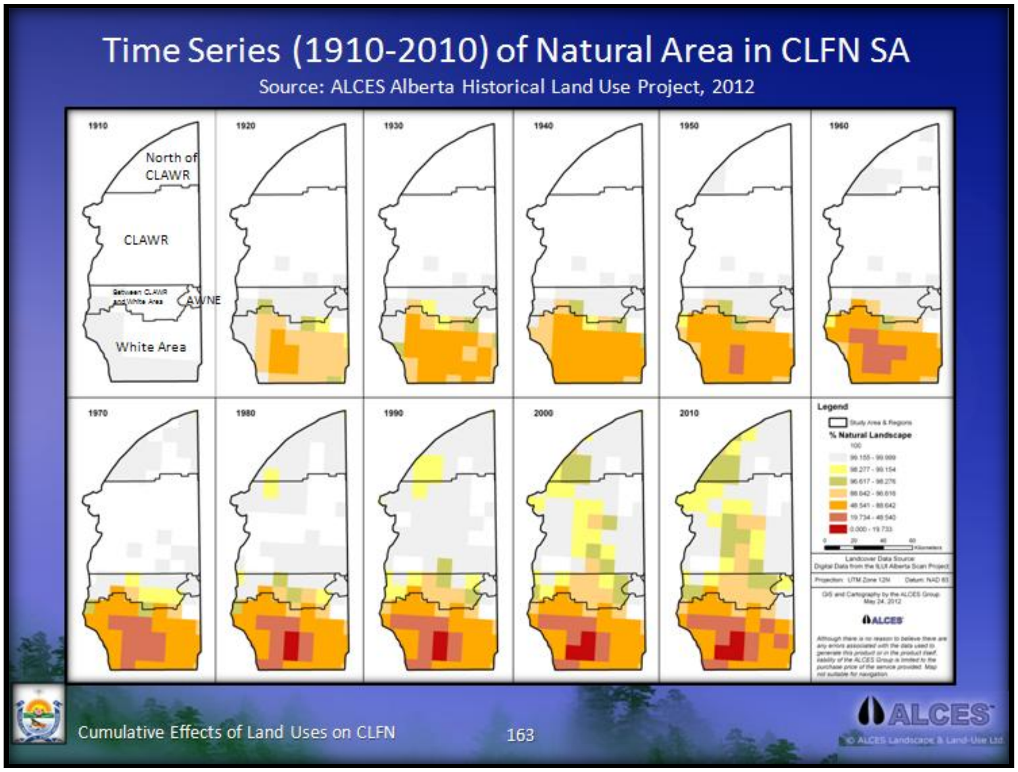


Figure 99. Historical time series (1910-2010) of natural area in CLFN SA.

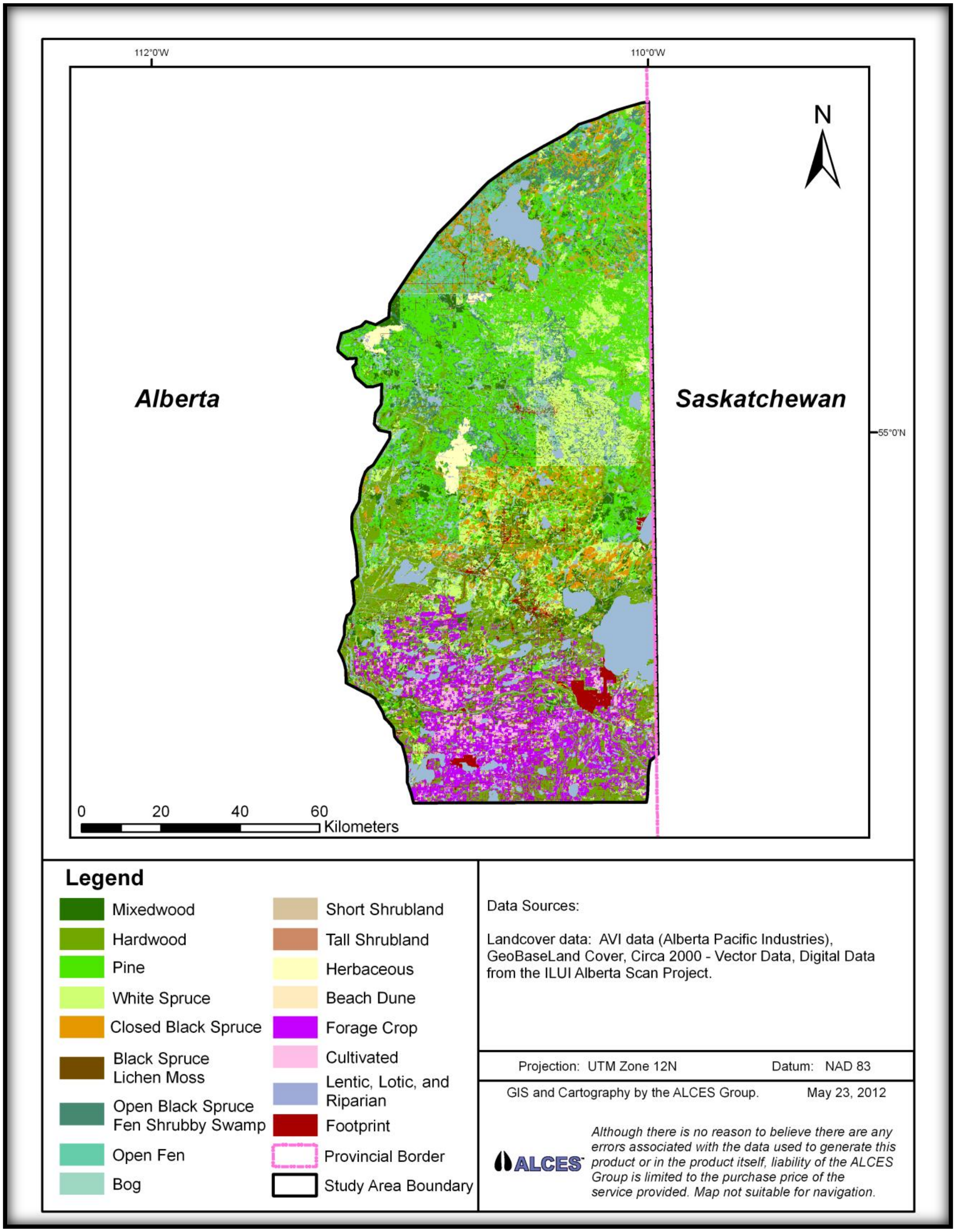


Figure 100. Current (2012) landscape types in CLFN SA illustrating the prevalence of croplands in the southern reaches of the study area.

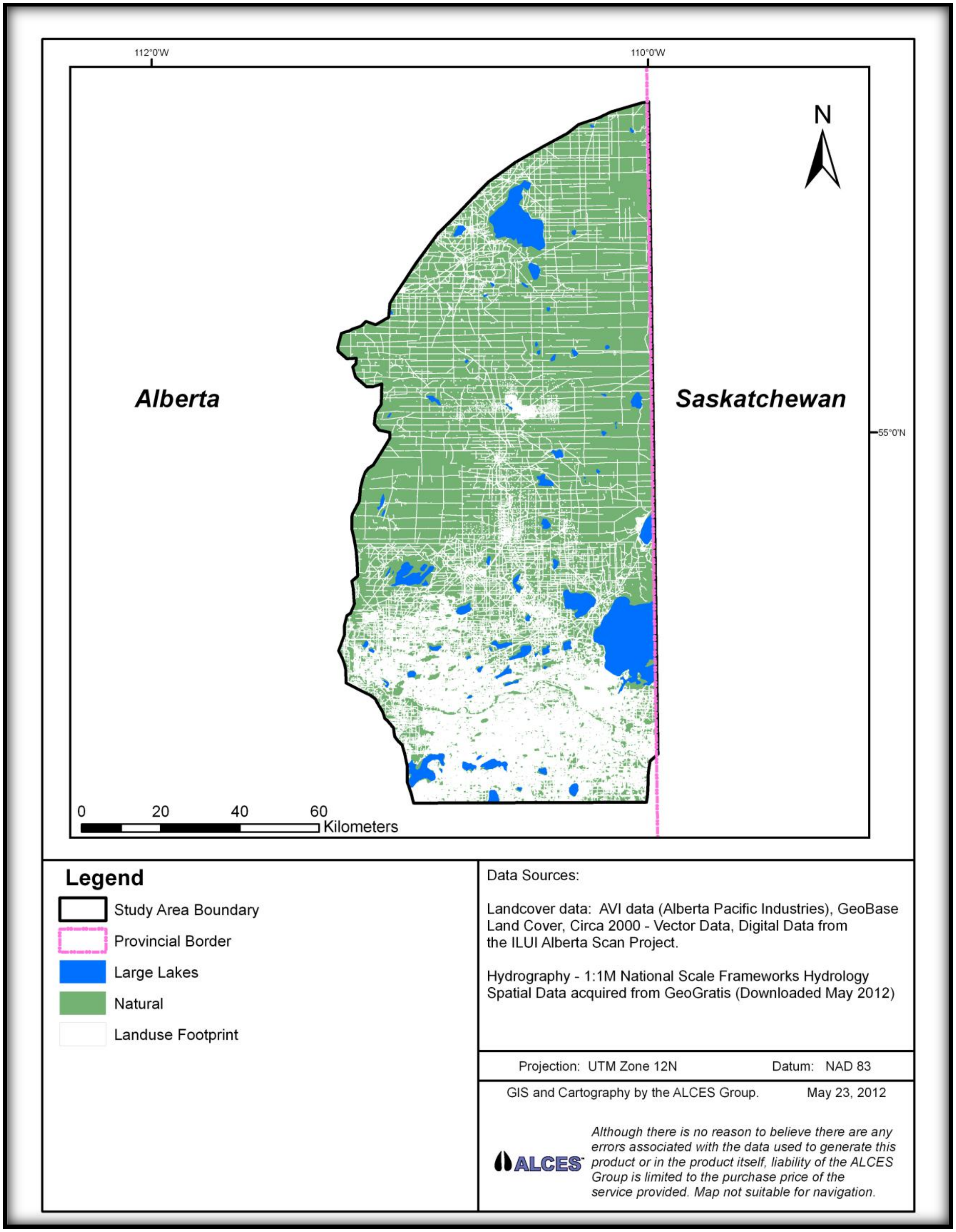


Figure 101. Buffered anthropogenic footprint in CLFN SA. CLAWR not shown in white.

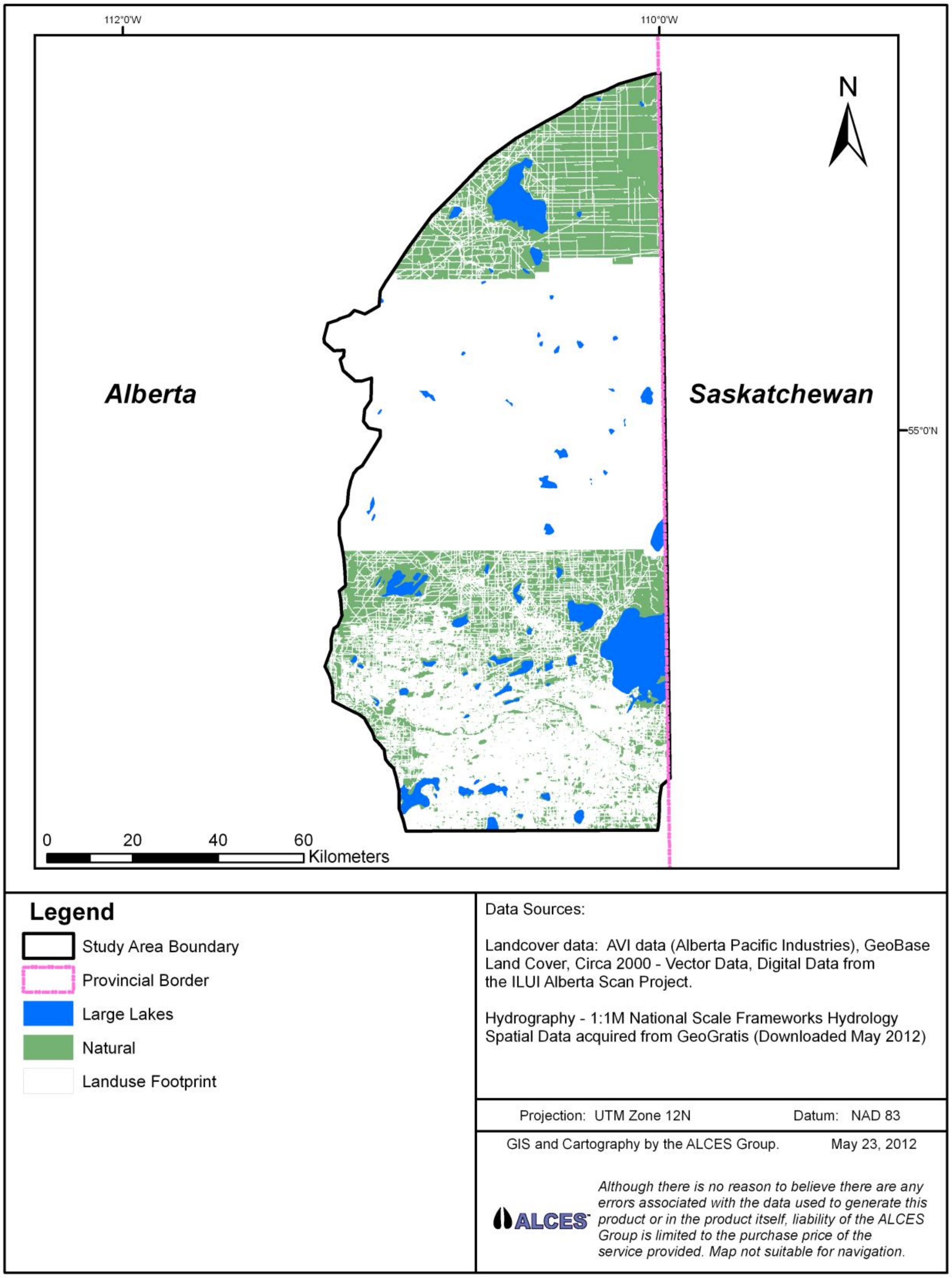


Figure 102. Cumulative loss of natural landscape in CLFN SA from land-use footprint. 100 m buffer placed on linear and curvilinear features. CLAWR shown in white.

6. PERFORMANCE INDICATORS

A set of social/cultural, economic, and ecological/landscape indicators were selected to inform the discussion about both the benefits and liabilities that attend historic, current and future land-use trajectories on the CLFN SA (Figure 103). It is implicit within the ALCES cumulative effects approach that all land-uses, without exception, create both benefits and liabilities (http://www.alces.ca/Videos/index?id=11), and an important objective of cumulative effects assessments is to provide an informed dialogue about the relative balance of these opportunities and risks.

Where appropriate throughout this report, the results showing indicator performance are presented using tables, graphs, and maps.

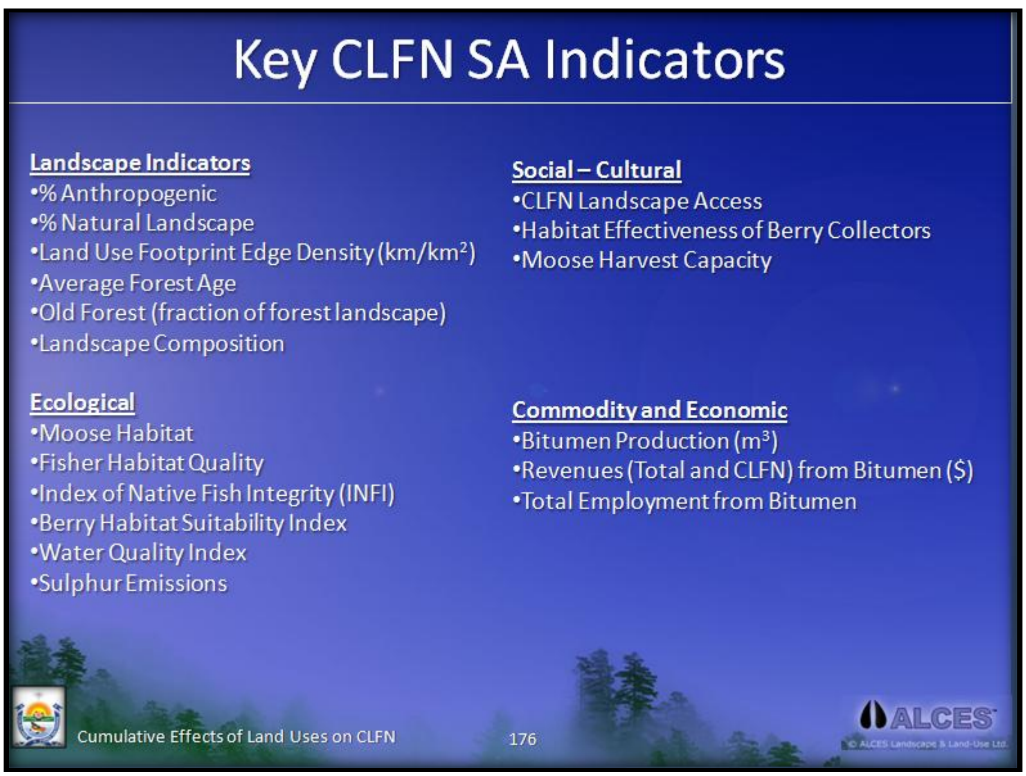


Figure 103. Selected landscape, ecological, social-cultural and economic CLFN SA performance indicators.

Table 2. Key performance indicators for CLFN ALCES simulator

Class	Indicator	Description
Economic and Social Indicators		
Economic	Commodity Production	Amount of annual commodity production by land-use activity: • Heavy oil (m^3) • CSS bitumen (m^3) • SAGD bitumen (m^3) • Crop Production (tonnes)\ • Cattle Harvest (tonne)
	Revenue	Gross revenue ($) generated by commodity sale for each land-use sector. Sectors examined include: • Heavy oil (m^3) • CSS bitumen (m^3) • SAGD bitumen (m^3)
Social	Direct Employment	Direct employment (annual direct FTE positions) for each land-use sector multiplied by an employment coefficient). Sectors include: • Heavy oil (m^3) • CSS bitumen (m^3) • SAGD bitumen (m^3)
	Non-aboriginal Population	Total regional non-aboriginal human population as calculated by a projected growth rate.
	Aboriginal Population	Total regional aboriginal human population as calculated by a projected growth rate.
Land-use and Ecological Indicators		
Land	Total Area Disturbed	Total amount of human-caused surface disturbance (i.e., direct land-use footprint).
	Fragmentation (Linear Density km/km^2)	Landscape fragmentation as measured by Linear Density (total length of linear and polygonal features within a given area, expressed as km/km^2).
	Forest Age	Forest age as reported by: • average forest age (years) • percent old forest (>100 yrs)
Wildlife and Fish	Moose Habitat Suitability Index (HSI)	Relative ranking of moose habitat quality (1 = perfect habitat, 0 = no value). The moose HSI is based on a model developed for the Regional Municipality of Wood Buffalo in Alberta (Kirk et al. 2009). The HSI value may be interpreted as an indicator of moose population status.
	Fisher HSI	Relative ranking of fisher habitat quality (1 = perfect habitat, 0 = no value). The fisher HSI is based on a model developed for the Regional Municipality of Wood Buffalo in Alberta ((Kirk et al. 2009). The HSI value may be interpreted as an indicator of fisher population status.
	Index of Native Fish Integrity (INFI)	INFI conveys changes in abundance and composition of fish species that are most likely to change in response to human effects such as rare fish, apex predators, common specialists, common generalists, and irruptives. An index value of 1.0 reflects an undisturbed fish community, while an index value of 0 reflects a highly disturbed community. The INFI model was developed for northeast Alberta, with the relationship between INFI and study area attributes based on expert opinion. Variables that negatively affect INFI include human density, water use, and watershed discontinuity due to hanging culverts (Lagimodiere and Eaton 2009).
Water	Average Relative Water Quality Index	An index of relative landscape-scale water quality calculated from nitrogen, phosphorus and sediment load rates. Values range from 1.0 (high water quality) to 0 (very poor water quality).

6.1 LANDSCAPE AND ECOLOGICAL INDICATORS

The integrity of water, plants and wildlife, and the landscapes on which they depend and interact, is of primary importance and concern to CLFN. As such, the indicators of water quality, moose, fisher, fish and berries were selected and simulated in this project. Since these physical and ecological indicators are affected by both the natural and anthropogenic landscape, it is important to quantify temporal and spatial changes in landscape characteristics and relate these changes to biotic indicators.

This section describes in a very general sense the key dynamics that relate physical features (water), biotic components (fish, moose, fisher) and landscape metrics (natural, anthropogenic, fragmentation, core area). More detailed insights to these relationships are provided in the CLFN ALCES Manual (Appendix A).

6.2 METHODOLOGIES

6.2.1 Water Supply and Demand

All land-uses require water directly or indirectly. The major system components in which water resides and moves in the hydrological module of ALCES are: surface lentic (standing), surface lotic (moving), and aquifers. Fluxes of water between these pools occur as precipitation, evaporation, transpiration, surface runoff, and horizontal and vertical aquifer transit.

By tracking the composition of the landscape, and the gross and net water demands associated with commodity production and landscape composition, the CLFN ALCES model computes gross and water demand associated with crops, livestock, residential (domestic), the hydrocarbon, forestry and industrial sectors.

6.2.2 Relative Water Quality Index

Water quality was assessed by tracking changes to sediment, nitrogen, and phosphorus runoff, parameters that are negatively related to overall water quality. Runoff associated with simulated landscapes were assessed by applying runoff (tonnes/ha/year) and attenuation coefficients (proportion of runoff reaching the aquatic system) used by the North Saskatchewan Watershed Alliance (2009) to assess water quality in the North Saskatchewan Watershed in Alberta (Table 3). For each water quality parameter, a water quality index will then be calculated by dividing runoff associated with an undisturbed landscape by the simulated runoff estimate. Reductions in the index reflect a decline in water quality (i.e., if export has doubled, the index value is 0.5).

Table 3. Coefficients for assessing phosphorus, nitrogen, and sediment runoff associated with simulated landscapes.

Land cover type	Phosphorus		Nitrogen		Sediment	

	Runoff (T/ha/year)	Delivery (proportion of runoff)	Runoff (T/ha/year)	Delivery (proportion of runoff)	Runoff (T/ha/year)	Delivery (proportion of runoff)
Deciduous forest	0.0002	0.004	0.0025	0.03	0.24	0.03
Coniferous forest	0.0002	0.004	0.0025	0.03	0.24	0.03
Mixed forest	0.0002	0.004	0.0025	0.03	0.24	0.03
Shrub	0.0002	0.2	0.0025	0.03	0.25	0.03
Bryoids	0.0002	0.004	0.0025	0.03	0.24	0.03
Herbaceous	0.00017	0.17	0.00106	0.03	0.2404	0.03
Grassland	0.00017	0.17	0.00106	0.03	0.2404	0.03
Treed peatland	0.0002	0.004	0.0025	0.03	0.24	0.03
Shrub peatland	0.0002	0.004	0.0025	0.03	0.24	0.03
Herb. peatland	0.0002	0.004	0.0025	0.03	0.24	0.6
Barren	0.00005	0.1	0.00275	0.5	0.25	0.5
Water	0.00	0.25	0.00	1.00	0.00	1.00
Annual cropland	0.00097	0.1	0.006	0.6	1.44	0.03
Forage cropland	0.00033	0.05	0.004	0.3	0.77	0.03
Major road	0.0035	1.00	0.005	1.00	2.00	1.00
Minor road	0.0035	1.00	0.005	1.00	2.00	1.00
Inblock road	0.0035	1.00	0.005	1.00	2.00	1.00
Transm. line	0.00075	0.2	0.0051	0.2	2.00	0.2
Pipeline	0.00075	0.2	0.0051	0.2	2.00	0.2
Seismic	0.00075	0.2	0.0051	0.2	2.00	0.2
Wellsite	0.00795	0.2	0.00225	0.2	0.869	0.2
Industrial plant	0.00795	0.2	0.00225	0.2	0.869	0.2
Oilsands mine	0.0015	0.1	0.0086	0.1	0.869	0.1
Gravel pits	0.0015	0.1	0.0086	0.1	0.869	0.1
Settlements	0.00022	0.8	0.0103	0.8	0.209	0.8
Rural residential	0.00019	0.2	0.00152	0.2	0.209	0.2

6.2.3 Landscape Metrics

Landscape metrics generally tracked by projects using ALCES include:

- Natural area (ha and fraction)
- Anthropogenic area (ha and fraction)
- Anthropogenic edge; landscape fragmentation (km and km/km^2)
- Forest core area (fraction)
- Forest age (years)
- Old forest (fraction and ha)

6.2.4 Natural Areas

For the purposes of our analyses, natural areas are defined as physical landscapes and plant communities whose structure and function is shaped by natural disturbance regimes and ecological processes. They are naturally dynamic and not excessively under the influence of anthropogenic events or processes. The ALCES simulator has the ability to classify reclaimed land-use footprints (for example, a reclaimed seismic line) as a natural area, or can classify it as a reclaimed anthropogenic feature that is now within a natural landscape type.

The distribution and abundance of many native species of plants and animals are highly correlated to the amount and structure of natural landscapes. These species are generally adversely affected by anthropogenic features (croplands, roads, settlements, linear features, industrial complexes) and their prevalence often declines as landscapes become more industrial.

Because stakeholders often attribute value to natural areas for intrinsic reasons, or the wildlife species they support, this attribute is presented as an indicator for the CLFN SA.

6.2.5 Anthropogenic Area

Whereas some native species may lose abundance or distribution in landscapes defined by land-use, other species prosper. These species of plants or animals, often referred to as exotic invasives, may be considered as either desirable or undesirable.

Anthropogenic area can also serve as a proxy for a host of other social or economic values of interest. For example, tracking the area of croplands, pastures, wellpads, or settlements, can reveal much (computationally) for such indicators as crop production, cattle herd size, hydrocarbon production, or human population.

6.2.6 Biotic Indicators

It is widely understood that many species of biota (plant, animals) are sensitive to changes in boreal ecosystems caused by either natural disturbance regimes (Stelfox et al., 1995, Figure 104) or land-uses (CEMA SEWG). Individual species also convey significant value to stakeholders because of spiritual (caribou), economic (furbearers), recreation or subsistence (edible berries, fish, moose) value. As such, tracking selected ecological indicators can provide value to stakeholder groups assessing the consequences (benefits, liabilities) of defined land-use trajectories. (Figure 105, Figure 106, Figure 107).

A rigorous assessment of the response of biota to a dynamic landscape requires simulation models to track all natural disturbance regimes and land-uses, and temporal and spatial changes in specific structural elements found within each landscape type. By simulating natural disturbance regimes with their appropriate spatial and temporal variance, it becomes possible to quantify the range of natural variability of each species (Figure 108), and how performance of indicators changes when landscapes are subjected to land-uses or altered natural disturbance regimes (Figure 109, Figure 110).

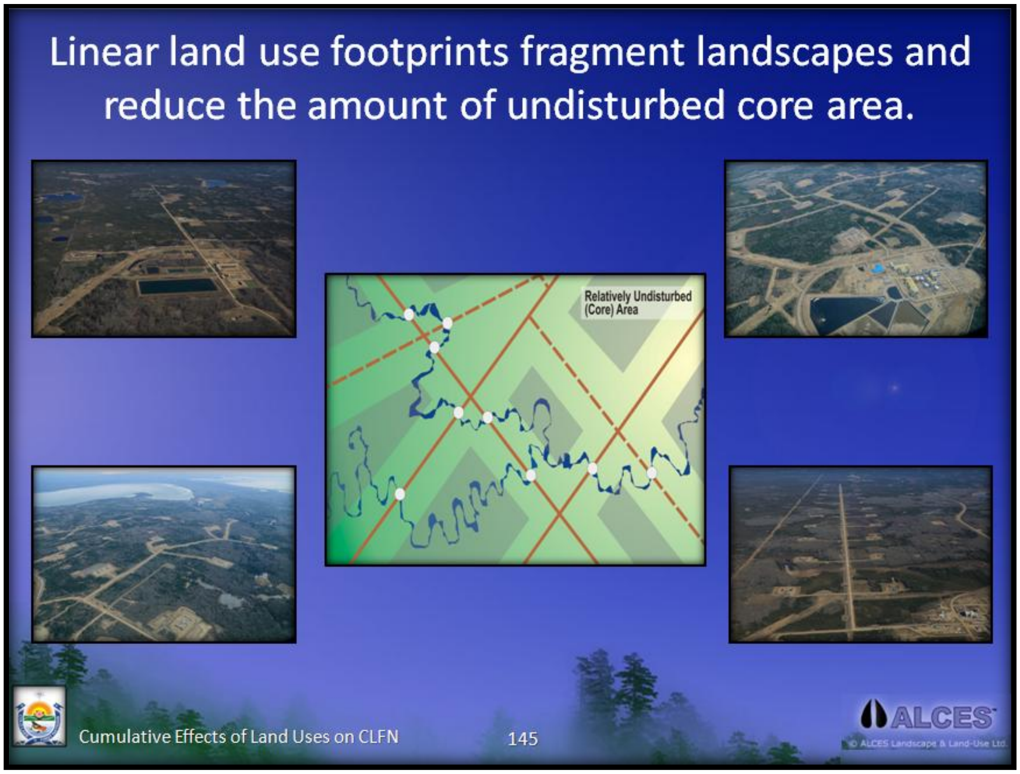


Figure 104. Linear and polygonal land-use footprints fragment landscape and reduce the amount of undisturbed core area.

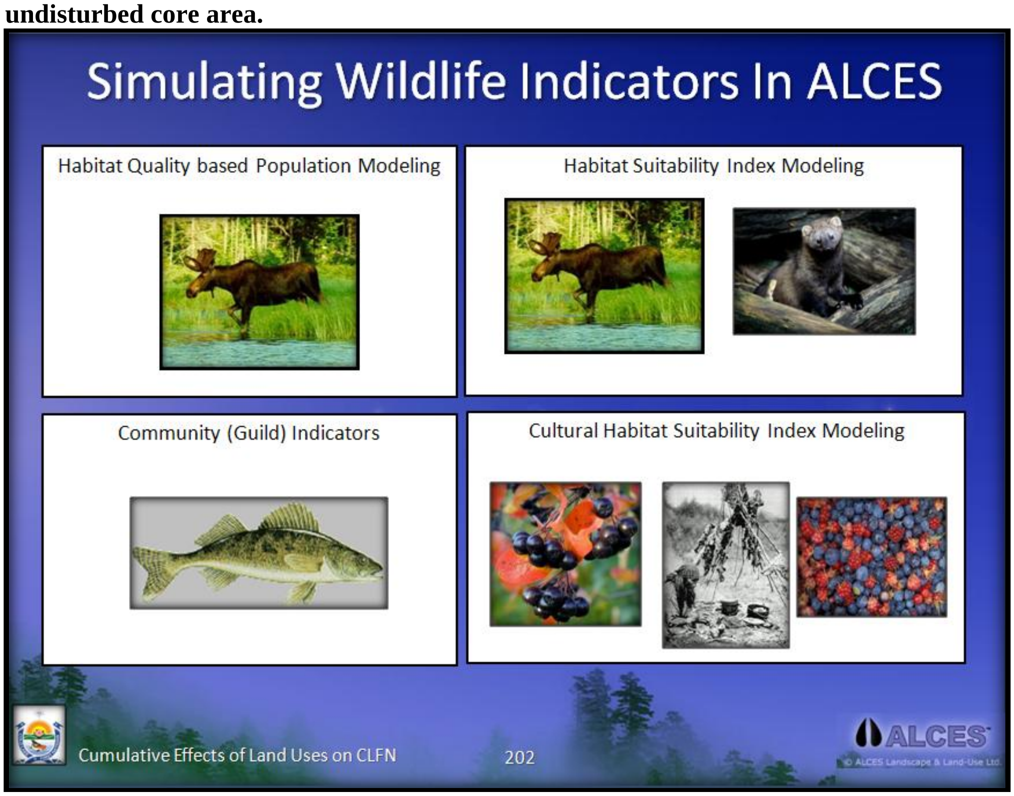


Figure 105. The major ecological indicators simulated in the CLFN ALCES Simulator.

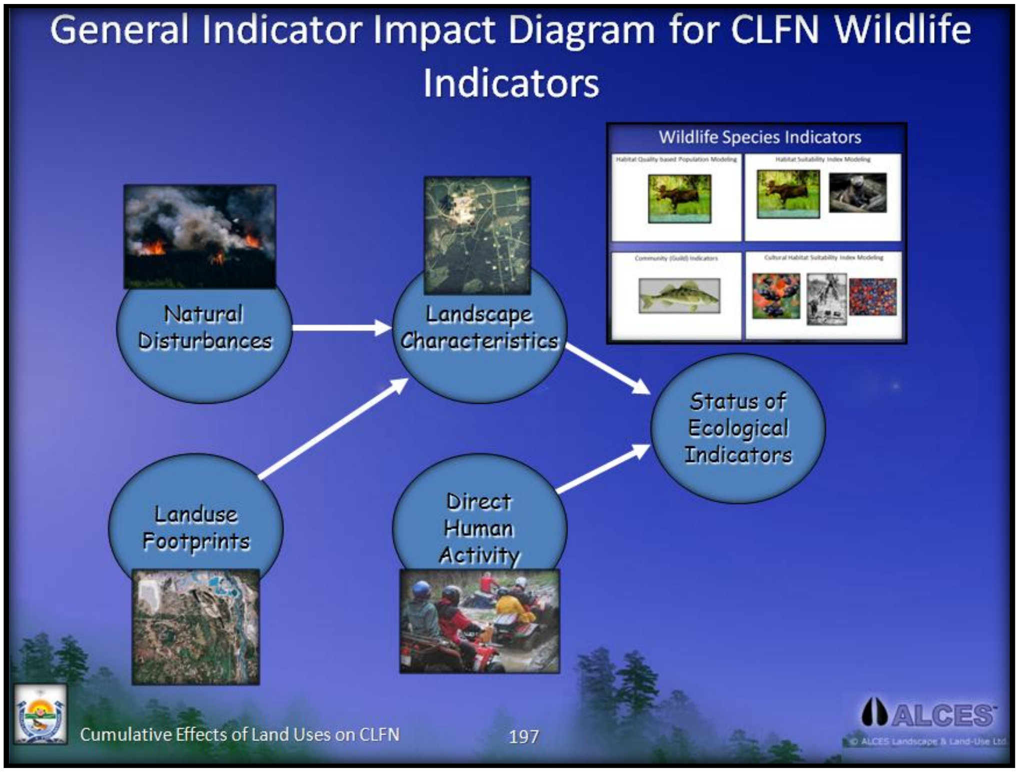


Figure 106. Ecological indictors are affected by a suite of natural disturbance regimes, human land-uses, and the direct activities of humans.

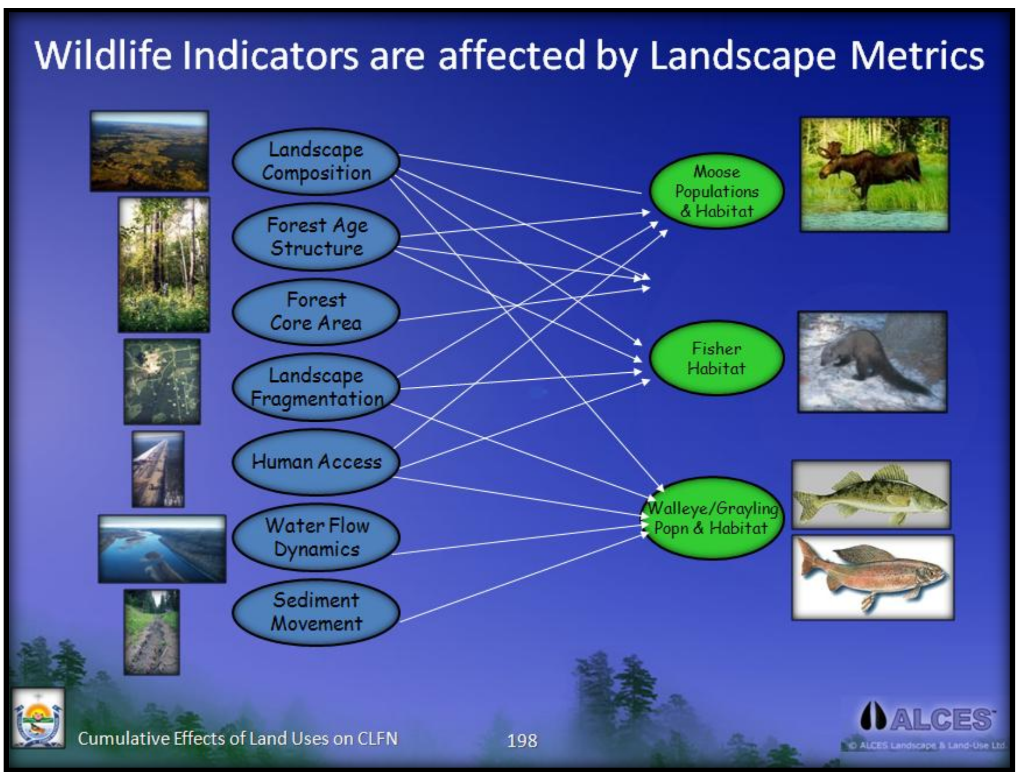


Figure 107. Key landscape metrics affecting performance of ecological indicators.

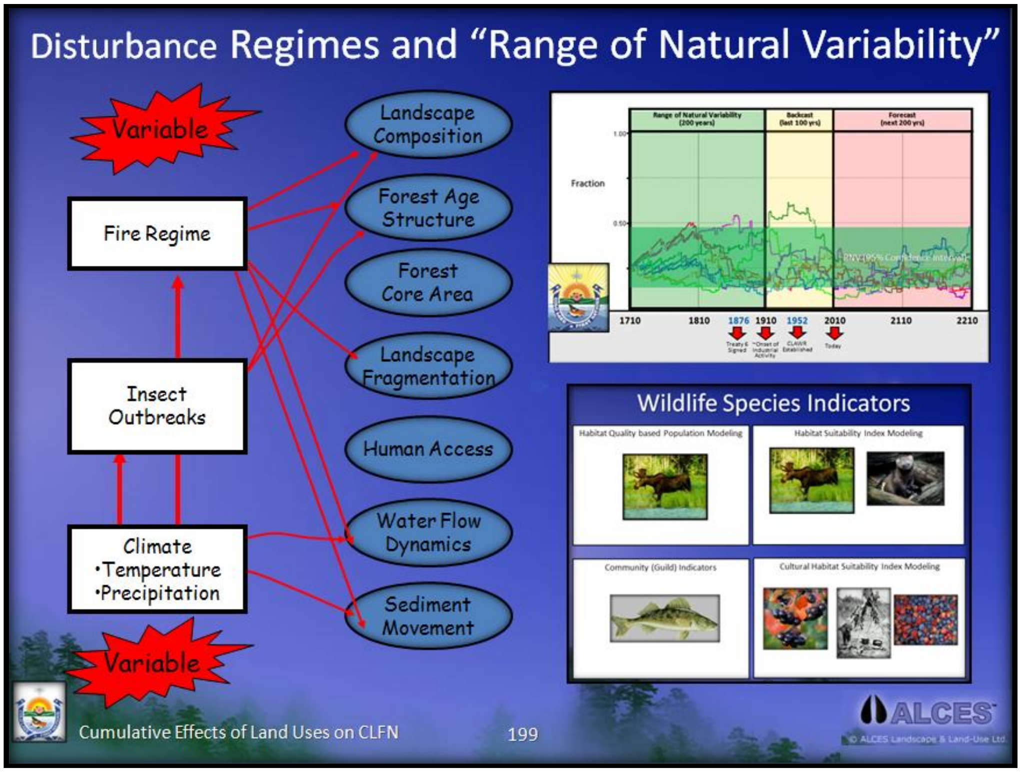


Figure 108. Natural disturbance regimes affect landscape metrics, which in turn, create a range of natural variation (RNV) in the performance of ecological indicators.

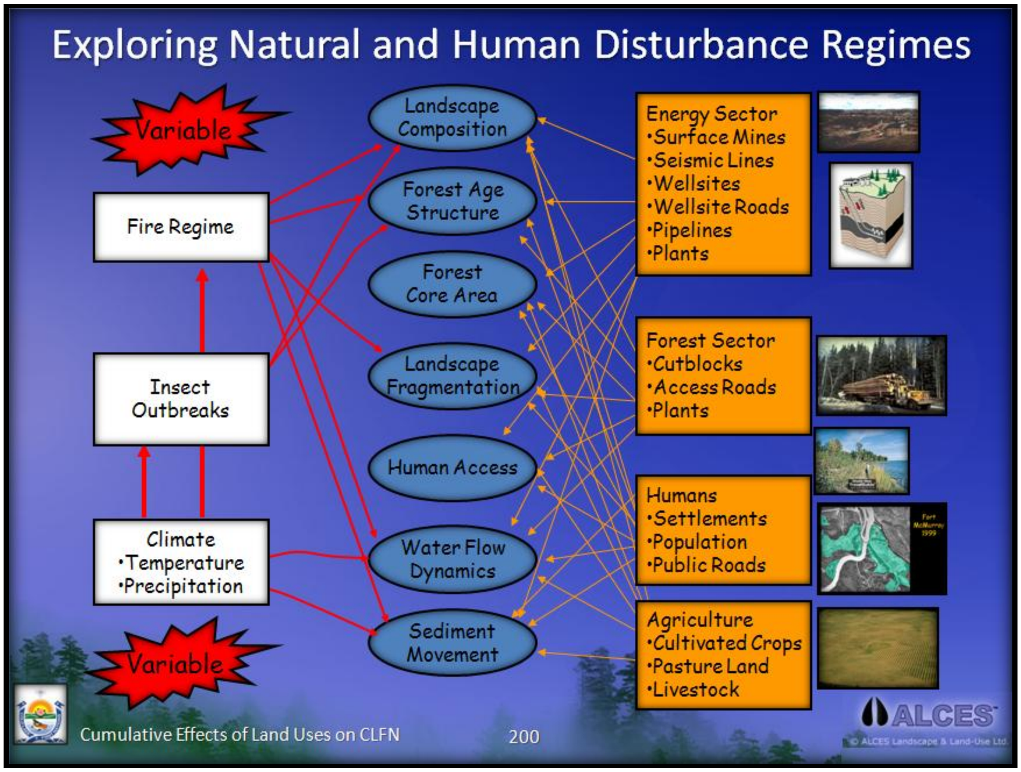


Figure 109. In contemporary settings, landscape metrics are affected by both natural disturbance regimes and human land-uses.

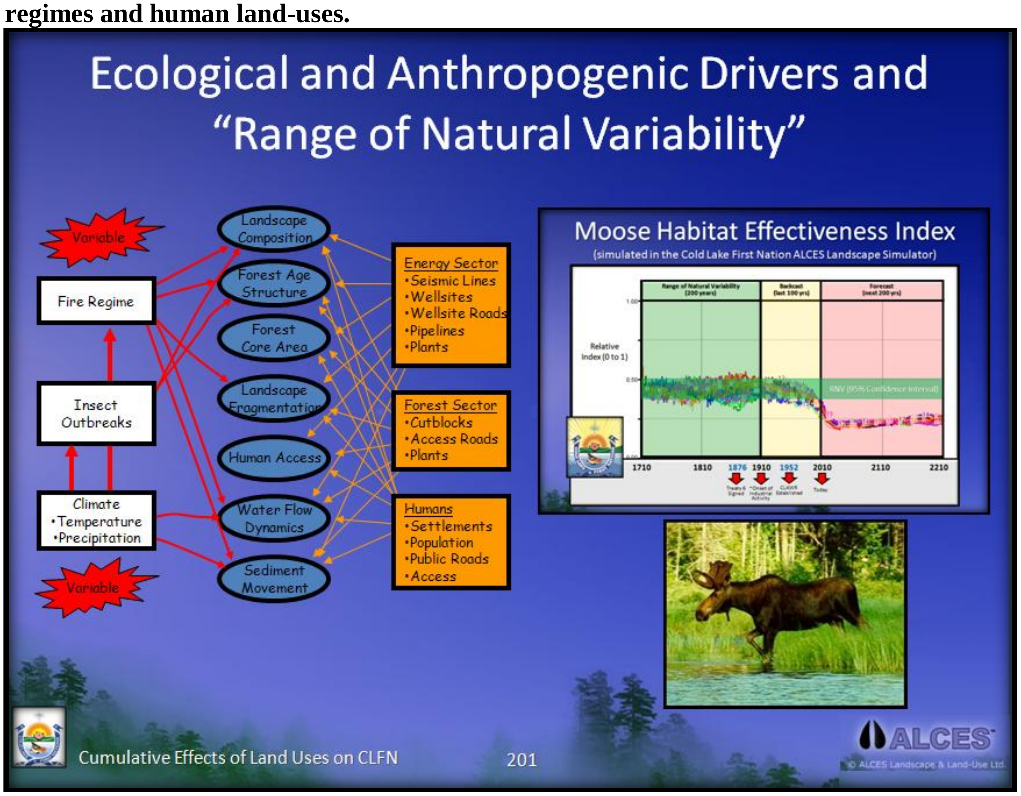


Figure 110. By simulating both natural disturbance regimes and human land-uses, it is possible for ALCES to simulate the RNV and determine whether past or future land-use trajectories will alter the performance of ecological indicators relative to RNV.

6.2.7 Moose Habitat Effectiveness

The response of moose habitat to changes in landscape composition was assessed using a habitat suitability index (HSI) model developed for northeastern Alberta. HSI models are knowledge-based (as opposed to empirical) models that can incorporate information from a variety of sources. The moose HSI is based on literature review and expert opinion. The model was originally developed for the Cumulative Environmental Management Association (www.cemaonline.ca), and subsequently revised through the Lower Athabasca Regional Planning process.

The HSI model combines information related to habitat availability and quality to calculate an index that ranges from 0 to 1. Steps required to calculate the index are summarized below.

a) For each cover type (including footprints), habitat availability is assessed as the product of its proportional abundance and its habitat value. Habitat value is a parameter that expresses the utility of a cover type to the species, where 0 indicates no utility and 1 indicates capacity to support the species' maximum density. To account for avoidance and mortality, the habitat value of landcover in proximity of anthropogenic footprints such as roads can be reduced by applying buffers to footprint and down-weighting the value of habitat within the buffer by a proportional use coefficient, i.e., the proportion of habitat within the buffer that is used. The width of the buffers can be reduced to account for strategies that limit human access and therefore the impact of anthropogenic footprints.
b) Habitat quality is a value ranging from 0 to 1 that incorporates the effect of other landscape attributes on habitat such as forest age and human population density. For each relevant landscape attribute, a response surface ranging from 0 to 1 dictates the relationship between habitat quality and the status of the attribute. Each attribute is given a weight, whereby the sum of weights equals 1. Habitat quality for each landcover type is then calculated as the sum of the products of the quality of each habitat attribute and its weight.
c) Habitat suitability (i.e., HSI) is then calculated as the sum of the products of each cover type's habitat availability and habitat quality.

The moose HSI assumes that deciduous forest has the highest habitat value, followed by mixedwood forest and shrubland due to the capacity of these cover types to provide browse and cover (Table 4). To account for the impact of human access, especially hunting, anthropogenic footprints are buffered by 50 to 200 m when calculating habitat availability (Table 5). Buffer widths are reduced in scenarios where access management is applied based on interviews with Alberta wildlife management experts (Sullivan 2011). In addition, the 200 m buffer associated with existing seismic lines was reduced by 50% for future (i.e., simulated) seismic lines which are assumed to be low impact. An objective of low impact seismic is to reduce their use as trails by people. Although the extent to which human access is reduced along low impact seismic is yet to be assessed by research, it seems likely that motorized access will be more challenging along the narrow lines. We assume a 50% reduction in human access (and therefore impacts to moose) along low impact seismic in the absence of empirical data.

Forest age is assumed to be the only determinant of habitat quality (Table 6). Although linear disturbance density and human density were also included as habitat quality attributes in the original model developed for CEMA, they were removed here to avoid double counting (i.e., exaggerating) the impact of human access which is already represented by footprint buffers. The moose HSI is assessed separately in ALCES for protected and unprotected portions of the landscape, and an overall average HSI value is then calculated as an area weighted average. When calculating HSI in protected portions of the landscape, anthropogenic footprint is considered to be negligible.

Status of the moose HSI is assessed relative to an estimated range of natural variation. Departure from RNV was used to infer risk to species (e.g., moose) by applying a set of risk categories that are proposed Alberta's Biodiversity Management System and based on those used by International Union for the Conservation of Nature (Michael Sullivan, ASRD, pers comm).

6.2.7.1 General information on moose and justification for use as an indicator.

Moose are important culturally and provide a subsistence source of country food for northern aboriginal communities (Pyc 1999, Wein et al. 1991). Management of moose in northern Alberta is largely focussed on stabilizing and increasing moose densities in order to provide optimal hunting opportunities (ASRD 2002). Moose surveys are conducted every 5 to 20 years for a given WMU.

The regional moose population of northeast Alberta is generally thought to be stable, with densities of moose being greater in the southern portion (~ 20-37 moose / 100 km^2) compared to the northern WMUs (~ 5-18 moose /100 km^2; ASRD unpublished data). This is likely due to agricultural influences and reduced number of predators in farming areas (Schneider and Wasel 2000); wood lots, riparian areas and grain alfalfa/hay fields associated with agricultural land-use in the southern area provide desirable forage and likely influence moose distribution. Moose concentrate during late winter in riparian zones and old burn areas and use available habitats differently depending on the season and whether they live within lowland or upland landscapes (Osko et al. 2004).

Moose are browsers as opposed to grazers and prefer early successional habitats that typically provide abundant food. Under good habitat conditions, female moose may give birth as 2 year olds (Schwartz 1992, Boer 1992) and twins are more common when food availability is high (Franzmann and Schwartz 1985, Boer 1992). Moose have a high reproductive output compared to other similar sized ungulates (Gaillard 2007), making the species adaptive and resilient to natural environmental variation and able to reproduce quickly when food resources are abundant (Ferguson 2002).

Moose are well adapted morphologically and behaviourally to winter snow conditions in northern boreal forests (Telfer and Kelsall 1984). Moose populations can be limited or regulated by interactions of ecological and climatic factors, but the main factors affecting resilience of moose populations are primarily related to 1) overall habitat productivity, i.e., food abundance (Ferguson et al. 2000), and 2) total mortality from natural predation and human caused deaths (Messier 1994). For example, moose populations that live in productive habitats have high reproductive output and may be regulated by food abundance despite natural predation by wolves (Messier 1994). Conversely, moose that live in habitats with poor productivity have reduced reproductive potential and the population will likely be regulated at low densities by wolf predation (Messier and Crete 1985). Consequently, direct and indirect loss in habitat quantity and quality can reduce resilience of moose populations. Resilience of a moose population may also be reduced when total mortality increases due to natural predation from more than one species, i.e., wolves and bears, combined with the effects of human harvest (Gasaway et al. 1992, Messier 1994).

Table 4. Habitat value by cover or footprint type for the moose HSI model. Values are based on a HSI model developed for CEMA.

Cover or footprint type	Corresponding class from model developed for CEMA	Value
Deciduous	Hardwood	0.93
Mixedwood	Mixedwood	0.7
Coniferous	White spruce, Pine (weighted average[1])	0.49
Shrub	Shrub tall, Shrub low	0.7
Bryoids	Open black spruce lichen moss	0.2
Herbaceous	Native herbaceous	0.5
Treed peatland	Open black spruce fen, Close black spruce fen (average)	0.5
Shrub peatland	Open black spruce fen	0.6
Herbaceous peatland	Bog	0.2
Barren	Beach, dune	0
Water	Lotic, Lentic	0.2
Annual cropland	Cultivated crop	0
Forage cropland	Forage crop	0
Road	Minor road	0.4
Inblock road	Inblock road	0.6
Transmission line	Transmission line	0.5
Seismic line	Seismic line	0.6
Wellsite	Wellsite	0.1

Table 5. The width of buffers placed around industrial footprints, and percent use of habitat within the buffers. High (i.e., protection) and moderate (i.e., best practices) access management strategies are implemented by multiplying buffer width by 0 and 0.15, respectively.

Footprint type	Buffer width (m)	Buffer use
Road and rail	100	0.25
Inblock road	50	0.9
Transmission corridor	100	0.5
Pipeline	100	0.5
Seismic	200	0.5
Wellsite	100	0.5
Industrial plant	200	0.25
Oilsands mine	200	0.25
Gravel pits	200	0.25
Settlements	500	0.5
Rural residential/camp	500	0.5

Table 6. Habitat quality by age class for moose.

Forest age class	Habitat quality
0-20	1
21-40	1
41-60	0.9
61-80	0.4
81-100	0.2
101-120	0.1
121-140	0.1
141-160	0.2
161-180	0.3
>180	0.6

6.2.8 Moose Harvest

Of the various natural foods available to the peoples of CLFN, moose is considered an important staple during pre-European times and is still actively hunted. Traditional demand for moose meat by CLFN was based on research of Tanner et al. (2001) conducted for the First Nations of Fort McKay (Figure 111). Based on a family size of 6.6 individuals, annual demand for moose harvest would range from 1.24 to 1.58, with an average value of 1.40 moose/individual/yr.

Key metrics used in the CLFN ALCES model for simulating population and harvest dynamics of moose include the following:

Maximum carrying capacity (individuals/km^2):	0.5
Maximum fraction of population that can be harvested annually:	25%
Moose liveweight (kg)	250
Fraction of liveweight that is carcass	55%

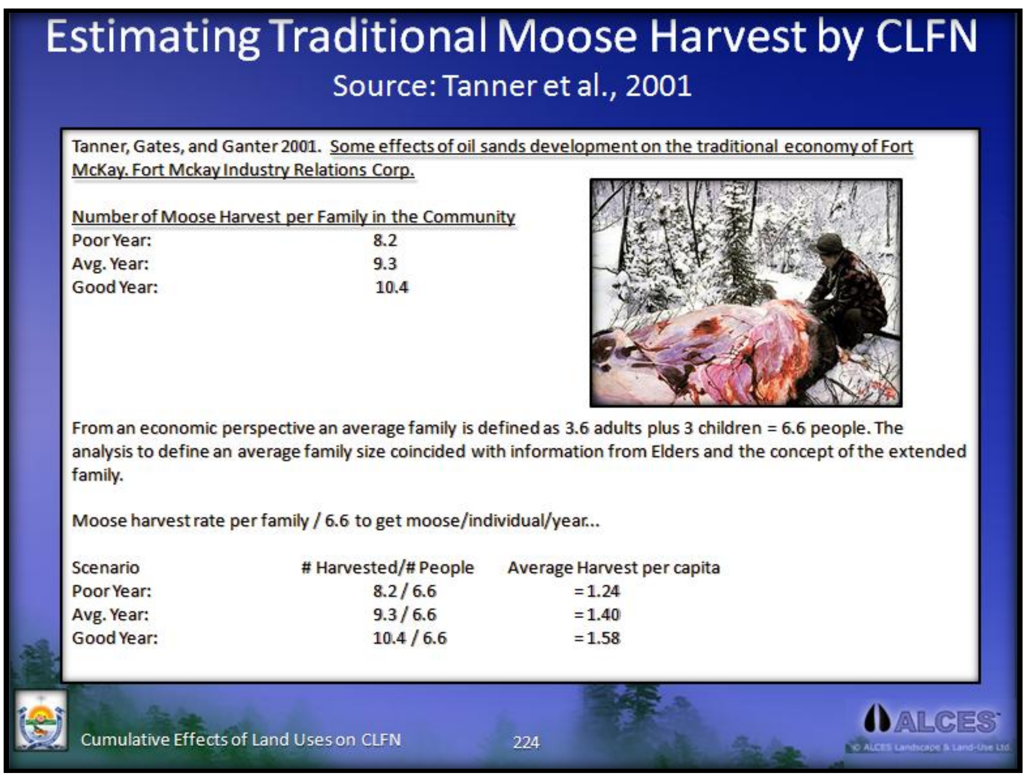


Figure 111. Estimating traditional moose harvest demand by CLFN.

6.2.9 Fisher

As with moose, the response of fisher habitat to simulated landscape changes will be assessed using a HSI model (see the previous section on the moose HSI for a general description of HSI models). The fisher HSI is based on literature review and expert opinion. The model was developed for the Cumulative Environmental Management Association.

The fisher HSI assumes that upland coniferous and mixedwood forest have the highest habitat value due to the capacity of these cover types to provide cover and prey throughout the year (Table 7). To account for the impact of human access, especially trapping, anthropogenic footprints are buffered by 100 m when calculating habitat availability (Table 8). As with the moose HSI, the buffer associated with future seismic lines is reduced by 50% to incorporate the potential reduction in human access along low impact seismic lines. Habitat quality is determined by forest age, with older forest having higher quality due to the importance of canopy closure for cover, and large-diameter overstorey trees for dens (Table 9). The fisher HSI is assessed separately in ALCES for protected and unprotected portions of the landscape, and an overall average HSI value is then calculated as an area weighted average. When calculating HSI in protected portions of the landscape, anthropogenic footprint is considered negligible.

As with the moose HSI, the status of the fisher HSI is interpreted using risk categories that are based on departure from the estimate RNV.

Table 7. Habitat value by cover or footprint type for the fisher HSI model. Values are based on a HSI model developed for CEMA.

Cover type	Corresponding class from model developed for CEMA	Value
Hardwood	Hardwood	0
Mixedwood	Mixedwood	1.00
Softwood	White spruce, Pine (weighted average[2])	0.61
Shrub tall	Shrub tall	0
Shrub low	Shrub low	0
Bryoids	Open black spruce lichen moss	0
Herbaceous	Native herbaceous	0
Grassland	Native herbaceous	0
Treed peatland	Open black spruce fen, Close black spruce fen (average)	0.05
Shrub peatland	Open black spruce fen	0
Herbaceous peatland	Bog	0
Barren	Beach Dune	0
Water	Lotic, Lentic	0
Annual cropland	Cultivated crop	0
Forage cropland	Forage crop	0

Table 8. The width of buffers placed around industrial footprints, and percent use of habitat within the buffers by fisher with and without access management.

Footprint type	Buffer width (m)	Buffer use without access management	Buffer use with access management
Major road	100	0.1	0.5
Minor road	100	0.1	0.5
Inblock road	100	0.1	0.5
Transmission corridor	100	0.1	0.5
Pipeline	100	0.1	0.5
Seismic	100	0.1	0.5
Wellsite	100	0.1	0.5
Industrial plant	100	0.1	0.5
Oilsands mine	100	0.1	0.5
Gravel pits	100	0.1	0.5
Settlements	100	0.1	0.1
Rural residential/camp	100	0.1	0.1

Table 9. Habitat quality by age class for fisher.

Forest age class	Habitat quality
0-20	0.00
21-40	0.00
41-60	0.40
61-80	0.70
81-100	1.00
101-120	1.00
121-140	1.00
141-160	1.00
161-180	1.00
>180	1.00

6.2.10 Index of Native Fish Integrity

Fisheries management in Alberta is focussed on conservation of fish populations and habitat in light of increased angling pressure and use of aquatic ecosystems from a growing human population (ASRD 2006). Populations of sport fish in northeast and east central Alberta have been heavily affected by human activity. For example, Sullivan (2003) showed that angling pressure was nine times higher outside the CLAWR than at lakes inside the CLAWR, and that average catch rates of anglers dropped from 83% to 6%, respectively, between lakes inside and outside of the CLAWR. Similarly, alteration and direct loss of habitat and changes in water quality as a result of anthropogenic land-uses may also have an important effect on distribution and abundance of fish populations.

In north-east and east-central Alberta, the resilience of fish populations and fish habitat are largely affected by the following anthropogenic key stressors (Lagimodiere and Eaton 2009):

- fishing pressure (fish mortality from recreational, commercial and subsistence fishing);
- access (habitat fragmentation related to stream crossing and density of linear features);
- land disturbance (direct alteration and loss of fish habitat);
- climate change;
- water demand and use;
- reduced water quality (i.e., sediment and nutrient runoff); and spills/accidental releases of pollutants.

The Index of Native Fish Integrity (INFI) is an important indicator on the resilience of fish communities because it describes both the response of fish populations to cumulative anthropogenic stressors, and the relative degree of effort and likelihood for recovering the fish community at a landscape scale. A reduction in INFI conveys changes in abundance of fish species that are most likely to change in response to anthropogenic effects such as rare fish, apex predators, common specialists, common generalists, and irruptives.

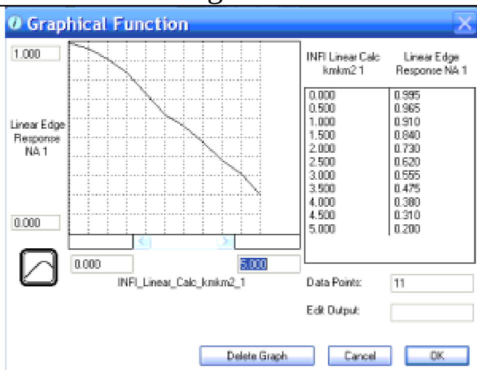
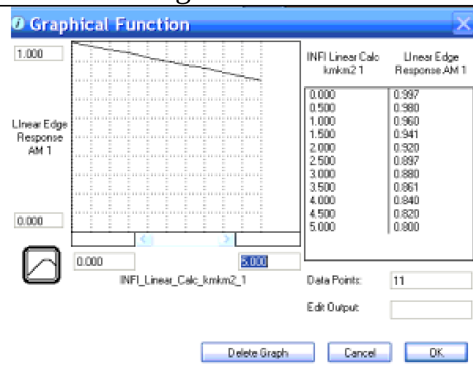
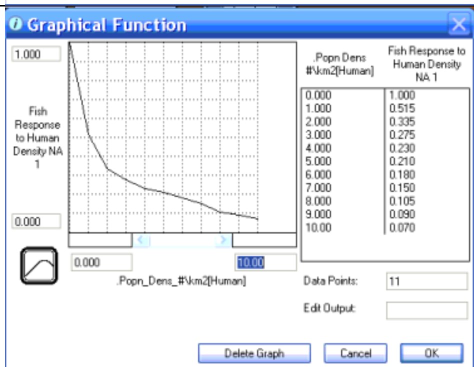
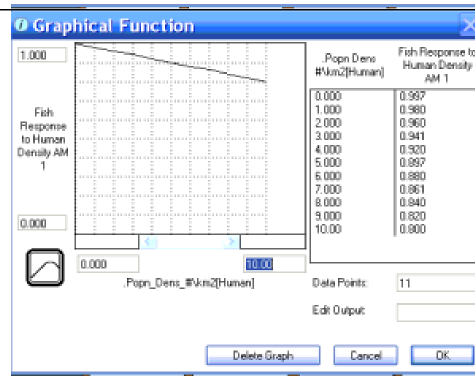
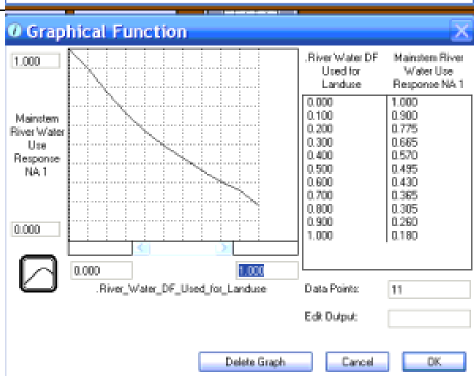
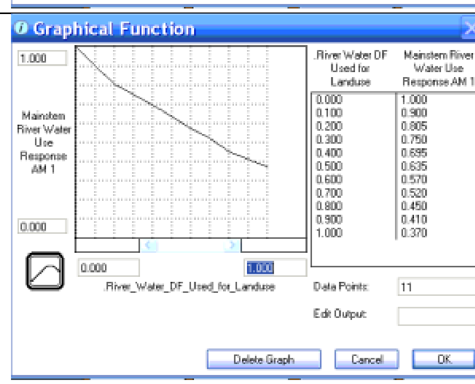
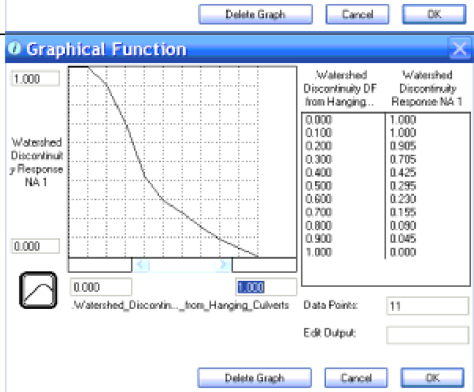
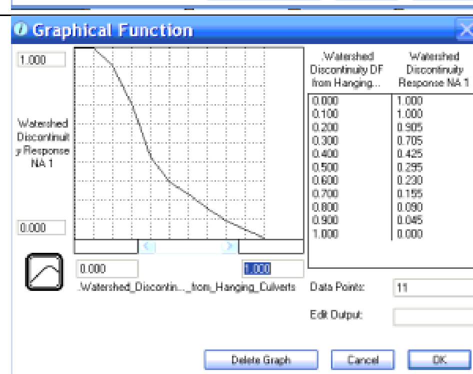
The status of the fish community was assessed using the index of native fish integrity (INFI), a measure that conveys changes in abundance and composition of fish species with a value ranging from 1 (undisturbed community) to 0 (highly disturbed community). Fish communities associated with different INFI values are presented in Table 10.

INFI response to scenarios was estimated using relationships with human population density, density of access, watershed discontinuity, and stream flow developed during a workshop held with regional fishery experts (Table 11). The workshop was held to inform scenario analyses completed by CEMA in northeastern Alberta. However, the relationships between INFI and the risk factors were consistent across the project's study area (Michael Sullivan, pers comm). Relationships were estimated with and without access, making it possible to explore the potential effectiveness of zoning to mitigate improved angler access facilitated by expanding industrial infrastructure. INFI will be assessed separately in ALCES for protected and unprotected portions of the landscape, and an overall average INFI value is then calculated as an area weighted average. When calculating INFI in protected portions of the landscape, road density, water consumption, and human access are assumed to be negligible.

Table 10. Fish community descriptions associated with INFI values of 1, 0.5, and 0 (from Sullivan 2006).

Fish Habitat Type	INFI = 1	INFI = 0.5	INFI = 0
Rivers	Abundant walleye and pike (all sizes). Common catches of Arctic grayling, slimy sculpin, burbot, trout-perch, dace and suckers.	Abundant small walleye and pike, few large fish. Common catches of burbot, trout-perch, dace, and suckers. Few Arctic grayling and sculpin.	Very few small walleye and pike, few large fish. Rare catches of Arctic grayling and burbot, trout-perch and dace. Abundant suckers and fathead minnow.
Large Streams	Abundant Arctic grayling and small pike (depending on slope of stream). Common catches of larger walleye, pike, slimy sculpin, dace, suckers and lake chub. Rare catches of fat head minnow and brook stickleback.	Abundant small Arctic grayling and small pike (depending on slope of stream). Rare catches of larger walleye, pike, and Arctic grayling. Common catches of suckers, lake chub, fathead minnow and brook stickleback.	Few small Arctic grayling and small pike (depending on slope of stream). Very rare catches of larger walleye, pike, and Arctic grayling. Abundant catches of suckers, lake chub, fathead minnow and brook stickleback.
Small Streams	Abundant small Arctic grayling and small pike (depending on slope of stream). Common catches of dace, suckers, stickleback and fathead minnow.	Rare small Arctic grayling and small pike (depending on slope of stream). Common catches of suckers, stickleback and fathead minnow.	Very rare small Arctic grayling and small pike (depending on slope of stream). Abundant catches of suckers, stickleback and fathead minnow.
Large Lakes (> 300 ha)	Abundant walleye and pike (all sizes). Common catches of burbot and trout-perch.	Abundant walleye and pike. Few large fish. Rare catches of burbot, trout-perch, common catches of suckers, lake chub.	Very few small walleye and pike. Few large fish. Rare catches of burbot, trout-perch. Abundant catches of suckers, lake chub.
Small Lakes (< 300 ha)	No larger fish. Abundant brook stickleback and fathead minnows. Common catches of suckers and some small pike.	No larger fish. Abundant brook stickleback and fathead minnow. Common catches of suckers and some small pike.	No larger fish. Abundant brook stickleback and fathead minnow. Common catches of suckers and some small pike.

Table 11. Relationships between INFI and risk factors (linear edge density, population density, stream flow, and watershed discontinuity with and without access management)

No access management	Access management
	
	
	
	

6.2.11 Sulphur Emissions

The extraction of heavy oil and bitumen often involves the production of sulphur dioxide ($S0_2$), an atmospheric pollutant whose emission contributes to acid rain and can have significant adverse effects on soil and water chemistry and plant community structure.

The ability of hydrocarbon processing facilities to remove $S0_2$ from their production stream and therefore prevent its atmospheric emission is often related to the scale of the facility and the technologies deployed within a physical plant. From a regulatory perspective, the requirements of operators to remove $S0_2$ are related to production rates of sulphur within the gas feed to the plant (Sulphur Recovery Guidelines, ERCB). The specific requirements of the Sulphur recovery guideline are listed in the table below:

Table 12. Alberta Sulphur Recovery Guidelines

Sulphur Inlet Rate (tonnes /day)	Sulphur that must be recovered
1 - 5	70%
>5 - 10	90%
>10 - 50	96.2%
>50 - 200	98-5% - 98.8%
>200	99.8%

Adapted from Table 1 of ERCB Interim Directive ID 2001-3

In general, this would mean that smaller hydrocarbon facilities (i.e. those with lower hydrocarbon production) would require less (or zero) sulphur recover and larger faculties would require more. Based on our calculations of the average per unit sulphur in the region there is a reasonable expectation that there would be three classes of bitumen production facilities in the region.

The design-based per unit $S0_2$ production rates (i.e. based on the rates of production and sulphur emission in the project applications and approvals) from bitumen facilities in the region vary significantly (0.178-0.5521 kg $S0_2$/ m^3 of bitumen produced) with a mean rate of 0.38 kg/m^3. For the operating facilities in the CLFN SA the mean is about the same. For the purposes of these analyses, a conservative value of 0.25 kg $S0_2$/ m^3 of bitumen produced was adopted.

Table 13. Classes of Bitumen Extraction Facilities

Class		Inlet S (t/d)	Recovery (%)	Minimum (m^3)	Maximum (m^3)	Average (m^3)	Effective S Coefficient (tonnes S / m^3 bitumen)
S	**1**	1-5	0%	0	8,000	5,000	0.000250
M	**2**	>5-10	70%	8,001	40,000	25,000	.0000075
L	**3**	>10-50	90%	40,001	80,000	60,000	0.000025
VL	**4**	>50	96.2%	80,001	400,000	250,000	0.000010

For example, using the sulphur coefficient of 0.0025 t/ m^3, smaller facilities producing less than 8000 m^3 of bitumen/day are not required to remove S02, medium scale facilities producing 8,000-40,000 $m^3$of bitumen/day are required to recover 70%, and large facilities of 40,000-80,000 m^3/day are required to remove 90% of the contaminant.

To allow for the strategic level assessment of $S0_2$ production and emission in the CLFN SA, a sensitivity analyses was completed that contrasted 3 different production possibilities. The largest class of facility, over 80,000 m^3/day, was not included as it is unlikely that this size of facility would be developed in the region. These sensitivities explored the $S0_2$ emissions if all bitumen production were to be completed using small, medium, or large facilities. In reality, bitumen production within the CLFN SA will be achieved using a combination of these facilities types, but this analytical approach enables stakeholders to better understand the likely range of possible annual and cumulative loading of $S0_2$ on the regional landscape. These analyses make no attempt to quantify emission loading of $S0_2$ coming from regions that are upwind of CLFN SA.

6.2.12 Quantifying Risk

The land-use and ecological indicators examined in this project are listed in Table 2 and Figure 103.

The land-use indicators reported for the CLFN SA relate statistically to direct land-use 'footprint", landscape composition or the degree of fragmentation. Many wildlife and fish species have been found to be negatively correlated to increasing levels of habitat disturbance. Increasing levels of surface disturbance and fragmentation generally represent increasing risks to native wildlife and fish populations (Figure 106, Figure 107, Figure 108, Figure 109), and the integrity of ecological systems (Holling 1973; Forman and Alexander 1998; Trombulak and Frissell 2000). For these reasons, land-use indicators such as surface disturbance and fragmentation are considered to be relevant and practical indicators of cumulative effects.

The wildlife and fish indicators are calculated based on models that apply coefficients to levels of habitat disturbance, fragmentation, and/or forest age. Water and air indicator values are derived from the relationship between the levels of land-use and the average output rates of specific substances or by-products (e.g., amount of elemental sulphur per m^3 bitumen production; amount of nitrogen loading per lakeside cottage development). All ecological indicator relationships and coefficients used in this project were generated by CEMA-SEWG (CEMA 2008).

6.2.13 Ecological Indicator Risk Categories

Habitat Suitability Index

The interpretation of potential changes in environmental indicators can be aided by a standardized method for describing change that is both relevant and readily understood by stakeholders and decision makers. For the terrestrial ecological indicators such as moose, black bear and fisher, HSI results are displayed using pre-determined risk categories based on peer-reviewed criteria developed by the World Conservation Union and adopted by the international community, including Canada (Committee on the Status of Endangered Wildlife in Canada – COSEWIC), for evaluation of species at risk.

Indicator risk categories are based on the relative departure from the range of natural variability (RNV; Figure 112). Colour-coded risk categories are ranked and illustrated along a scale declining from the best condition (the lower boundary of the RNV), scaled as 0 percent decline, to the most disturbed condition expected, scaled as 100 percent decline. When applying risk categories to simulation results, the lower edge of the estimated natural range of variability was used as the undisturbed point of comparison.

They were applied in the following manner, using four colour codes:

Green: representing **stable** and equivalent to the COSEWIC / IUCN classification of "Stable". Defined as a decline of no more than 10% from the undisturbed (RNV) state.

Yellow: representing **low risk** and equivalent to COSEWIC / IUCN classification of "Special Concern". Defined as a decline of 10% to 50% from the undisturbed (RNV) state.

Orange: representing **moderate risk** and equivalent to the COSEWIC / IUCN classification of "Threatened" or "Vulnerable". Defined as a decline of 50% to 70% from the undisturbed (RNV) state.

Red: representing **high risk** and equivalent to the COSEWIC / IUCN classification of "Endangered". Defined as a decline of more than 70% from the undisturbed (RNV) state.

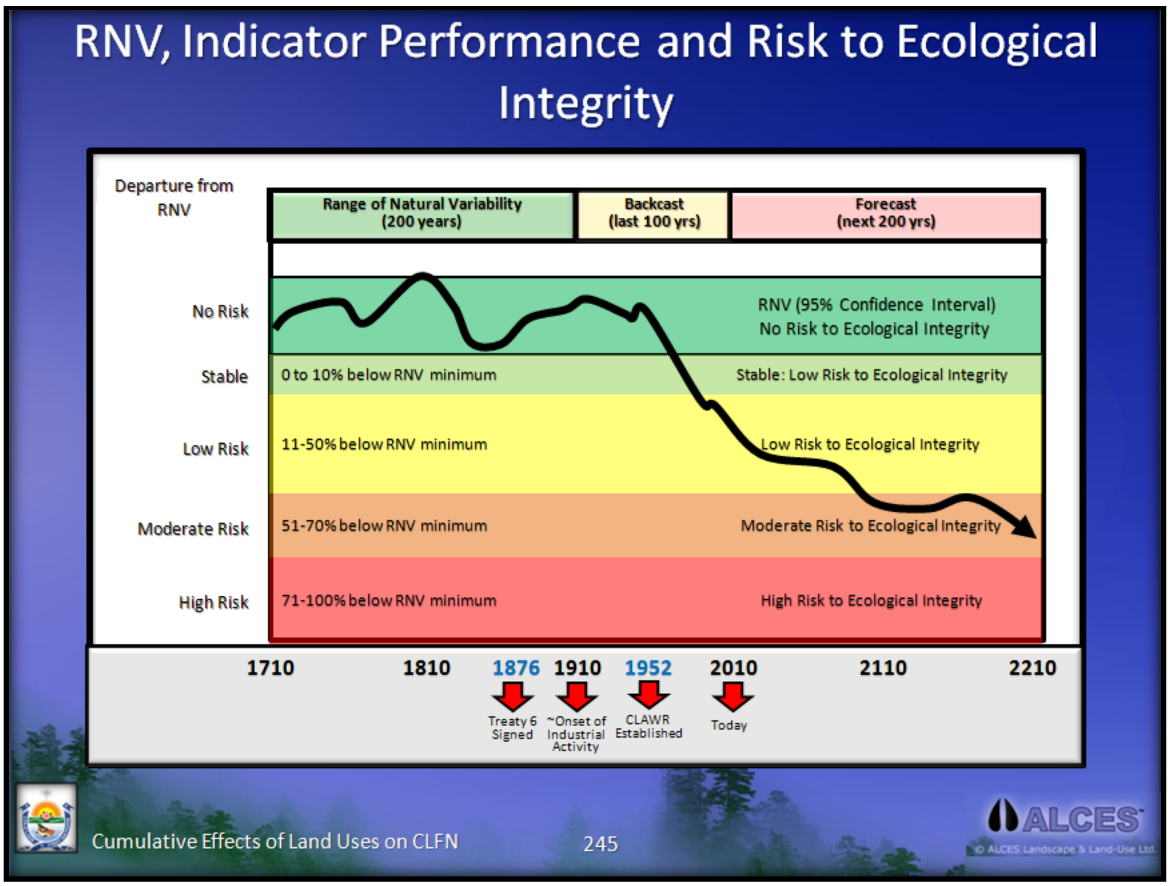


Figure 112. ALCES output graph indicating different risk categories to ecological indicators.

6.3 SOCIAL AND CULTURAL

Indicators in the theme of social and cultural include the fraction of the CLFN SA that is accessible to CLFN for use in traditional activities.

6.4 COMMODITY AND ECONOMIC

The economic contributions of the Cold Lake region to the local, regional and provincial economy is significant and has been an important contributor to Alberta's strong historical economic growth. Economic performance in this region has been driven by commodity production (hydrocarbons, crops, livestock) of which production of heavy oil and bitumen has been the overwhelmingly most important commodity.

6.4.1 Methodologies

The methodology deployed by the CLFN ALCES for the development of the heavy oil and bitumen reserves is detailed in Section 8.2.5. Revenues and employment directly related to bitumen production were based on applying coefficients to annual production values based on revenue and employment statistics for 2012.

7. SIMULATION METRICS

7.1 SIMULATION LENGTH

All simulation were 500 years in length of which the first 200 years (Yrs 0-200) captured key dynamics of RNV (range of natural variability), the next 100 years (Yrs 201-300) reflects the backcast period (general period from onset of industrial land-uses to current conditions), and the last 200 years (Yrs 301-500) represented a forecast intended to explore a plausible future driven by explicitly stated input assumptions.

7.2 RANGE OF NATURAL VARIABILITY AND REFERENCE POINTS

Ecological indicators invariably exhibit spatial and temporal variation and this natural heterogeneity does not require the presence of humans or their land-uses. Since indicators such as moose, furbearers, fish and edible berries would have responded numerically to stochastic changes in landscape characteristics (examples would include water temperature, snow depth, forest age), it is important to capture and describe this variance called "range of natural variability". RNV can be considered the normal variation (for example, 95% confidence interval) of a specific ecological attribute (species abundance, species distribution, or ecological process (for example decomposition)) that occurs in response to the full suite of natural and episodic perturbations that characterize an ecological system. An illustration of RNV is shown in Figure 113. Indicators for which RNV is illustrated in the CLFN ALCES project include:

- Moose Habitat Effectiveness
- Fisher Habitat Effectiveness
- Index of Native Fish Integrity
- Forest Age
- Water Quality

Landscape ecologists generally accept that the further land-use conditions move indicators away (either above or below) their RNV, the greater the level of risk to integrity of an ecological indicator. The concept of RNV and risk to ecological indicators has been broadly discussed by biologists within the Ministry of Sustainable Development of the Government of Alberta, and has been endorsed as a key measure by which to assess risk of ecological indicators examined in the Alberta Land-use Framework.

The goal of using RNV as part of these analyses is not to suggest that management objectives and goals should be to remain in or near RNV, but rather to graphically illustrate a relative reference point against which stakeholders can understand current and future risk associated with a stated set of land-use assumptions.

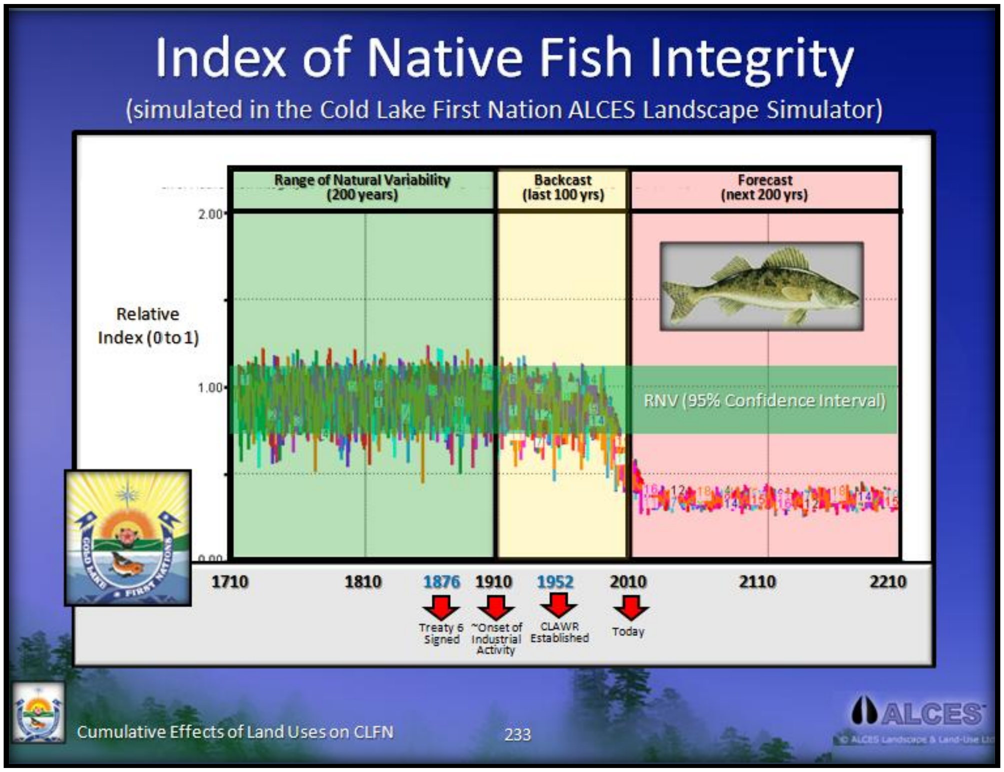


Figure 113. Example of typical ALCES graphic output illustrating simulation length, range of natural variability (RNV), key events, and performance of an indicator relative to RNV.

7.3 RECONSTRUCTING THE BACKCAST

To enable the CLFN SA ALCES model to complete a reasonable land-use backcast from the end of RNV era (1912) to current (2012) standing, we examined relevant townships from the Alberta Land-use Historical Time Series Dataset (2012). An example of these historical time series is provided for wellsites (Figure 115).

The objective of the Alberta Land-use Historical Time Series Dataset was to create maps at decadal intervals depicting the historical transformation of Alberta's landscape over the past century (1910 to 2010). The general approach was to start with today's (i.e., 2010) landscape composition and remove anthropogenic footprints at rates consistent with the best available historical land-use data.

7.3.1 Landscape Composition

Land cover was classified according to the natural subregions of Alberta. Cover types included the following natural subregions: Alpine, Subalpine, Montane, Upper Foothills, Lower Foothills, Foothills Parkland, Central Parkland, Peace River Parkland, Foothills Fescue, Northern Fescue, Mixed Grassland, Dry Mixed Grassland, Central Mixedwood, Dry Mixedwood, Northern Mixedwood, Boreal Highlands, Peace-Athabasca Delta, and Kazan Upland Precambrian Shield. The spatial distribution of forage and cropland was assessed using the Agriculture Canada and Earth Observation for Sustainable Development data (based on circa 2000 landsat imagery). The abundance and location of anthropogenic footprints were derived from a variety of footprint inventories (Table 14). The data sets were selected to include the most current data available with coverage across the province. The datasets were deemed to be relatively accurate, with the exception of the CanVec seismic inventory which was corrected to overcome a substantial under-representation of the current seismic footprint[3].

Table 14. Data sets used to assess the current distribution of anthropogenic footprint in Alberta.

Footprint	Data source
Major and minor roads	Canvec, updated to 2009. Line data buffered to a total width of 40 m and 24 m for major and minor roads, respectively.
Railroads	Canvec, updated to 1994. Line data buffered to a total width of 20 m.
Seismic	Canvec, updated to 1995 and corrected. Line data buffered to a total width of 5 m.
Pipelines	ERCB, updated to 2011. Line data buffered to a total width of 15 m.
Wellsites	ERCB, updated to 2011. Point data buffered to 100 m x 100 m.
Industrial sites	Canvec, updated to 1994. ERCB facility point data, updated to 2011. Point data buffered based on the average digitized extent of a randomly selected subset of each facility type.
Mines	Global Forest Watch Canada mine datasets. Spatial extent of mines based on SPOT5 2007 imagery.
Gravel pits	Canvec, updated to 1994.
Transmission lines	Canvec, updated to 1994. Line data buffered to a total width of 40 m.
Settlements	Canvec, updated to 2009. Point data buffered by actual and assumed settlement areas[4].
Rural residential	Alberta Government water wells, updated to 2011.
Recreational	Canvec. Spatial extent of ski hills based on SPOT5 2007 imagery.

The footprint and land cover data were integrated to produce a single landscape composition data layer. Integration required removing land cover that was overlain by footprint. When integrating, footprints occasionally overlapped with each other. To avoid double counting

[3] The seismic inventory was corrected so that total seismic length equaled the provincial total, as calculated by ABMI from circa 2008 Alberta Sustainable Resource Development that were not available for this project. The correction factor applied to the CanVec seismic inventory varied across natural subregions, based on subsamples from each natural subregion that were assessed using SPOT5 2007 imagery and compared to CanVec.

[4] The spatial footprints of a subset of Alberta's settlement were digitized, and used to fit a relationship between settlement size and population. The relationship was then applied to estimate the size of settlements whose footprint was not digitized.

anthropogenic disturbance, overlapping footprints were assigned to a single footprint type, with more permanent footprints such as settlements or roads taking precedence over temporary footprints such as seismic lines and well sites. In addition to the current landscape composition data layer, a presettlement landscape composition data layer was created. The presettlement data layer, which reflects land cover prior to integration with the footprint inventories, was used during the backcast modeling to revert current footprint to historical land cover.

The current and presettlement landscape composition data were summarized on a 10 x 10 km cell basis, in terms of the area of each land cover and footprint class in each cell. The 10 x 10 km resolution was used because it is consistent with the size of townships, a familiar land unit in the province (i.e., Alberta Township System), and because it was the highest resolution achievable with the resources available for the project.

7.3.2 Historical Land-use Trajectories

Historical footprint data were used to estimate each cell's footprint at decadal intervals back to 1910. Historical data were available for only a subset of footprint types, requiring the use of surrogates to approximate historical trajectories for some footprints. Information used to approximate historical footprint trajectories is now described.

Energy Sector

The historical trajectory for wells was based on spud date information included in the Energy Resources and Conservation Board well data set. Historical footprint data were not available for pipelines, seismic lines, or plants. In the absence of better data, these footprints were assumed to have grown within each cell at the same rate as hydrocarbon wells (i.e., based on spud dates).

Agricultural Sector

The historical trajectory for cropland and pasture was based on a data set identifying the date (in 5-year increments) of first cultivation in 1:250,000 map sheets (Miistakis Institute, pers. comm.). To approximate the rate of agricultural expansion from the date of first cultivation data, it was assumed that agriculture land in a given 1:250,000 map sheet increased linearly from 0 at date of first cultivation to its current extent over a period of six decades. The six-decade expansion period was based on a review of the provincial historical agriculture land trajectory (www.abll.ca); the provincial trajectory was well approximated by the date of first cultivation trajectory when a six-decade expansion period was applied.

In addition to cropland and pasture, trajectories for cattle population and feedlots were constructed. To estimate the current cattle population within each cell, the province's cattle population was distributed spatially based on the relative size of the cattle population by ecodistrict (according to Agriculture Canada data) and the prevalence of land cover and footprint types assumed to be associated with cattle. The historical cattle population trajectory was then approximated to be consistent with the provincial historical cattle population trajectory and the trajectories of the land cover types. Feedlots are thought to have emerged as a footprint in Alberta in the late 1950s (http://www.westernfeedlots.com/index.php?id=31). Information was not available, however, to identify the spatiotemporal patter of feedlot expansion from the late 1950s to today. In the absence of better information, the area of feedlots in each cell was assumed to increase from 0 in the late 1950s to its current extent at the rate of cattle population growth in the province during this period (www.abll.ca).

Human Settlements

The footprint of settlements was assumed to have expanded at the same rate as their population, according to community population data obtained from the Miistakis Institute. Human population not incorporated by the community population data set was assumed to be rural; the trend in rural population was based on the difference between the historical provincial and community population data. The historical growth in rural residential footprint was assumed to be proportional to the rate of growth in water wells in a cell, according to drill dates from the Alberta Government water well data set.

Mines

The area of each mine in the province was assumed to have expanded linearly from 0 at its date or inception to its full extent by the date of mine closure (or today if the mine is still operating). Inception and closure dates were obtained from the internet.

Roads

A historical highway data set obtained from Miistakis was used to backcast major road footprint to 1950. Backcasting of major roads not included in the Miistakis data set or developed prior to 1950 was based on expert opinion, an internet search, and a region's date of first cultivation. Historical data were not available to inform the backcasting of minor roads. Instead, minor roads were assumed to have expanded at the same rate as other land-use footprints that are correlated with the current spatial distribution of minor roads. Gravel pits were assumed to have expanded at the same rate as minor roads.

The relationship between minor roads and other footprint types was estimated through regression. Candidate explanatory variables in the regression included the area of agricultural land, major roads, well sites, settlements, and rural residential. Timber harvest was also incorporated as a candidate explanatory variable by calculating each cell's harvest intensity (m^3/ha) from Global Forest Watch Canada's forest tenure data set. Statistical modelling of the relationship between minor road and the explanatory variables was problematic at the cell scale. The residuals were not normally distributed and exhibited significant spatial autocorrelation (according to Moran's Index). Model performance was improved by reducing the resolution to 10 x 10 cell blocks. At this scale, residuals were normally distributed and spatial autocorrelation was reduced. At the 10 x 10 cell scale, significant explanatory variables were rural residential area, well site area, crop and pasture area, and harvest intensity. A linear regression model with these four explanatory variables achieved a coefficient of determination of 97%. According to the relationship, at the scale of 10 x 10 cell blocks: each hectare of rural residential footprint is associated 0.611 ha of minor road; each hectare of well is associated with 0.112 ha of minor road; each hectare of crop or pasture is associated with 0.015 ha of minor road; and each m^3 of AAC per ha[5] is associated

[5] AAC intensity among 10 x 10 cell blocks varied from 0 to 1.69 m3/ha.

with 1.89 e+007 ha of minor road. These coefficients were applied to historical trajectories for the explanatory footprints to estimate the rate at which minor road increased within each 10 x 10 cell block. The historical AAC trajectory was based on a historical forest tenure data set obtained from the Miistakis Institute.

Transmission Lines

Historical data were not available to inform the backcast of transmission lines. In the absence of better information, transmission lines were assumed to have expanded at the same rate as a region's urban population. Transmission line footprint often occurs in cells that do not contain settlement footprint. Therefore, the resolution was reduced to 10 x 10 cells when approximating the historical rate of transmission line growth based on settlement footprint.

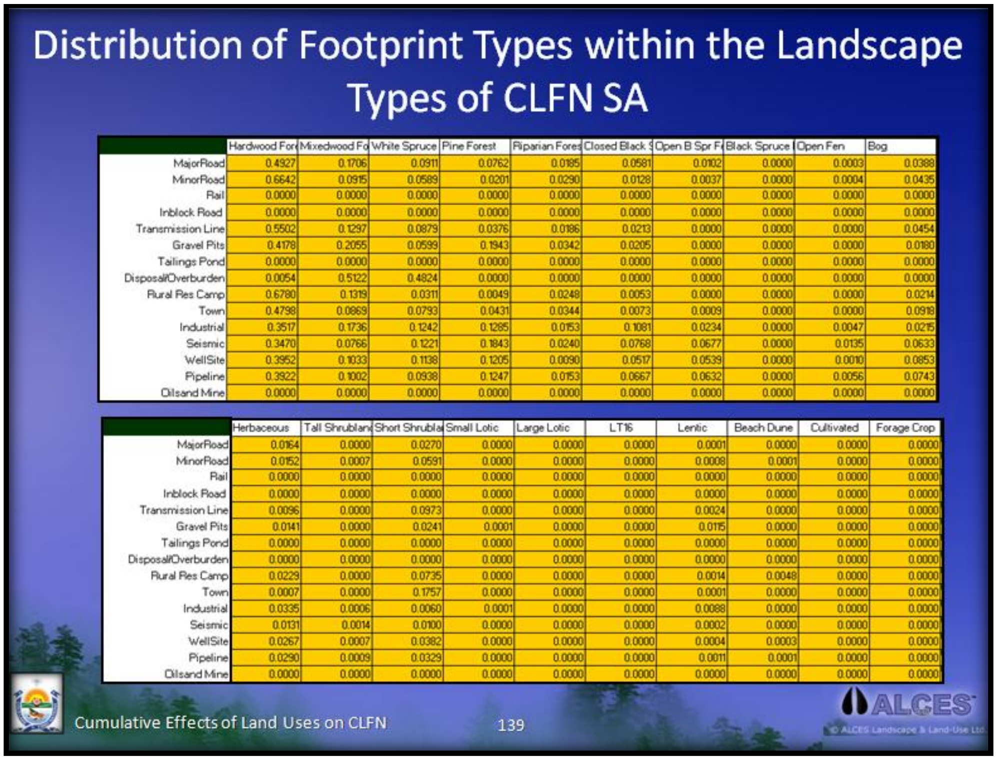
Recreation Features

The backcast for ski hills was informed by their inception dates, identified in an internet search. All other recreation footprint was assumed to have expanded at the same rate as a region's urban population. As when backcasting transmission lines, a 10 x 10 cell resolution was applied when approximating the historical rate of recreation feature growth based on settlement footprint.

7.4 DESCRIBING THE CURRENT LANDSCAPE

The initial (circa 2012) composition of CLFN SA was constructed from a set of public domain and proprietary GIS datasets that allowed the ALCES team to account for the spatially explicit and spatially stratified area (ha) and edge (km) of each landscape and footprint types (Figure 29). Each footprint type was overlain on landscape types to compute the spatial distribution of each footprint type (Figure 114).

Spatial data pertaining to selected First Nations features (burial sites, cabins, trails, travel routes) were provided to the ALCES Group by Nu Nenne-Stantec Inc as assembled by the Cold Lake First Nations Traditional Knowledge Study, (2011). These data allowed the ALCES Group to calculate metrics (length, area and distribution) of each of these important cultural features.



	Hardwood For	Mixedwood Fo	White Spruce	Pine Forest	Riparian Fores	Closed Black S	Open B Spr F	Black Spruce	Open Fen	Bog
MajorRoad	0.4927	0.1706	0.0911	0.0762	0.0185	0.0581	0.0102	0.0000	0.0003	0.0388
MinorRoad	0.6642	0.0915	0.0589	0.0201	0.0290	0.0128	0.0037	0.0000	0.0004	0.0435
Rail	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Inblock Road	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Transmission Line	0.5502	0.1297	0.0879	0.0376	0.0186	0.0213	0.0000	0.0000	0.0000	0.0454
Gravel Pits	0.4178	0.2055	0.0599	0.1943	0.0342	0.0205	0.0000	0.0000	0.0000	0.0180
Tailings Pond	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Disposal/Overburden	0.0054	0.5122	0.4824	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Rural Res Camp	0.6780	0.1319	0.0311	0.0049	0.0248	0.0053	0.0000	0.0000	0.0000	0.0214
Town	0.4798	0.0869	0.0793	0.0431	0.0344	0.0073	0.0009	0.0000	0.0000	0.0918
Industrial	0.3517	0.1736	0.1242	0.1285	0.0153	0.1081	0.0234	0.0000	0.0047	0.0215
Seismic	0.3470	0.0766	0.1221	0.1843	0.0240	0.0768	0.0677	0.0000	0.0135	0.0633
WellSite	0.3952	0.1033	0.1138	0.1205	0.0090	0.0517	0.0539	0.0000	0.0010	0.0853
Pipeline	0.3922	0.1002	0.0938	0.1247	0.0153	0.0667	0.0632	0.0000	0.0056	0.0743
Oilsand Mine	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

	Herbaceous	Tall Shrublan	Short Shrubla	Small Lotic	Large Lotic	LT16	Lentic	Beach Dune	Cultivated	Forage Crop
MajorRoad	0.0164	0.0000	0.0270	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000
MinorRoad	0.0152	0.0007	0.0591	0.0000	0.0000	0.0000	0.0008	0.0001	0.0000	0.0000
Rail	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Inblock Road	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Transmission Line	0.0096	0.0000	0.0973	0.0000	0.0000	0.0000	0.0024	0.0000	0.0000	0.0000
Gravel Pits	0.0141	0.0000	0.0241	0.0001	0.0000	0.0000	0.0115	0.0000	0.0000	0.0000
Tailings Pond	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Disposal/Overburden	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Rural Res Camp	0.0229	0.0000	0.0735	0.0000	0.0000	0.0000	0.0014	0.0048	0.0000	0.0000
Town	0.0007	0.0000	0.1757	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000
Industrial	0.0335	0.0006	0.0060	0.0001	0.0000	0.0000	0.0088	0.0000	0.0000	0.0000
Seismic	0.0131	0.0014	0.0100	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000
WellSite	0.0267	0.0007	0.0382	0.0000	0.0000	0.0000	0.0004	0.0003	0.0000	0.0000
Pipeline	0.0290	0.0009	0.0329	0.0000	0.0000	0.0000	0.0011	0.0001	0.0000	0.0000
Oilsand Mine	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Figure 114. Distribution of land-use footprint types within landscape types of CLFN SA.

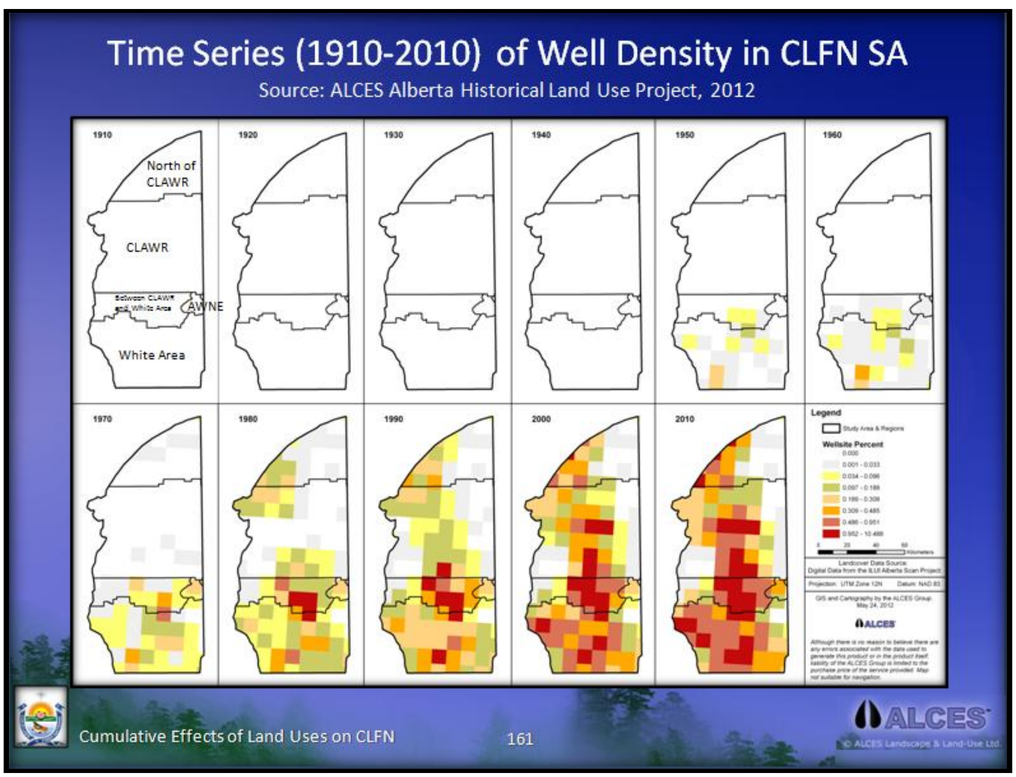


Figure 115. Historical time series of wellsites in the CLFN SA at a quarter township scale.

7.5 EXPLORING THE FUTURE

The value of the future scenario is not to know but to learn. It is not possible, or desirable, to possess sufficient certainty about all deterministic and random variables in complex systems to build forecast models that actually predict the future.

For some, the inherent uncertainty of the future is sufficient for them to discourage or find disreputable the science (and art) of forecast modeling. These folks would rather live in the myopic world of here and now. Unfortunately, having access only to today and history provides a narrow view of the world of opportunities and consequences, and condemns us, as the saying goes, to “drive forward at high speed while looking through our rearview mirror”.

Rather than fearing the exploration of the future, stakeholders should embrace the uncertainty, and use the power and speed of contemporary simulation models to test concepts, conduct sensitivity analyses, challenge dogmas, and seek those elements of systems that have high impact and high uncertainty – for it is to those components that we wish to direct our inquiries and research effort and dollars.

7.5.1 Different Types of Future Scenarios

For the purposes of this project, RNV implicitly internalizes the presence of CLFN and their traditional activities. As such, there is no analytical method for separating the RNV simulated fire regime from that which occurred prior to the arrival of CLFN. For the purposes of this project, CLFN ancestors are considered to arrive in the CLFN SA at the time of glacial ice recession and to continuously inhabit the region throughout the full simulation length. All simulations were conducted in Monte Carlo mode to allow the CFN ALCES model to display inherent variation in meteorology, fire, and plant community dynamics.

The CLFN ALCES model has been designed and attributed to allow stakeholders to rapidly explore the consequences of alternative land-use “what-if” scenarios that capture alternative strategies that can include:

- Business as Usual
- Adjusting Pace and Magnitude of Land-use Growth
- Exploring Best Management Practices
- Management by Objective
- Adopting Ecological Thresholds

7.5.1.1 Business as Usual

For the purposes of these analyses, the CLFN ALCES simulations were restricted to a “business as usual” scenario. This scenario is best described as a future simulation that complies with known and expected development of all relevant natural disturbance regimes and land-uses. No major changes in land-use policies are implied in this scenario.

All inputs relating to specific natural disturbance regimes and land-uses are explicit and can be readily observed by stakeholders using the CLFN ALCES model. It is the goal of this report to provide the reader with a core set of key input assumptions – others can be provided at the request of the ALCES Group. The major architectural structure of the CLFN ALCES simulator is described in Appendix A.

7.5.2 Spatial Constraints in Mapper Using Inclusionary Masks

Placement of all future land-use footprint in Mapper can follow any defined spatial arrangement. Commonly, Mapper uses inclusionary masks to direct footprints to plausible geographies based on a series of relevant rules for each land-use sector (crops, livestock, transportation, hydrocarbon, forestry, residential, recreation). The spatial inclusionary masks used in the CLFN SA project are illustrated in Figure 116. As such, all future growth that is computed to occur must be spatially constrained within these polygons. The distribution of footprint features within inclusionary masks can be informed by a suite of user-defined controls that allow new features to be concentrated around existing features or dispersed in a random fashion.

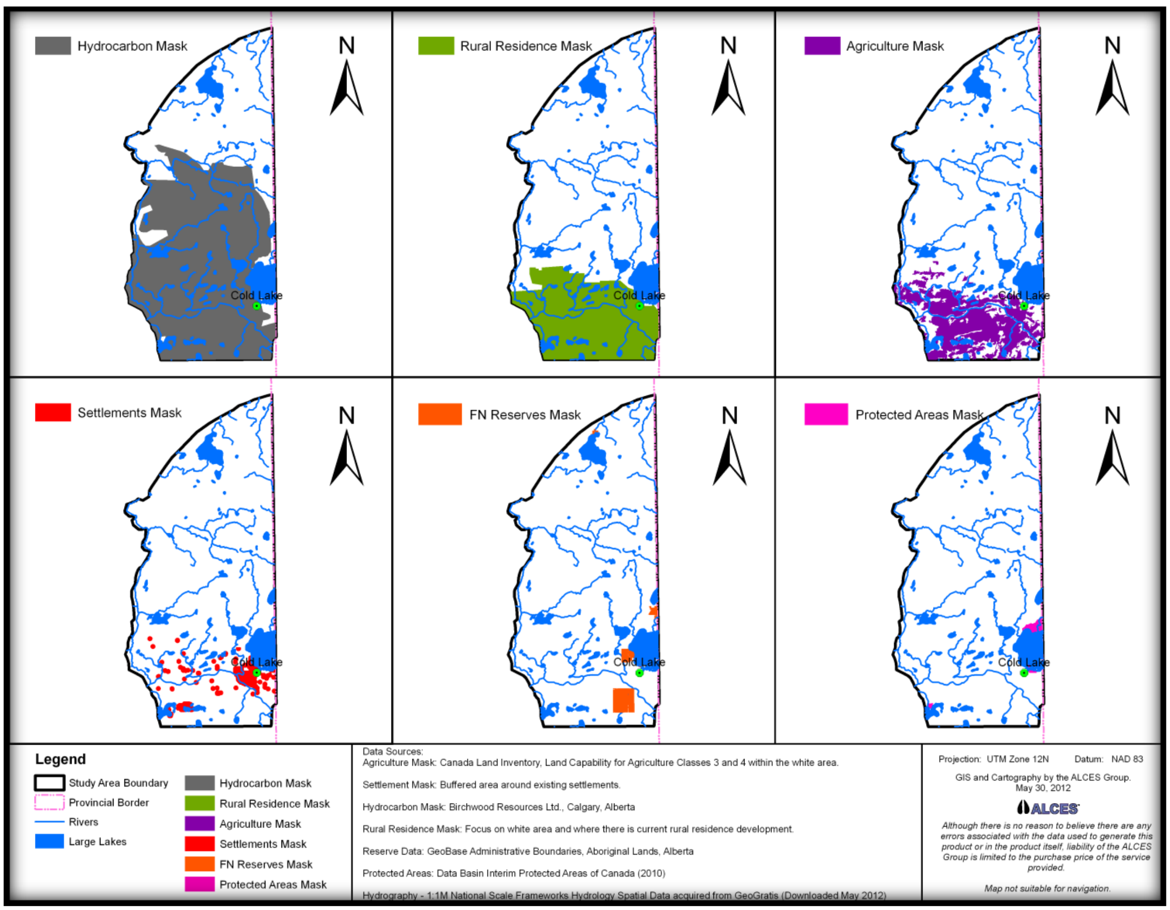


Figure 116. Spatial constraint inclusionary maps used for the ALCES simulator for CLFN SA.

8. LAND-USE ASSUMPTIONS

8.1 GENERAL INPUT ASSUMPTIONS ABOUT FUTURE GROWTH OR RECESSION OF LAND-USE

Table 15. Major assumption defining future simulations in CLFN ALCES.

Land-use	Key Assumptions of Specific Land-uses in Future Era
Croplands	Croplands continue to expand at rates much slower than historic and cease to expand once Class 4 soils are no longer available. This pace reflects an expansion of ~240 ha/yr for a period of 90 years.
Livestock	Cattle are the primary livestock species simulated and grow at a rate consistent with increased forage crop production in CLFN SA.
Settlements	Although settlement area has expanded during the past 5 decades at an average annual rate greater than 6%/yr, this exponential pace cannot be sustained for any substantial period of time in the future. We assume that settlement area will grow by 1.0 %/yr throughout the future simulation era.
Aboriginal Populations	CLFN populations are grown at a rate of 1.5 %/yr for the next 50 years, a rate that is consistent with historical growth rates of past five decades. Growth rates are then reduced to 1%/yr for the duration of the simulation. Populations reside in combination of towns, rural residential and reserves.
Non-aboriginal Populations	Non-aboriginal populations are grown at a rate of 1.5 %/yr, a rate that is consistent with historical growth rates of past five decades. Growth rates are then reduced to 1%/yr for the duration of the simulation. Populations reside in combinations of towns and rural residences (acreages)
Forestry	Logging absent as a large scale land-use and only occurs to the extent required for salvaging merchantable grade wood associated with the footprint of the hydrocarbon sector.
Military	CLAWR persists in the future and maintains similar access restrictions as imposed currently
Parks	Current matrix of parks neither increases nor decreases in size.
Natural Gas	No additional footprint (wellpads, seismic lines, pipelines) are constructed. Any natural gas that is produced as a secondary commodity of a different hydrocarbon type and is flared.
Heavy Oil	Of the estimated 10.25 B m^3 of heavy oil considered to be in place, 0.51 B m3 (5%) is estimated to be recoverable using primary extraction technologies. Future footprint metrics of heavy oil production are those currently defining the heavy oil industry in CLFN SA.
CSS Bitumen	Of the estimated 14.39 B m^3 of bitumen considered to be in place, 3.6 B (25% is estimated to be recoverable using CSS extraction technologies. Future footprint (seismic lines, wellpads, pipelines) metrics of CSS production are those currently defining the CSS industry in CLFN SA.
SAGD Bitumen	Of the estimated 4.44 B m^3 of bitumen considered to be in place, 2.22 B m^3 (50%) is estimated to be recoverable using SAGD extraction technologies. Future footprint (seismic lines, wellpads, pipelines) metrics of CSS production are those currently defining the SAGD industry in CLFN SA.
Transportation	Public road network neither increases nor decreases but roads associated with rural residential and wellsites are constructed and remain permanent features.

8.2 SPECIFIC INPUT ASSUMPTIONS ABOUT FUTURE LAND-USE SCENARIO

8.2.1 First Nations and Their Settlements

The ALCES CLFN model simulates a suite of land-use and landscape metrics that are considered relevant to aboriginal communities (Figure 117). These indicators can be assembled in different configurations to report on performance of various integrity indicators. Because of time constraints, only portions of the Aboriginal Peoples Sustainability modules were deployed in this project.

For the CLFN SA project, no increase or decrease in the number or size of reserves occurs during the simulation period. The size of the First Nation population and their residence footprint is simulated to grow at 1.5%/yr for the next 50 years, and at 1%/yr thereafter.

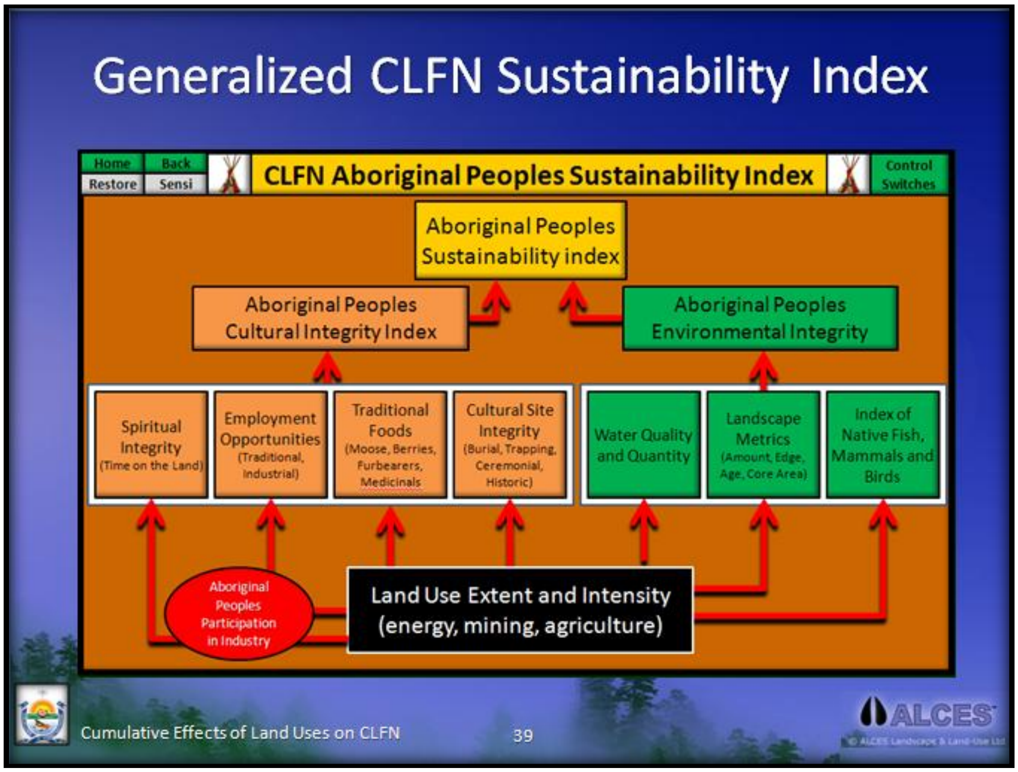


Figure 117. Generalized CLFN Sustainability Index used in the CLFN ALCES simulator.

8.2.2 Non-Aboriginal Populations and Their Settlements

For the CLFN SA project, the size of the non-aboriginal population and their residence footprint is simulated to grow at 1.5%/yr for the next 50 years, and at 1%/yr thereafter.

8.2.3 Agriculture

Agriculture (both croplands and livestock) can significantly affect all aspects of ecological integrity (Figure 118) including water quantity and quality, air quality, landscape fragmentation, and the amount of wildlife habitat and soil organics.

For the future simulation, cultivated and forage crops continue to expand in the CLFN SA at a rate of 240 ha/yr until such time as remaining Class 4 soils have been fully consumed. At this juncture, no further cropland expansion occurs. Croplands are lost annually, however, to the expanding footprint of transportation, settlements, and energy sector.

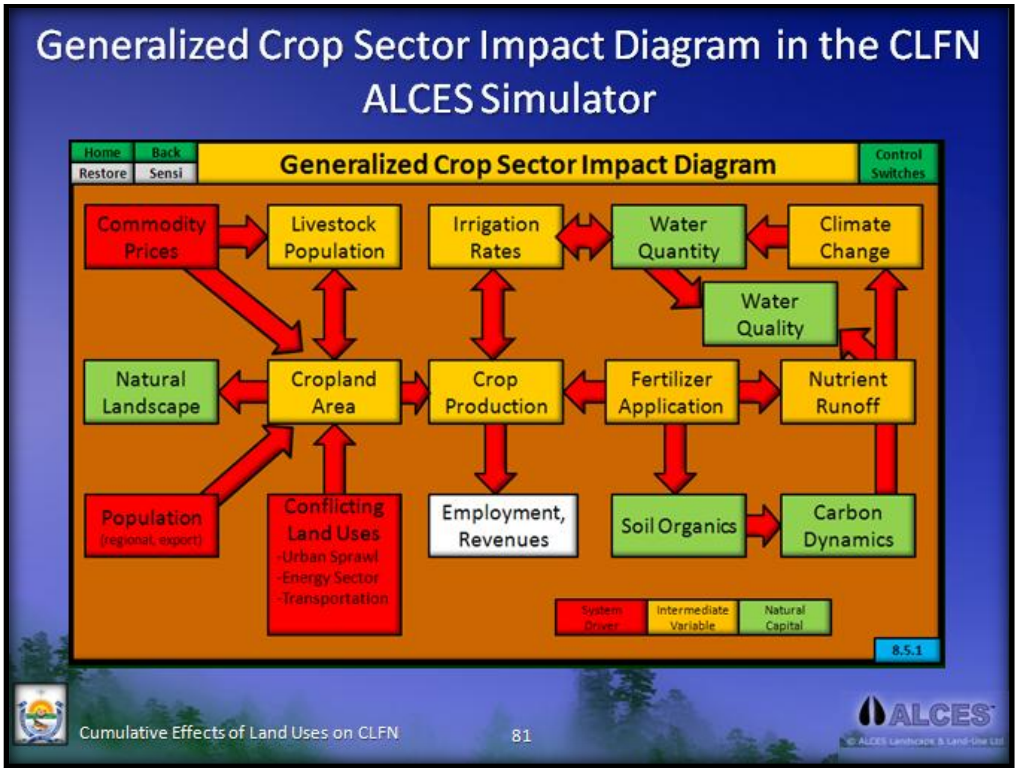


Figure 118. Generalized crop sector impact hypothesis diagram in the CLFN ALCES simulator.

8.2.4 Forestry

No commercial forestry operations were conducted as part of historical, current or future simulations in CLFN SA. Wood salvage was allowed to occur for selected footprint types (large roads, pipelines, transmission lines) that were constructed through merchantable forests.

It is relevant that commercial forest harvest is ongoing in Saskatchewan immediately east of the CLFN SA and within their Traditional Territories.

8.2.5 Hydrocarbons (Bitumen and Heavy Oil)

The general methodologies employed by the ALCES IV model for simulating the oil and gas sector are described in the CLFN ALCES Technical Manual (Appendix A). The Hubbert/Naill life history approach (Figure 119) to reserve delineation, exploration and production used by ALCES requires input values that pertain to the following reserve variables:

- Total Reserve in Place

- Historical Reserve Production
- Current Proven Hydrocarbon Volumes

The majority of CLFN SA has been leased by the hydrocarbon sector for exploration and production (Figure 120).

When simulating the future development of a regional hydrocarbon reserve, it is not possible, or desirable, to predict the precise temporal and spatial conditions. The objective is to explicitly state ones assumptions and to construct plausible future trajectories that allows stakeholders to better understand the pace and magnitude of the reserve development and the suite of benefits and liabilities that attend the stated trajectory.

In addition to reserve data, metrics (average size, width, lifespan) for current and future footprints are required for the following variables:

- Seismic lines
- Wellpads and their access roads
- Production and delineation wells
- Pipelines

Initial values for hydrocarbon reserves (Figure 121, Figure 122, Figure 123, Figure 124) and energy sector footprint metrics (Figure 120) were provided by Alex Lemmens of Birchwood Resources, a company with significant experience in insitu extraction of unconventional oil in the region. Where uncertainties of input values existed, conservative estimates were adopted to directionally under-estimate future footprint growth and over-estimate reclamation rates. This project also considered the input assumptions as adopted by the Sustainable Ecosystems Working Group (SEWG) of the Cumulative Effects Management Association (CEMA), who recently completed a regional assessment of the energy sector in northeast Alberta (www.cemaonline.ca).

Of the total estimated recoverable reserves of 6.329 B m^3, ~0.51 will be extracted using primary heavy oil techniques, 3.425 B m^3 from CSS and 2.222 B m^3 from SAGD (Lemmens, pers. comm., 2012; Appendix B).

Estimates of the time horizon of extracting the majority of recoverable volumes range from several decades to multiple centuries and will be influenced by a multitude of factors including emergent extraction and processing technologies, market price of oil, and commitment by government to ecological goods and services. The simulation length of the future trajectory for the CLFN SA is 200 years (2012 to 2212), during which the vast majority (5.5 B m^3) of the total (6.3 B m^3) recoverable reserves are produced. The CLFN ALCES model has been customized to enable rapid exploration of alternative bitumen reserve recovery trajectories.

To develop a bitumen development mask for the CLFN SA to be used in ALCES Mapper, the ERCB deposit masks for Upper and Lower Grand Rapids, Cold Lake Clearwater and Ft. McMurray/Wabiskaw deposits were digitized. Future development was restricted to all thicker deposits and those intermediate thickness deposits proximal to the deepest deposit classes (Figure 125). Collectively, these map overlays allowed us to construct a master mask (Figure 125) that spatially constrained all future bitumen and heavy oil development (seismic lines, wellpads, access roads, pipelines, processing plants).

Although oil leases currently exist in the far northern portion of CLFN SA (Figure 120), uncertainty concerning the underlying oil reserve metrics leads to a decision by the CLFN ALCES analysts to adopt a conservative decision and not develop these regions further.

The CLFN SA inclusionary mask for future heavy oil/bitumen development is contrasted against historical production wells and the Traditional Territory of CLFN (Figure 126). Summary metrics of hydrocarbon in-place volumes, recovery rates, and final recoverable volumes are provided in Figure 127.

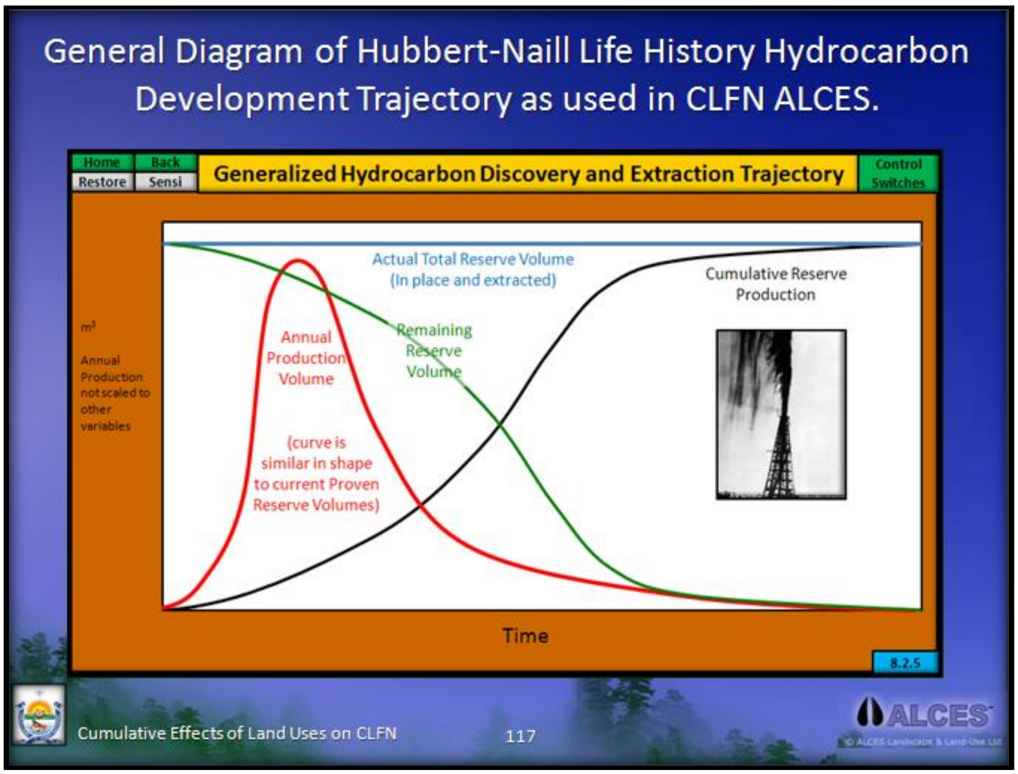


Figure 119. Generalized diagram of Hubbert-Naill Life History hydrocarbon development trajectory as used in the CLFN ALCES simulator.

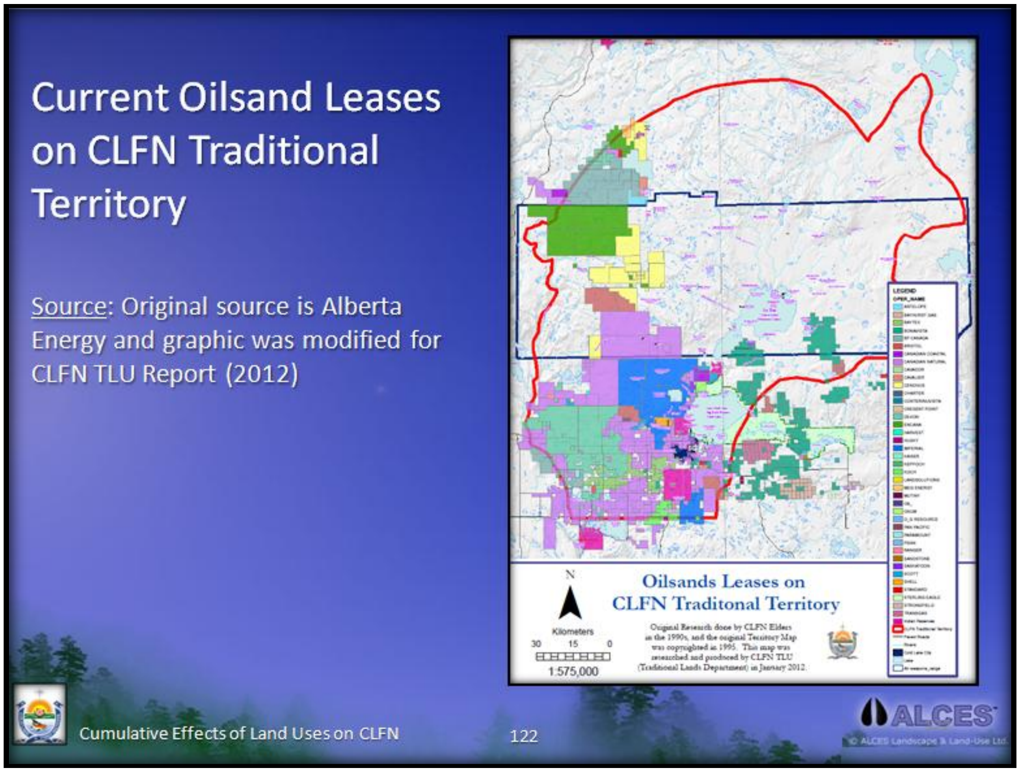
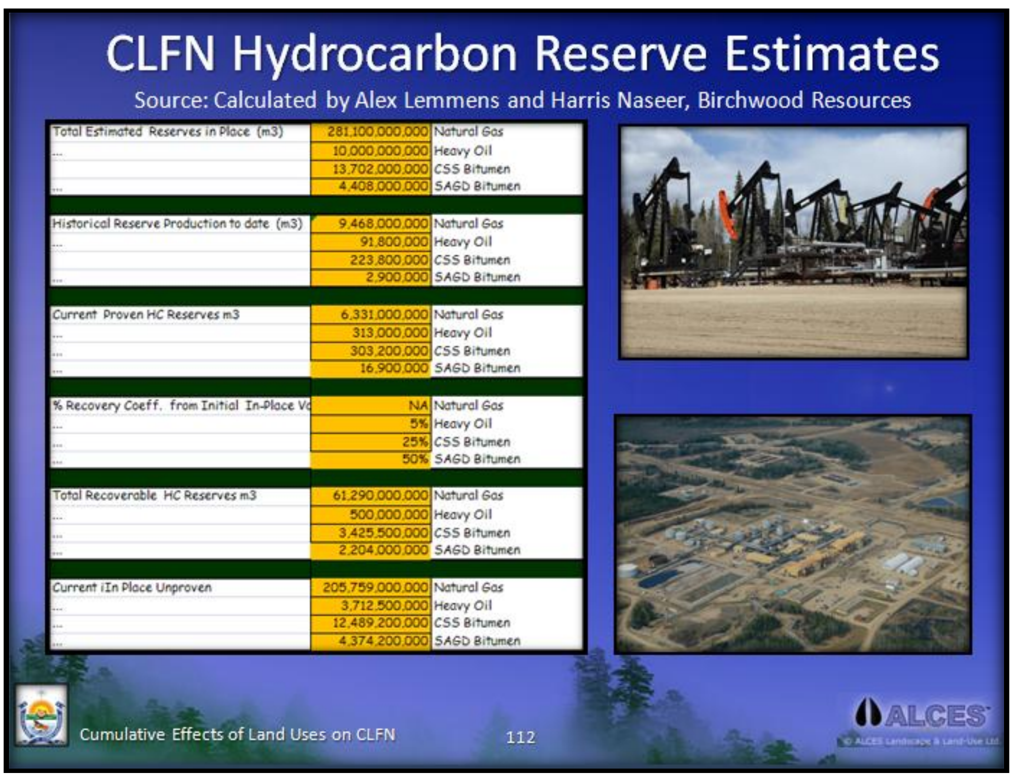


Figure 120. Current oilsand leases on CLFN traditional lands. Source: Alberta Energy.



Total Estimated Reserves in Place (m3)	281,100,000,000	Natural Gas
...	10,000,000,000	Heavy Oil
	13,702,000,000	CSS Bitumen
...	4,408,000,000	SAGD Bitumen
Historical Reserve Production to date (m3)	9,468,000,000	Natural Gas
...	91,800,000	Heavy Oil
	223,800,000	CSS Bitumen
...	2,900,000	SAGD Bitumen
Current Proven HC Reserves m3	6,331,000,000	Natural Gas
...	313,000,000	Heavy Oil
...	303,200,000	CSS Bitumen
...	16,900,000	SAGD Bitumen
% Recovery Coeff. from Initial In-Place Vo	NA	Natural Gas
...	5%	Heavy Oil
...	25%	CSS Bitumen
...	50%	SAGD Bitumen
Total Recoverable HC Reserves m3	61,290,000,000	Natural Gas
...	500,000,000	Heavy Oil
...	3,425,500,000	CSS Bitumen
...	2,204,000,000	SAGD Bitumen
Current iIn Place Unproven	205,759,000,000	Natural Gas
...	3,712,500,000	Heavy Oil
...	12,489,200,000	CSS Bitumen
...	4,374,200,000	SAGD Bitumen

Figure 121. Hydrocarbon reserve metrics for CLFN SA. Source: Birchwood Resources, 2012.

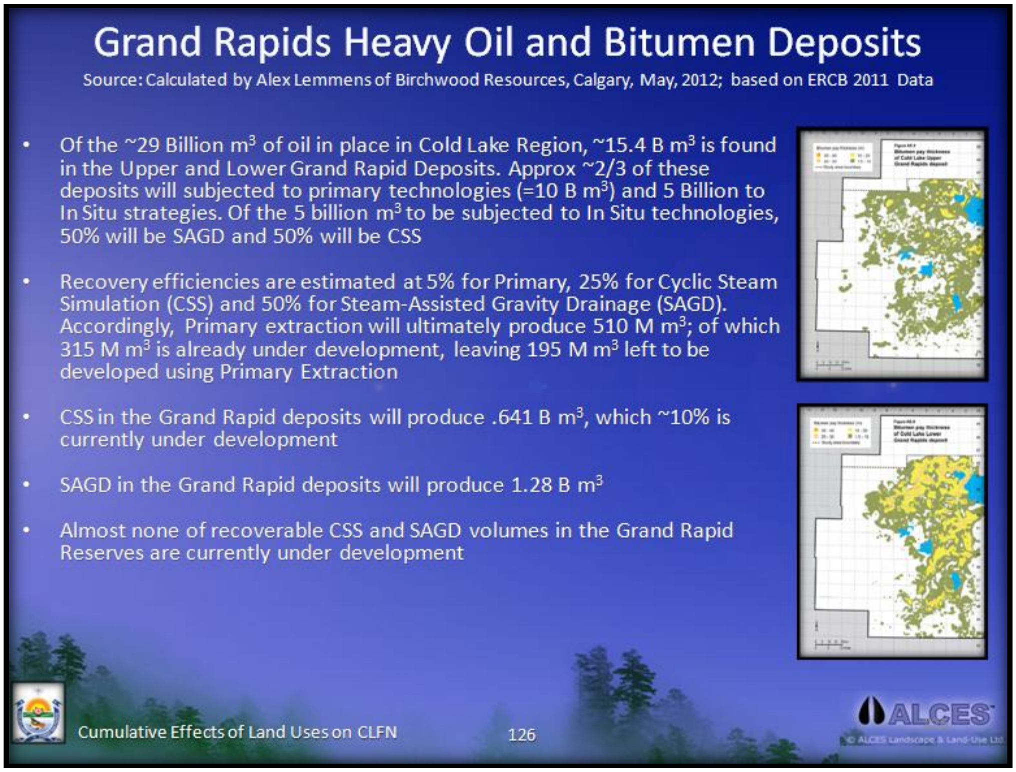


Figure 122. General reserve volume information of the Upper and Lower Grand Rapids deposits.

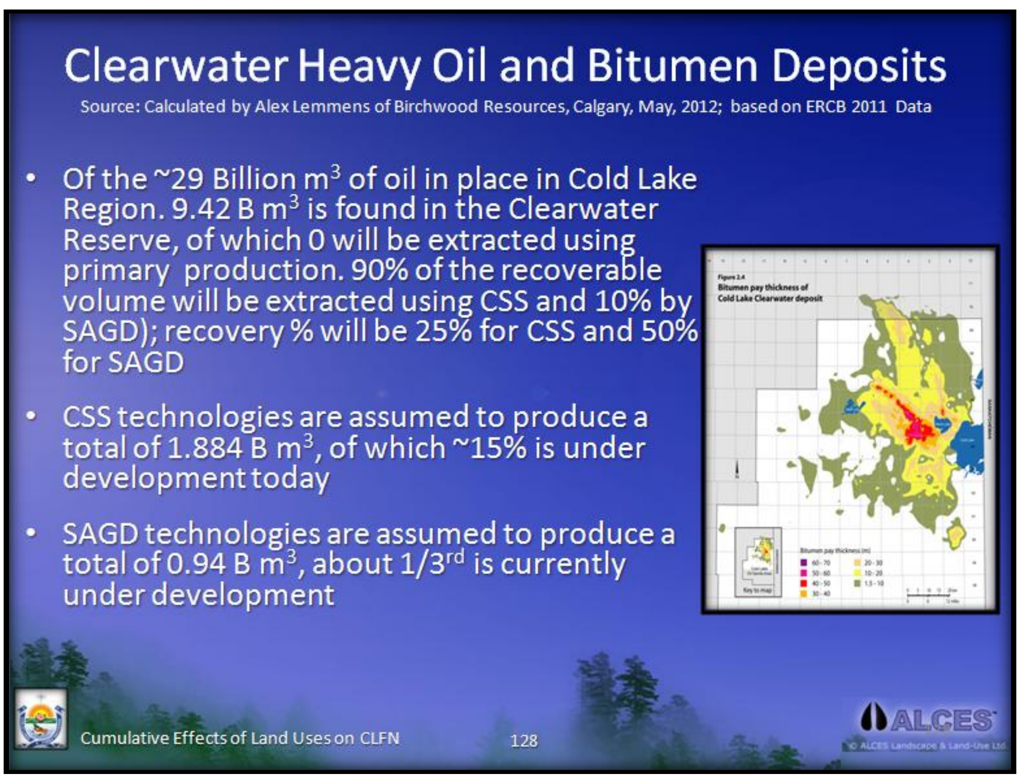


Figure 123. General reserve volume information of the Cold Lake Clearwater deposit.

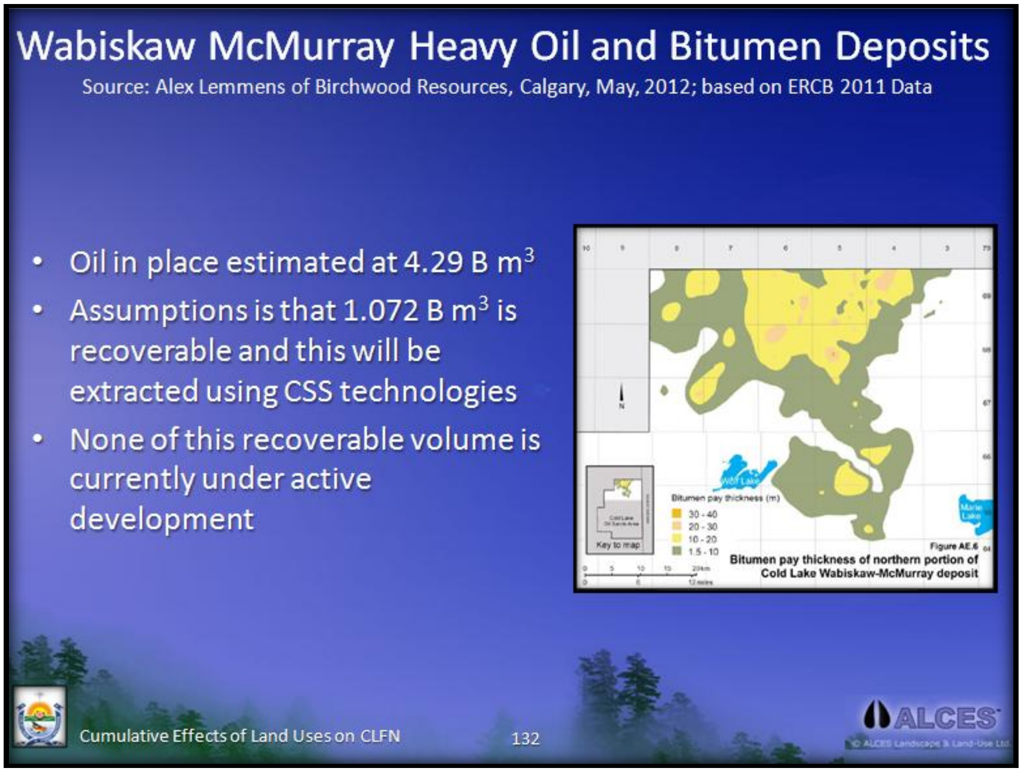


Figure 124. General reserve volume information of the Wabiskaw McMurray deposit.

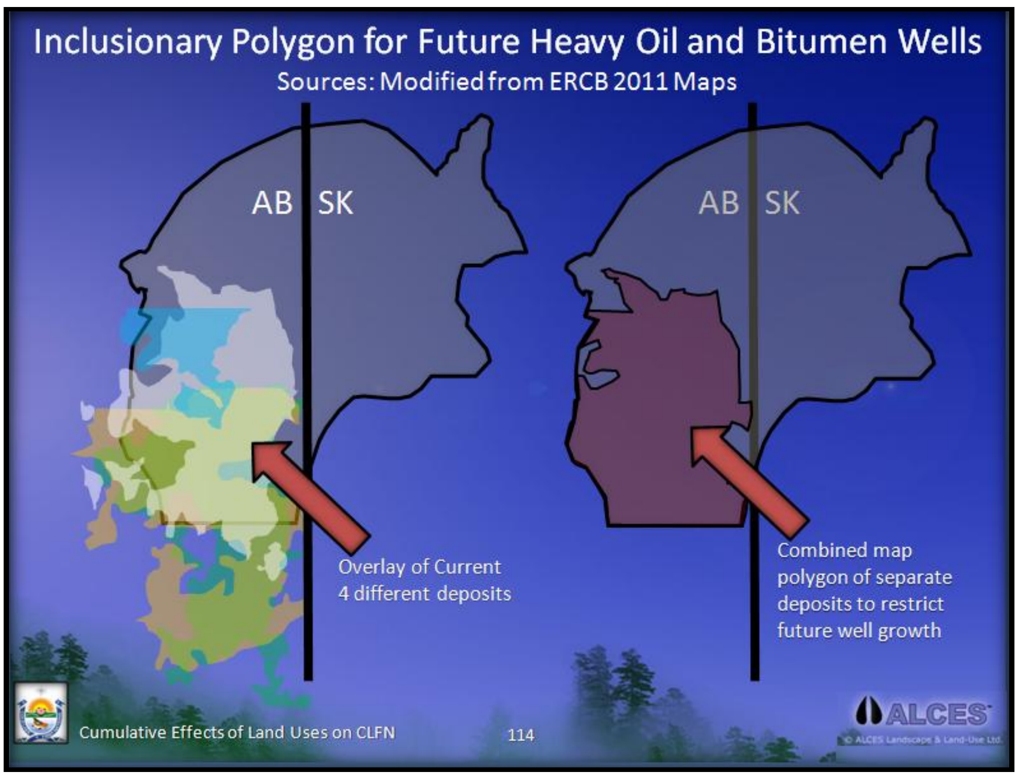


Figure 125. Overlay of individual deposits (Upper and Lower Grand Rapids, Cold Lake Clearwater and Wabiskaw/Ft. McMurray) (left) and composite map used to confine future growth of wells on CLFN SA.

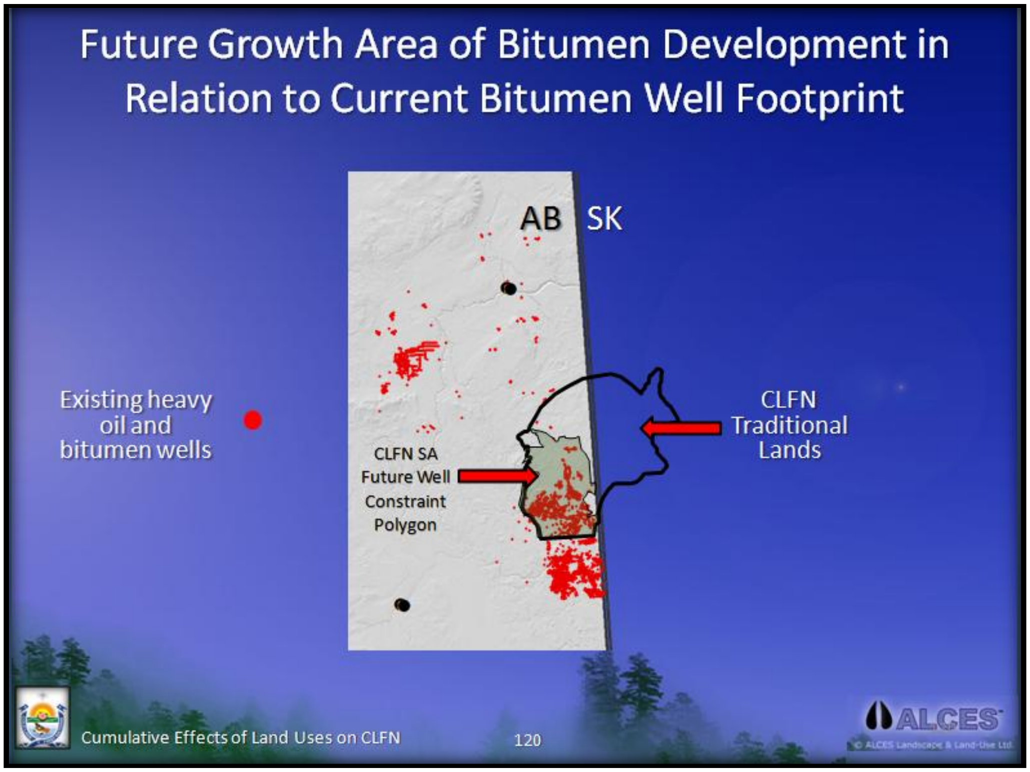


Figure 126. Comparison of composite CLFN SA map heavy oil/bitumen with existing bitumen and heavy oil wells in the Cold Lake region of Alberta.

CLFN Heavy Oil and Bitumen Volume Metrics

Source: Calculated by Alex Lemmens of Birchwood Resources, Calgary, May, 2012; based on ERCB 2011 Data

	Primary Extraction of Heavy Oil	Cyclic Steam Stimulation (CSS)	Steam-Assisted Gravity Drainage (SAGD)	Total Heavy Oil and Oilsands Volume
In-Place	Billion m^3	Billion m^3	Billion m^3	Billion m^3
Grand Rapids (U&L)	10.25	2.56	2.56	15.38
Clearwater	0.00	7.54	1.88	9.42
Wabiskaw/ Ft. McMurray	0.00	4.29	0	4.29
Total	10.25	14.39	4.44	29.09
Recoverable Fraction	5%	25%	50%	
Recoverable	Billion m^3	Billion m^3	Billion m^3	Billion m^3
Grand Rapids (U&L)	0.51	.64	1.282	2.43
Clearwater	0.00	1.89	0.94	2.82
Wabiskaw/ Ft. McMurray	0.00	1.07	0.00	1.07
Total	0.51	3.60	2.22	6.32

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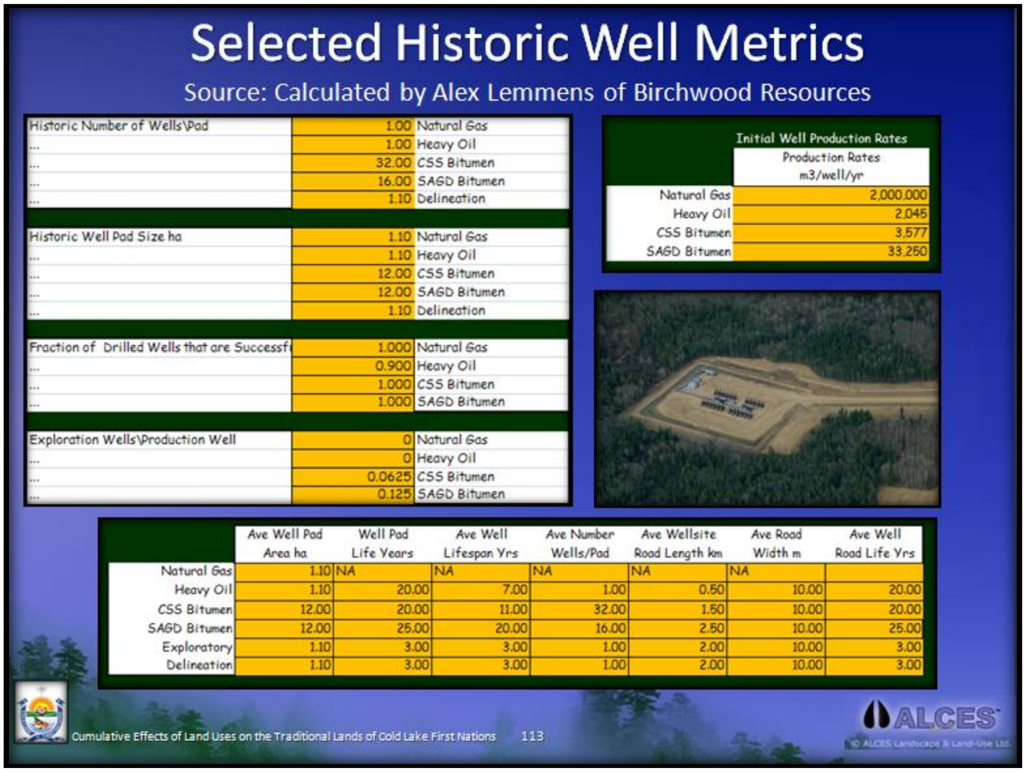
ALCES

Figure 127. Heavy oil and bitumen reserve data relating to CLFN SA provided by Birchwood Resources.



Selected Historic Well Metrics

Source: Calculated by Alex Lemmens of Birchwood Resources

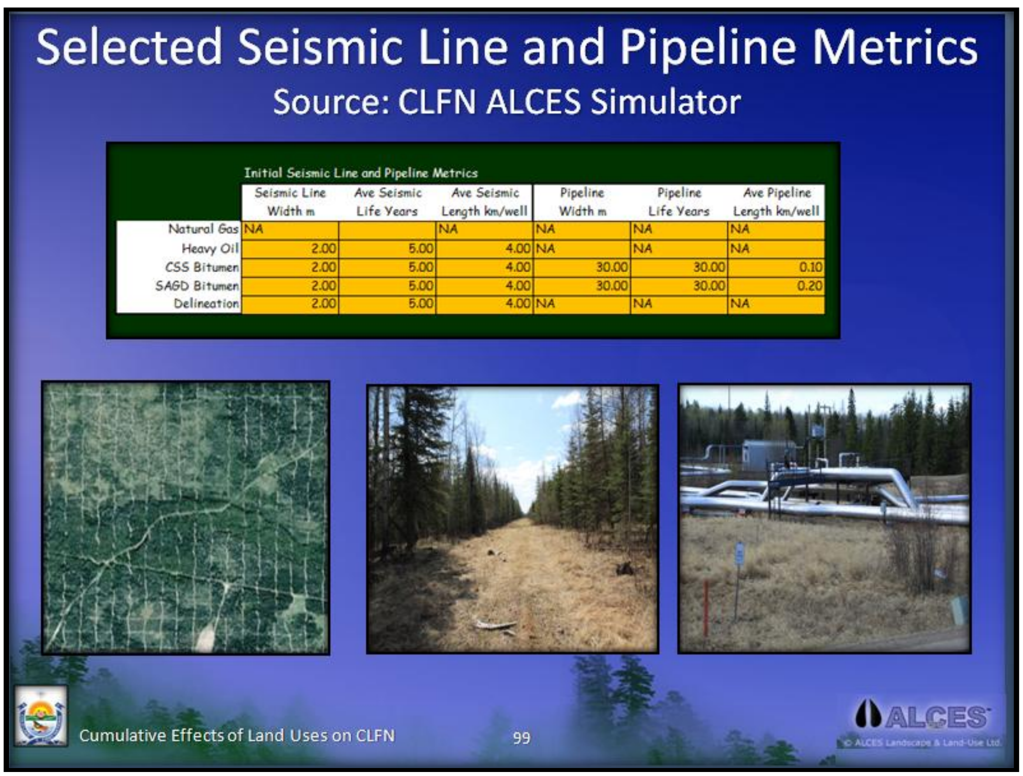
Historic Number of Wells\Pad	1.00	Natural Gas
...	1.00	Heavy Oil
...	32.00	CSS Bitumen
...	16.00	SAGD Bitumen
...	1.10	Delineation
Historic Well Pad Size ha	1.10	Natural Gas
...	1.10	Heavy Oil
...	12.00	CSS Bitumen
...	12.00	SAGD Bitumen
...	1.10	Delineation
Fraction of Drilled Wells that are Successf	1.000	Natural Gas
...	0.900	Heavy Oil
...	1.000	CSS Bitumen
...	1.000	SAGD Bitumen
Exploration Wells\Production Well	0	Natural Gas
...	0	Heavy Oil
...	0.0625	CSS Bitumen
...	0.125	SAGD Bitumen

Initial Well Production Rates

	Production Rates m3/well/yr
Natural Gas	2,000,000
Heavy Oil	2,045
CSS Bitumen	3,577
SAGD Bitumen	33,250

	Ave Well Pad Area ha	Well Pad Life Years	Ave Well Lifespan Yrs	Ave Number Wells/Pad	Ave Wellsite Road Length km	Ave Road Width m	Ave Well Road Life Yrs
Natural Gas	1.10	NA	NA	NA	NA	NA	
Heavy Oil	1.10	20.00	7.00	1.00	0.50	10.00	20.00
CSS Bitumen	12.00	20.00	11.00	32.00	1.50	10.00	20.00
SAGD Bitumen	12.00	25.00	20.00	16.00	2.50	10.00	25.00
Exploratory	1.10	3.00	3.00	1.00	2.00	10.00	3.00
Delineation	1.10	3.00	3.00	1.00	2.00	10.00	3.00

Figure 128. Well and wellpad metrics used in CLFN SA ALCES simulator. Source: Birchwood Resources, Calgary, Alberta, 2012.



Selected Seismic Line and Pipeline Metrics

Source: CLFN ALCES Simulator

Initial Seismic Line and Pipeline Metrics

	Seismic Line Width m	Ave Seismic Life Years	Ave Seismic Length km/well	Pipeline Width m	Pipeline Life Years	Ave Pipeline Length km/well
Natural Gas	NA		NA	NA	NA	NA
Heavy Oil	2.00	5.00	4.00	NA	NA	NA
CSS Bitumen	2.00	5.00	4.00	30.00	30.00	0.10
SAGD Bitumen	2.00	5.00	4.00	30.00	30.00	0.20
Delineation	2.00	5.00	4.00	NA	NA	NA

Figure 129. Seismic line and pipeline metrics in CLFN SA Alces simulator: Source: Birchwood Resources, Calgary, Alberta, 2012.

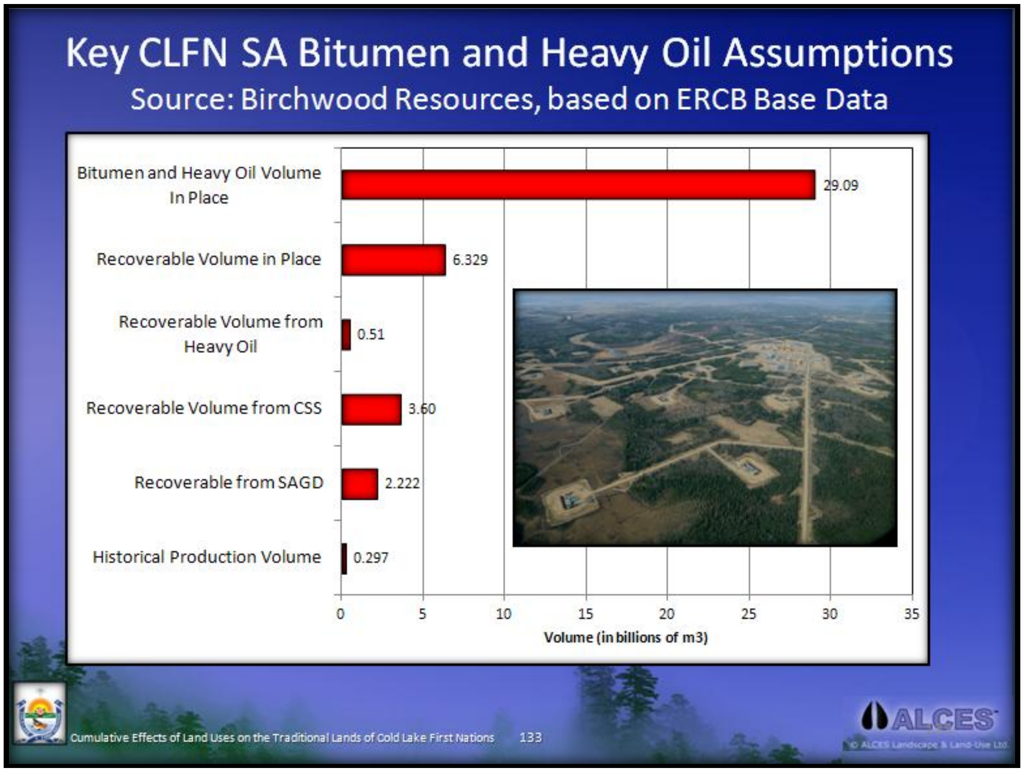


Figure 130. Summary of heavy oil and bitumen volume metrics in CLFN SA. Source: Birchwood Resources, Calgary, Alberta.

8.2.6 Military

The future "business as usual" scenario for the CLFN SA assumes that the current level of access restrictions of CLFN to CLAWR persists. No changes in the size of CLAWR or its boundary occur in this simulation.

8.2.7 Transportation

The business as usual scenario assumes that there will be no additional public road network constructed, but future roads will be constructed to:

- Access new rural residences
- Access insitu wellpads and infrastructure

Whereas the public road network and those to rural residences are permanent, the road network for the energy sector is transient and is reclaimed to its original landscape at the conclusion of its lifespan as a land-use footprint.

8.2.8 Protected Areas

The business as usual scenario assumes that the current size and location of provincial parks in the CLFN SA will not change. Current restrictions of CLFN traditional activities within the park network persist in the future simulation.

8.2.9 Key Reclamation Input Assumptions

All land-use footprints tracked in ALCES can be either permanent or transient. If footprints types are not permanent, then ALCES requires input assumptions on the average lifespan of each footprint type. ALCES adopts a 2nd order approach to reclaiming footprint types based on defined lifespans. For example, if wellpads have a 20 year lifespan, then 5% of wellpads are reclaimed annually, with oldest wellpads being reclaimed first.

It is important to give consideration to the metrics used for footprint reclamation, since landscape metrics influenced by footprints and their reclamation often have a significant effect on ecological indicators, particularly those that are sensitive to landscape fragmentation or core area. If footprints such as seismic lines are not allowed to reclaim at a rate likely to occur in reality, then the environmental effects of land-use trajectories may be exaggerated. Conversely, allowing seismic lines to reclaim in the model more quickly than in reality will likely under-estimate the true effect magnitude.

For the CLFN SA ALCES project, all footprint types were permanent except seismic lines, wellpads, wellpad access roads, and pipelines. Each of these features was given an average lifespan (Table 16). Seismic lines and pipelines constructed by ALCES on cultivated crops were given a lifespan of 1 year (indicating that their presence disappeared within one growing season).

Table 16. Key land-use footprint reclamation metrics used in the CLFN ALCES model.

Land-use Footprint	**Average Lifespan (yrs)**	**Reclamation Destination**
Major Roads	Permanent	Not relevant
Minor Roads	Permanent	Not relevant
Gravel Pits	Permanent	Not relevant
Inblock Roads	3	Reclaimed to original Landscape Type
Transmission Lines	Permanent	Not relevant
Rail	Permanent	Not relevant
Industrial Features	Permanent	Not relevant
Urban	Permanent	Not relevant
Rural Residential	Permanent	Not relevant
Seismic Lines	Related to seismic line width (2 year lifespan for seismic lines of average 2 m width for CLFN)	Reclaimed to original Landscape Type
Wellpads	CSS/Heavy (20), SAGD (25)	Reclaimed to original Landscape Type
Wellpad Access Roads	CSS/Heavy (20), SAGD (25)	Reclaimed to original Landscape Type
Pipelines	30	Reclaimed to original Landscape Type

9. RESULTS

9.1 GENERAL

Collectively, the footprints of the CLFN SA land-uses have lead to significant landscape transformation, particularly to the regions south of CLAWR. Linear/curvilinear features (seismic lines, pipelines, access roads, transmission lines) and polygonal features (croplands, settlements, wellsites, processing plants) have caused direct loss of natural landscape and wildlife habitat and have an indirect effect on those ecological processes that function at reduced performance when adjacent to either linear or polygonal land-use footprints.

The simulation results suggest that future changes to the structure and ecological function of CLFN SA will be as large in scale and pace as those that have occurred during the past 100 years. Not surprisingly, most of the ecological indicators will continue to be reduced in integrity in the upcoming decades. In many cases, performance of indicators begins to improve in about 50 years. This reversal in degradation, and the onset of improving trends, is directly the result of the reclaiming footprint of the energy sector, particularly seismic lines. If the optimistic reclamation rates used in these analyses are not realized, then the results presented herein may be highly optimistic.

9.2 BITUMEN PRODUCTION AND ECONOMIC

It is clear that the hydrocarbon sector in the CLFN SA is a key driver, at local, regional, and provincial scales, of both revenues and employment. This stature is unlikely to change in upcoming decades. From the perspective of CLFN, a key issue is ensuring a robust and quantitative understanding of both the benefits and liabilities associated with the bitumen industry, and a dialogue that allows for the sharing of opportunities and risks by the CLFN.

9.2.1 Bitumen and Heavy Oil Production Trajectories

Simulated production of heavy oil and bitumen has been increasing during the past several decades in CLFN SA and now occurs at a rate of ~20 M m^3/yr (Figure 131), or 440,000 bpd (Figure 132). Production rates are projected to increase to ~34 M m^3/yr within 40 years before beginning to decline.

Although heavy oil and bitumen production using primary extraction and CSS have been the dominant extraction technologies historically, SAGD technologies are now being deployed in the region and are expected to grow in production during the next several decades. Annual production of bitumen from SAGD is expected to match that from CSS production within 8 decades (Figure 133).

Cumulative production of bitumen is projected to approach 5 B m^3 by the end of the simulation period (Figure 134), of which ~50% will have been extracted by CSS, 40% from SAGD, and 10% from primary extraction (Figure 135).

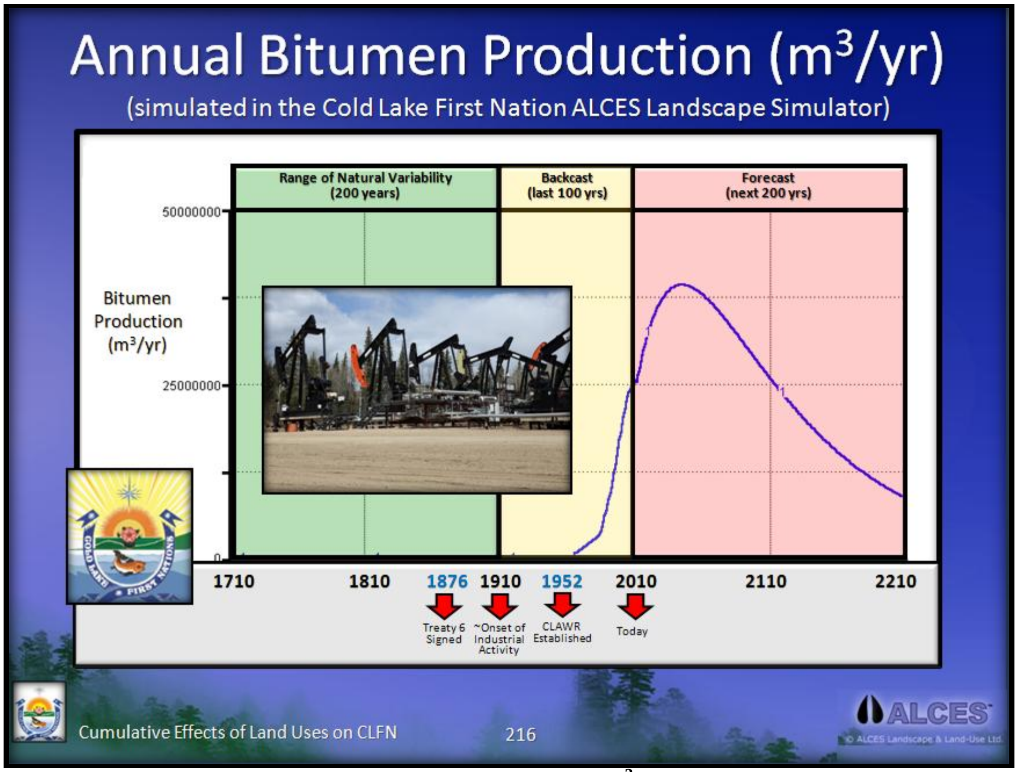


Figure 131. Changes in annual bitumen production (m^3/yr) in CLFN SA.

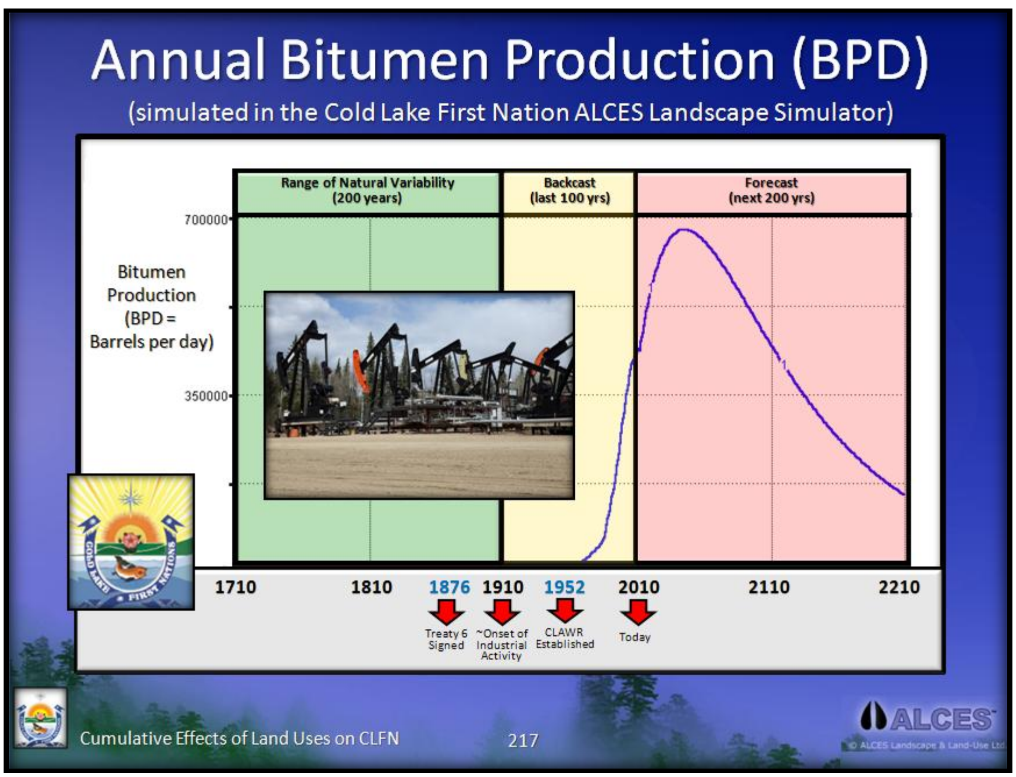


Figure 132. Changes in annual bitumen production (barrels/day) in CLFN SA.

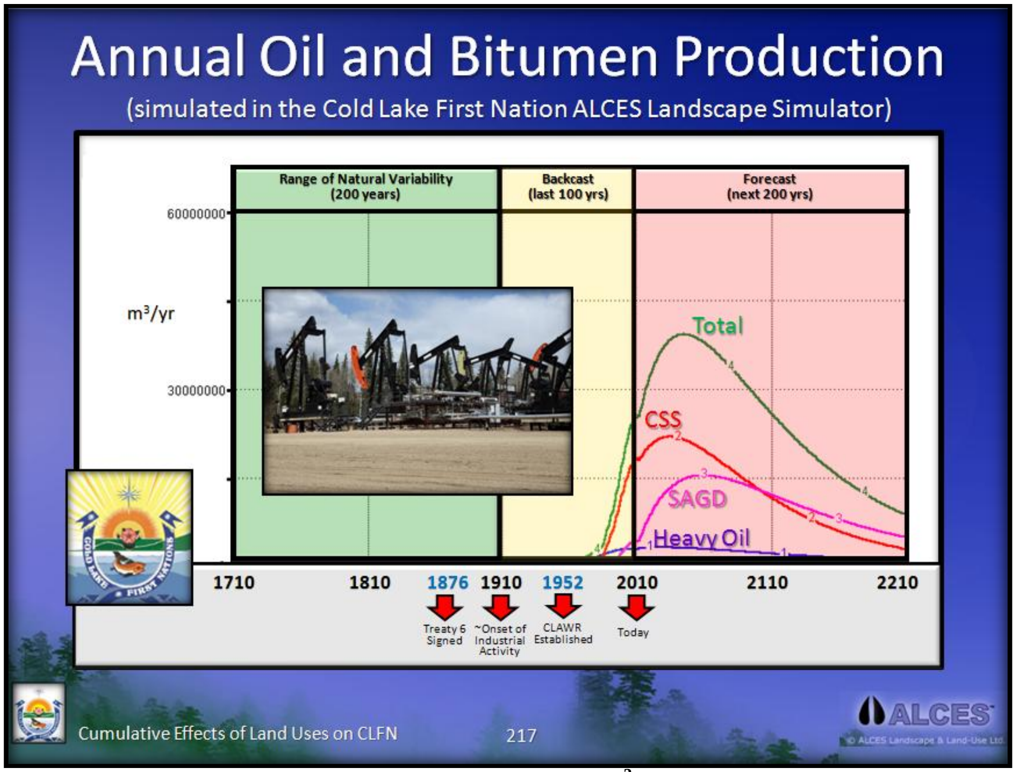


Figure 133. Changes in annual bitumen production (m^3/yr) from different oil extraction technologies in CLFN SA.

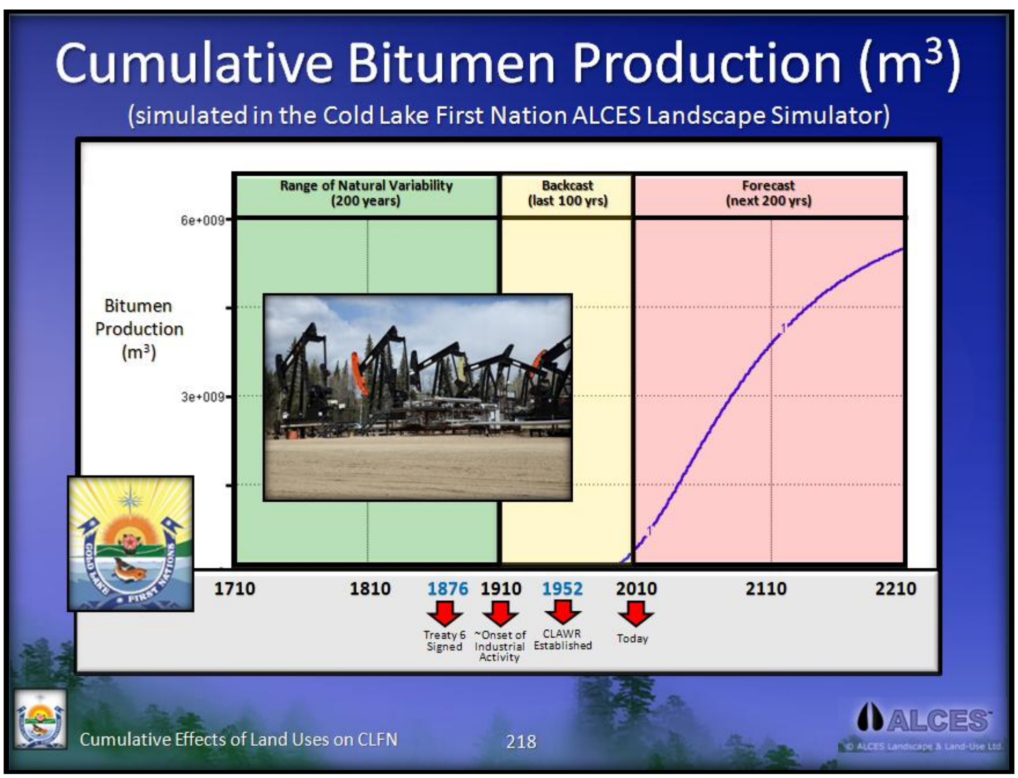


Figure 134. Changes in cumulative bitumen production in CLFN SA.

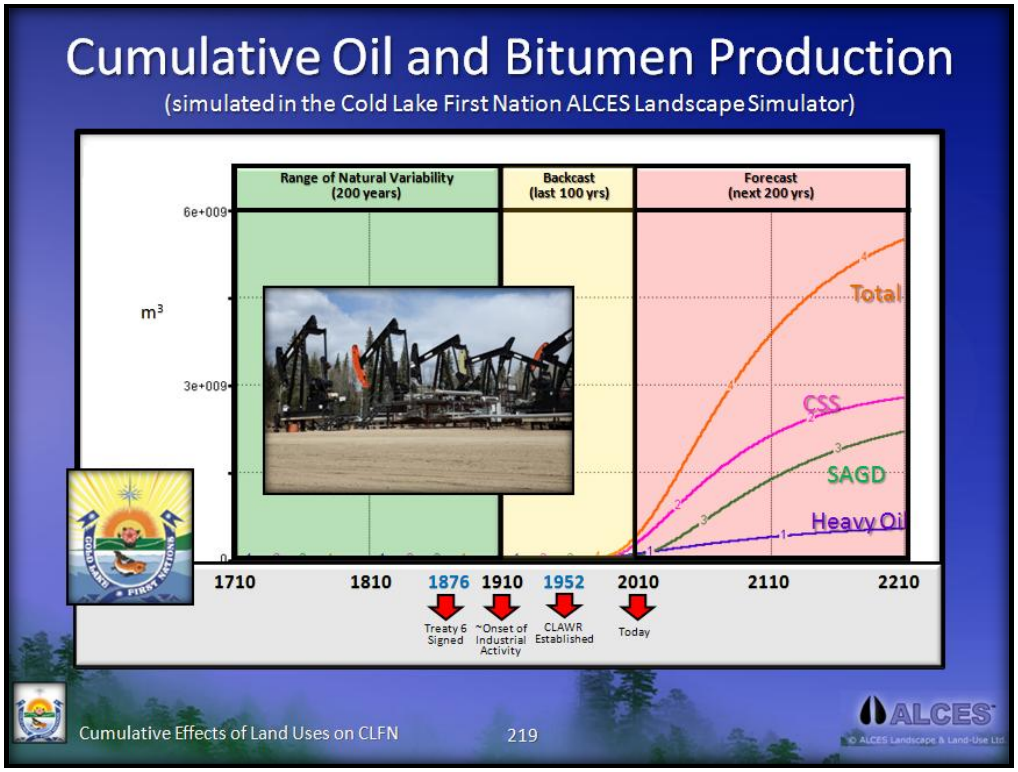


Figure 135. Changes in cumulative oil and bitumen production in CLFN SA.

9.2.2 Bitumen and Heavy Oil Revenues

Based on a key assumption that historical and future bitumen/oil commodity pricing remains at constant 2012 net-back values (350\$/m^3, Alex Lemmens, pers. comm, 2012), the gross annual revenue generated from CLFN SA bitumen production is currently at ~\$8B (Figure 136). CLFN SA bitumen revenues are expected to increase for 30-40 years where they will achieve maximum annual values of ~\$13B/yr. Beyond Yr 40 (2050), bitumen production levels and annual revenues are forecast to decline incrementally.

Those who believe the constant \$350/m^3 commodity price used in these analyses is either too high or too low can simply apply an adjustment ratio to compute changes in either net or cumulative values. As long as market demand and price do not exhibit significant temporal variation, the shape of the gross and cumulative revenues from CLFN SA would be unlikely to change.

As of 2012, cumulative revenue generated from CLFN SA bitumen production is estimated at \$192B (Figure 137). These cumulative revenues are expected to increase to ~\$1.92T within 200 years when ~5 B m^3 of bitumen have been extracted and marketed.

A revenue sharing arrangement was explored using the ALCES simulator whereby 5 cents/barrel (equivalent to 0.3145\$/m^3) would be paid to CLFN based on bitumen produced on the CLFN SA. This amount reflects ~0.089% of the current market value paid to the producer. The results of this “what-if” scenario (Figure 138, Figure 139) illustrate the relative revenue streams of both annual and cumulative payments to each of the energy sector and CLFN. To emphasize the minute fraction of revenue that would be directed to CLFN with this approach, the cumulative values are expressed using an identical scale in Figure 140.

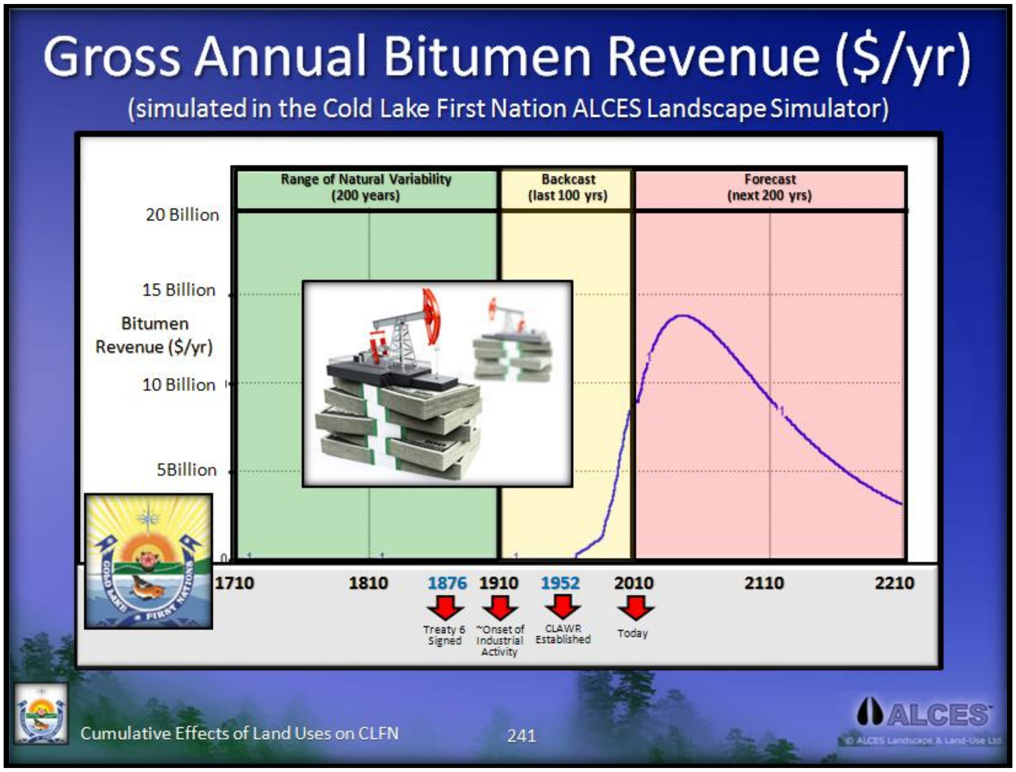


Figure 136. Changes in annual bitumen revenues in CLFN SA.

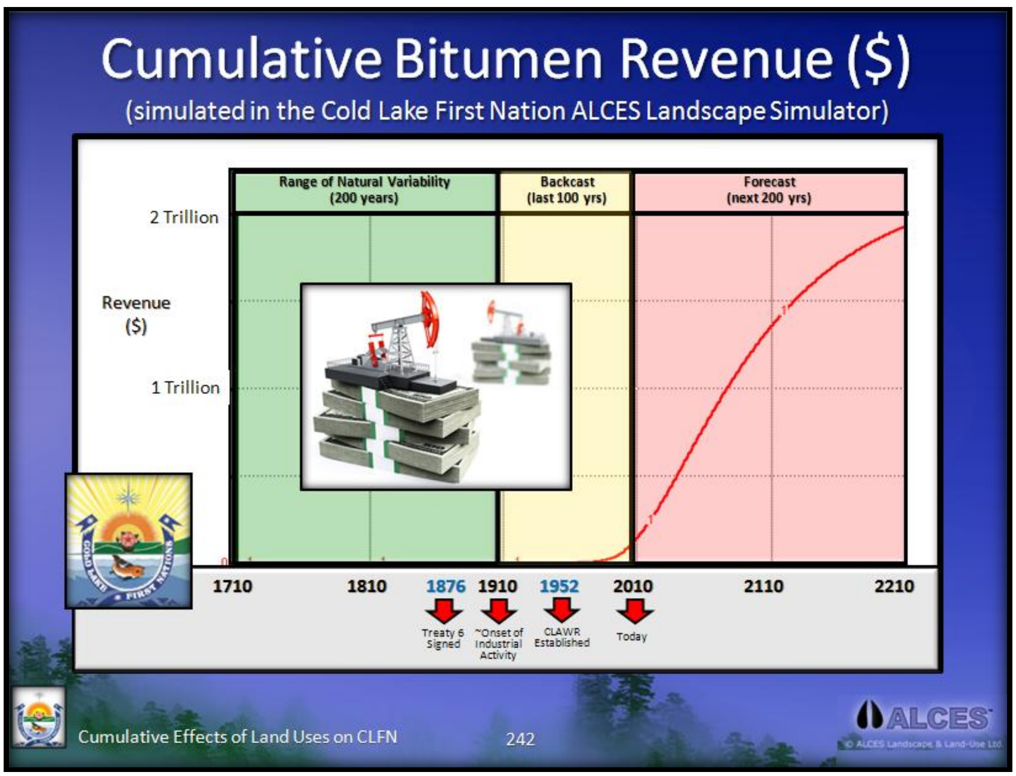


Figure 137. Cumulative bitumen revenues in CLFN SA.

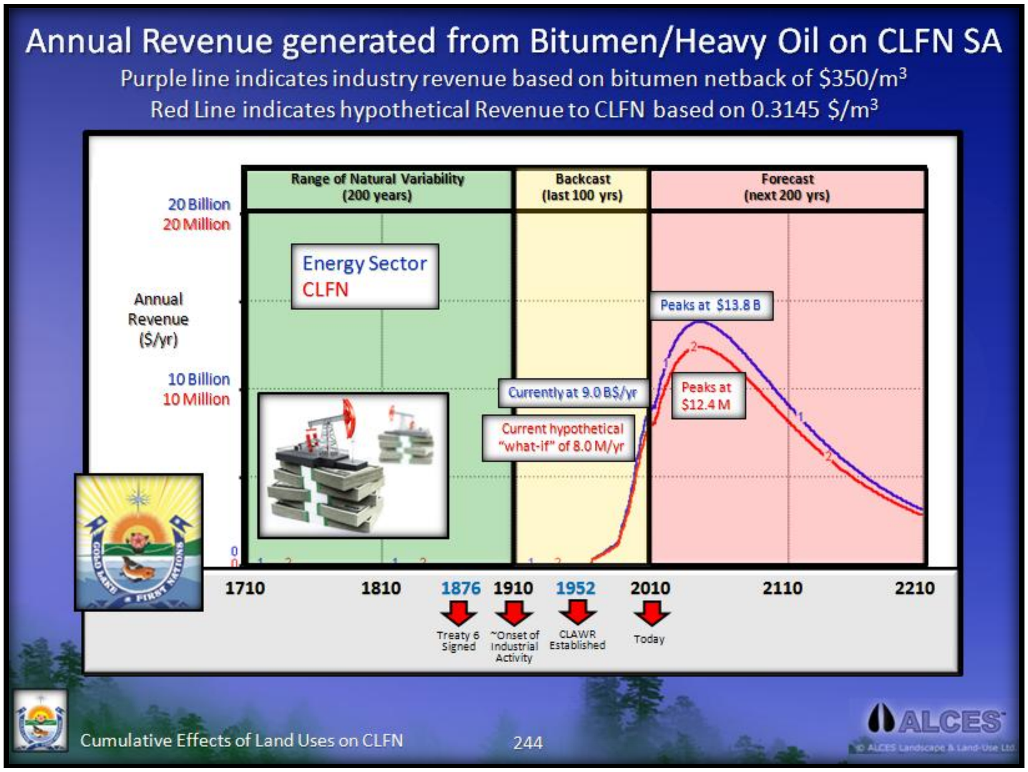


Figure 138. Changes in annual bitumen revenues in CLFN SA using a scenario exploring revenue sharing with CLFN.

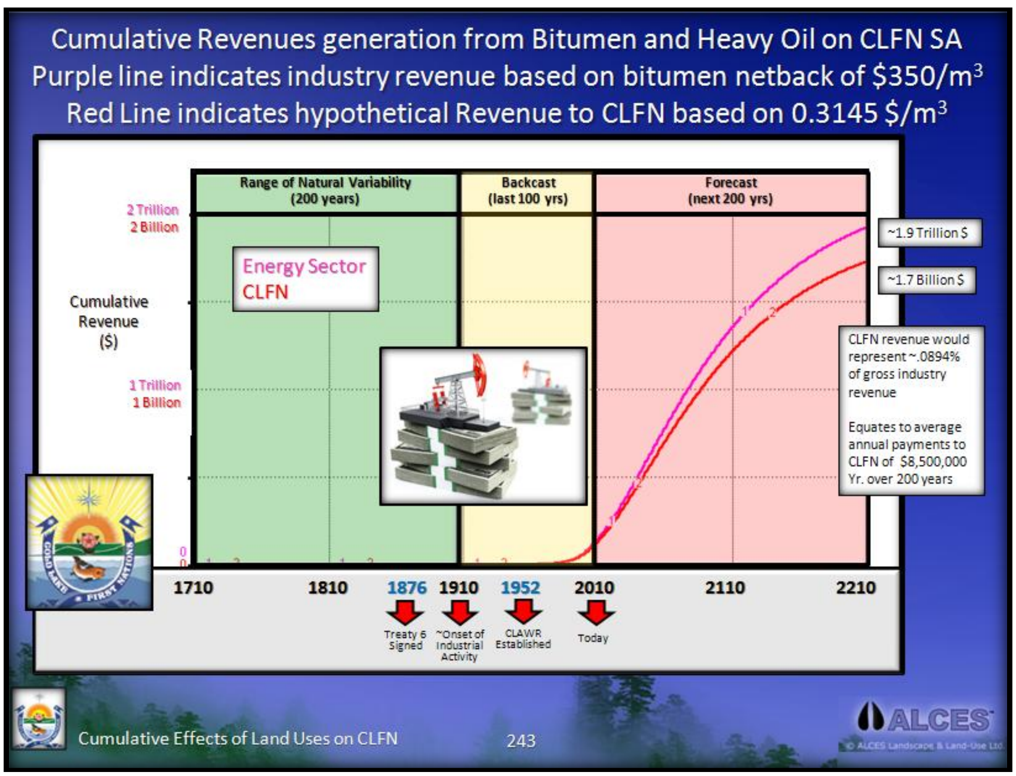


Figure 139. Changes in cumulative bitumen revenues in CLFN SA using a scenario exploring revenue sharing with CLFN.

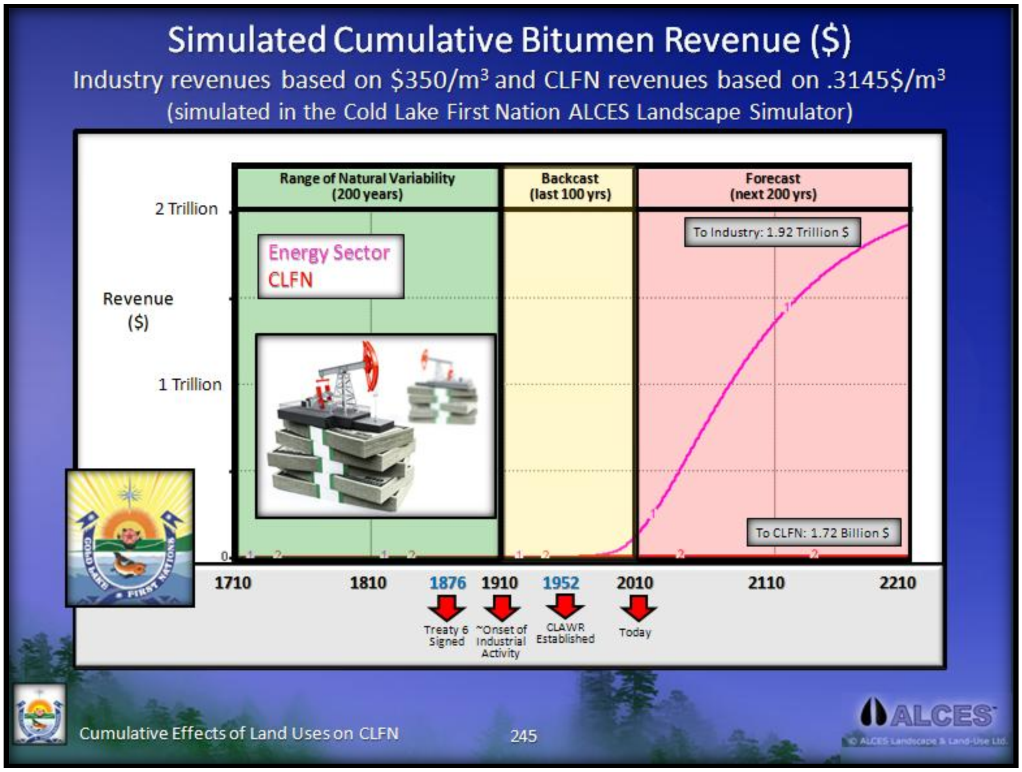


Figure 140. Changes in cumulative bitumen revenues in CLFN SA using a scenario exploring revenue sharing with CLFN. Revenues for both industry and CLFN are expressed at identical scale to emphasize relative differences in revenue.

9.2.3 Employment

Based on a key assumption that historical and future employment coefficients are set at constant 2012 values (0.0008 FTE/m^3 of produced bitumen (CEMA SEWG), employment related to bitumen is currently ~20,000 jobs (Figure 141). Employment is expected to increase for 30-40 years where it will achieve maximum levels of ~32,000. Beyond Yr 40 (2050), bitumen-related employment levels are forecast to decline incrementally with each passing decade. The cumulative number of full-time job-years historically associated with bitumen production on CLFN SA is 390,000 (Figure 142). By the end of the simulation period (2212), the cumulative employment relating to the production of 5 B m^3 of bitumen and heavy oil is 4,500,000 full-time job-years (Figure 142). The simulation makes the simplifying assumption that the ratio of full time employment (FTE) to 1 m^3 of bitumen production is a constant through time.

It is clear that the hydrocarbon sector in the CLFN SA is a key driver of both revenues and employment. This stature is unlikely to change in upcoming decades.

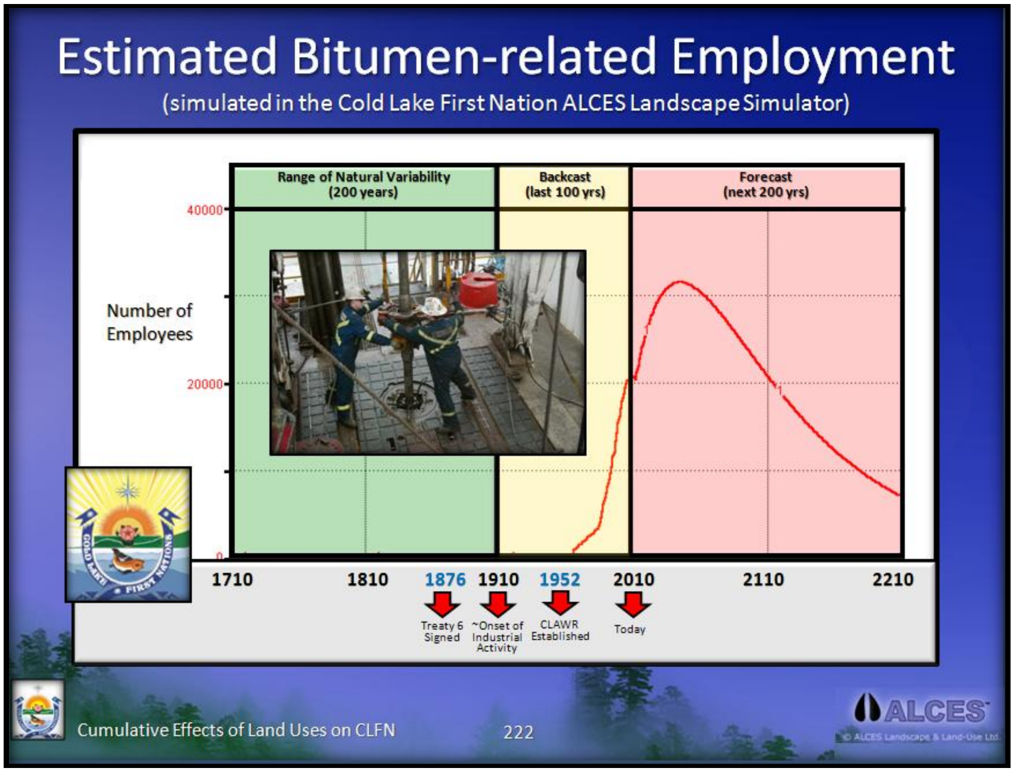


Figure 141. Changes in bitumen-related employment in CLFN SA.

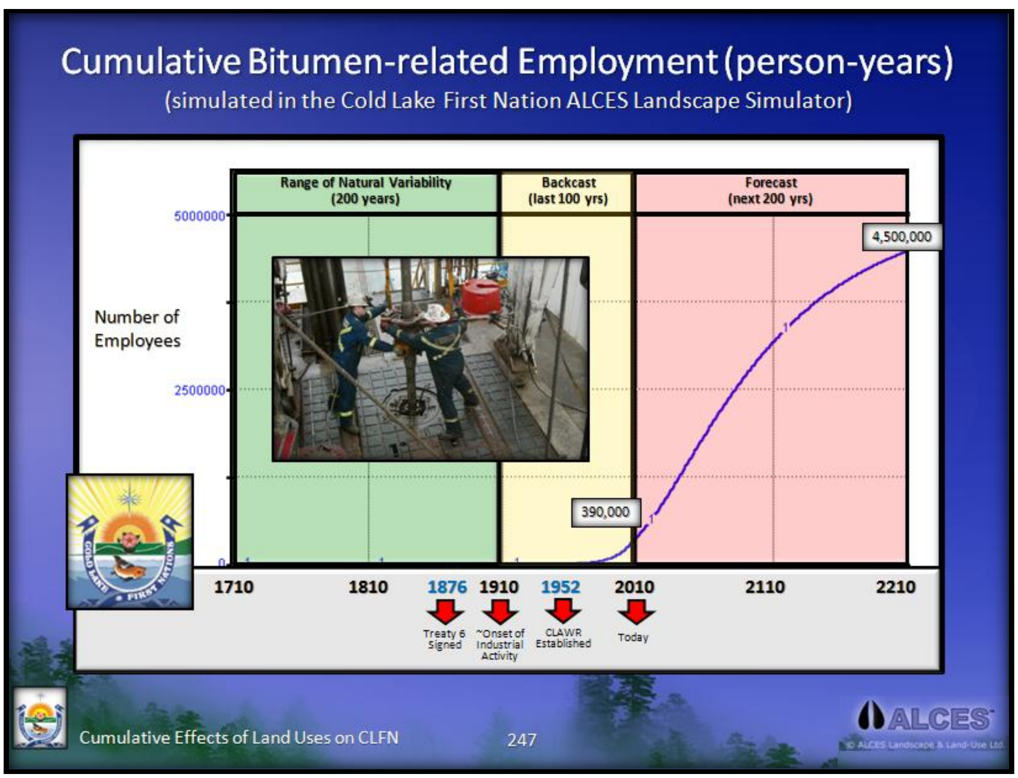


Figure 142. Cumulative number of job-years relating to bitumen production in CLFN SA.

9.3 LANDSCAPE METRICS AND ECOLOGICAL INDICATORS

9.3.1 Landscape Composition

The natural capital of Canada's boreal forest is immense (Anielski and Wilson, 2009) and the dynamic composition and fragmentation of these landscapes is a key factor explaining the diversity and abundance of biodiversity (Stelfox et al. 1995). The effects of land-use can be direct (for example, conversion of forest to crops), or indirect, such as the reduced use (or increased mortality of wildlife) of wildlife habitat adjacent to linear features such as roads or pipelines.

Human-caused linear features are a defining landscape driver for many biodiversity indicators. This is largely due to the increased direct and indirect disturbance caused by humans, plants, and animals that move, or expand along, the linear network (Figure 104). In some cases linear features can improve habitat for species such as moose, by providing access to younger plant communities and increased forage. This positive effect can be over-ridden by increased mortality from motorists, hunters, fishers, trappers, and animal predators. Vehicle-wildlife collisions, intentional and unintentional disturbance or harassment, harvest, avoidance of habitat along linear features, and changes in predator-prey dynamics all contribute to the cumulative effects of linear features on wildlife in the CLFN SA.

Roads, other linear corridors, and polygonal features are widespread features of most landscapes and are associated with negative effects on both terrestrial and aquatic ecosystem function (Trombulak and Frissell 2000). Access corridor density is considered to be the most useful landscape indicator because it integrates so many ecological impacts of roads, human use, and vehicles (Forman and Hersperger 1996, Trombulak and Frissell 2000, Forman et al. 2003). Based on these arguments, we present linear edge density (km/km^2) as a reasonable metric to discuss landscape fragmentation and issues relating to access.

Relationships between land-use feature density and species occurrence, habitat effectiveness, or population persistence have been developed for grizzly bear, birds, and boreal mammals (Thomas et al. 1979 and 1988, Lyon 1983 and 1984, McLellan and Shackleton 1988, Mace and Manley 1993, Reijnen and Foppen 1994, Jalkotzy et al. 1997, Anderson et al. 2002, Bayne et al. 2005a, b; Nielsen et al. 2007). In addition, increased road density also causes increased water yield and sediment transport to streams, increased number of movement barriers, and has also been correlated with declines in salmonid species, including bull trout (Jones and Grant 1996, USDA Forest Service 1996, Warren and Pardew 1998, Trombulak and Frissell 2000).

The CLFN SA has experienced a significant transformation during the past 100 years (Figure 143, Figure 144). Greatest increase in anthropogenic features include agriculture (~113,000 ha), the energy sector (~21,000 ha), settlements (~10,000 ha), transportation (~8,000 ha), and parks (6,463 ha). In terms of loss of landbase on which traditional activities of CLFN can occur, the establishment of the 470,000 ha CLAWR in 1952, was the most significant event.

By the conclusion of the simulation period (2212) a total of ~600,000 ha will have been directly altered by the land-uses of agriculture, transportation, residential and the energy sector (Figure 145). Of this gross area, ~300,000 ha are projected to be reclaimed and these reclaimed features include unused wellpads, wellpad access roads, seismic lines, and pipelines. If the rapid reclamation rates of energy sector footprints do not occur and inactive footprints do not revert back to the original landscape type (see for example, Figure 146), then the net footprint of 300,000 ha could be as large as the gross footprint of 600,000 ha.

To illustrate the critical importance of reclamation rates of energy sector footprints to the overall level of future landscape fragmentation and anthropogenic area, an additional set of simulations were completed in ALCES and ALCES Mapper (Figure 154, Figure 155, Figure 156, Figure 157).

It should be noted that we selected an average area-weighted seismic line width of 2.0 meters for this study despite guidance from Birchwood Resources that average seismic width in the region is closer to 4 m. Since seismic line lifespan is related to seismic line width (we have estimated that 2 m width seismic lines reclaim in 2 years), and seismic lines are the most prevalent linear feature on the landscape, it is very likely that the net linear footprint in these analyses is under-estimated based on highly optimistic rates of linear feature reclamation in the CLFN SA.

The spatial distribution of historical changes in anthropogenic area and edge are illustrated in Figure 150 and Figure 152, respectively. Highest levels of land-use area historically are concentrated in the southern portions of CLFN SA and are associated with cultivation and residential footprints. Highest concentration of land-use edge (km/km^2) are associated with the linear features of transportation and the hydrocarbon sector and are concentrated in the region south of CLAWR but north of the White Area, but also in the south central portions of CLAWR where current bitumen and heavy oil activity is highest.

Simulation results of the CLFN ALCES model indicate that future changes (next 200 years) to CLFN SA will equal or exceed any of the historical land-use changes that occurred during the past century (Figure 151 and Figure 153).

The mapping of future anthropogenic area and edge tells a complex story. The crop sector continues to expand in the White Area, albeit at a slower rate, until Class 4 soils are no longer available. The footprint associated with residential (towns and acreages) continues to expand in the White Area at a pace concomitant with expanding regional human populations. The anthropogenic footprint area associated with the energy sector continues to expand for the next several decades, then gradually declines when rates of reclamation exceed rate of new seismic lines, wellsites, pipelines and processing plants. The reader is again cautioned that our energy sector reclamation rates are highly optimistic and assume, for example, that all wellsites are reclaimed immediately after their productive life is completed. The total amount of footprint area, however, does not decline throughout the simulation, as the rate of reclamation of transient features (energy sector) never exceeds the rate at which permanent features (crops, major roads, settlements) expand.

The mapping of future anthropogenic edge (km/km^2) reveals a different temporal pattern. The majority of current and future footprint edge is associated with the hydrocarbon sector. These features (seismic lines, wellsites, access roads, pipelines) are given a defined lifespan and at the end of their functional lifespan (Figure 128) begin to reclaim.

In terms of net footprint edge (km/km2), average landscape edge densities peak at ~4 km/km^2 at year 2040 and then begin to incrementally decline. It is important to recognize that there will be significant spatial variation in these densities.

A most startling observation is that gross edge density would be in the order of ~24 km/km^2, much of which would be caused by the dense network of 2-D and 3-D seismic lines that traverse the landscape and delineate the spatial dimensions of underlying reserves. Other features which contribute significantly to overall edge density include pipelines, access roads to wellpads, and access roads to rural residential. Examples of the land-use edge density associated with extraction of heavy oil and bitumen from CLFN SA are shown in Figure 148 and Figure 149. It is reasonable to expect that the energy sector may be able to rely on future seismic line technology that is less dense than observed today. If so, then these very high future densities may not be achieved. This possible trend is one reason why the ALCES Group chose to attribute seismic lines with a very short lifespan of 2 years.

Mapping at quarter-township scales indicate that some of these grid cells achieve net linear edge densities that exceed 10 km/km^2. This may seem unrealistic to some, but as a reference point a 3-D seismic grid with 100 m spacing would generate a linear edge density of 20 km/km^2.

From a simulation perspective in the CLFN ALCES model, all seismic lines and pipelines that are constructed over agricultural fields experience reclamation within 1 year of construction.

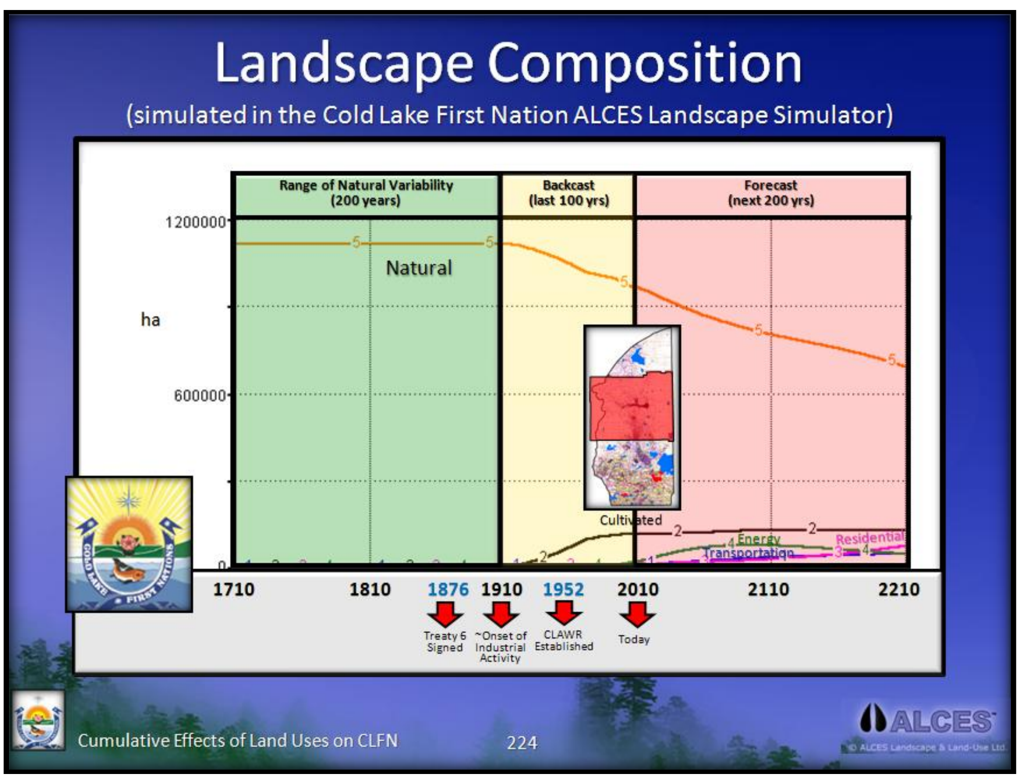


Figure 143. Changes in landscape and land-use classes in CLFN SA.

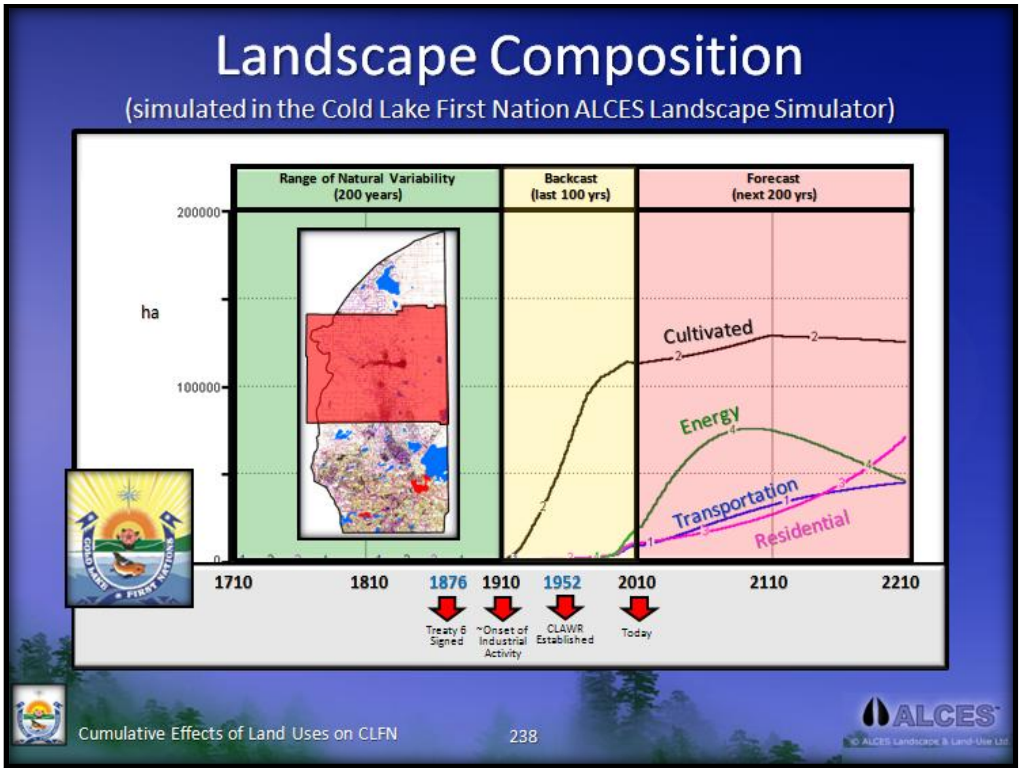


Figure 144. Changes in land-use classes in CLFN SA.

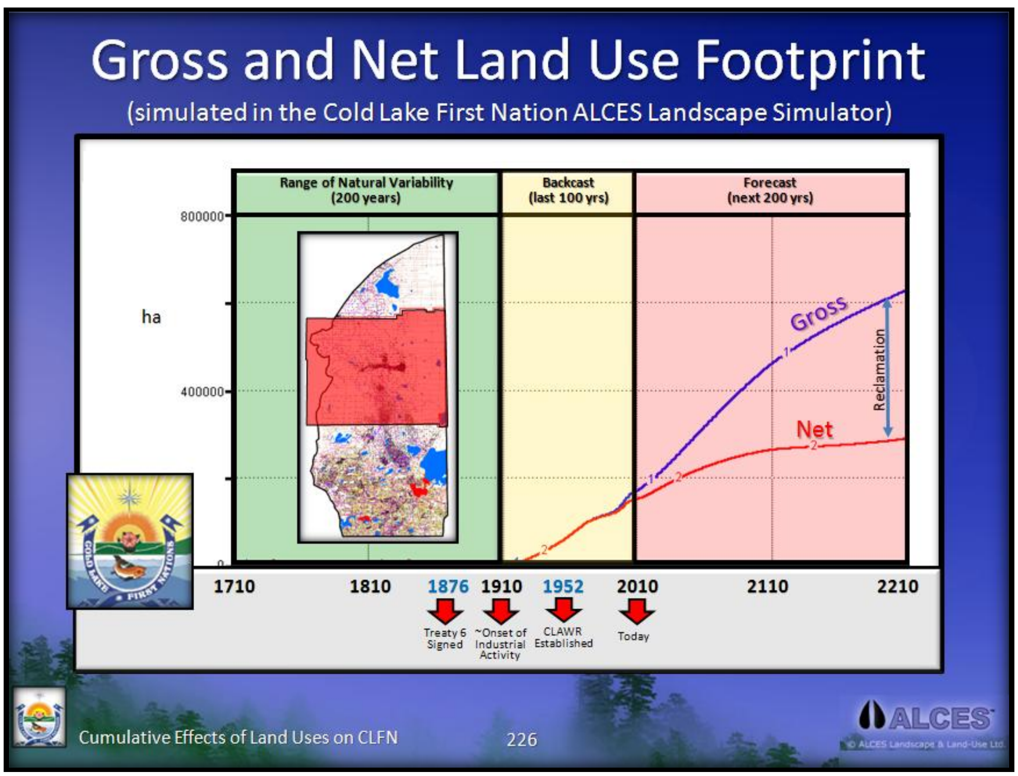


Figure 145. Historical, current and future changes in gross and net land-use class area in CLFN SA.

Figure 146. An example of a "reclaimed" industrial site on CLFN SA. Establishment of vegetative cover does not necessarily imply that natural plant community succession will occur.

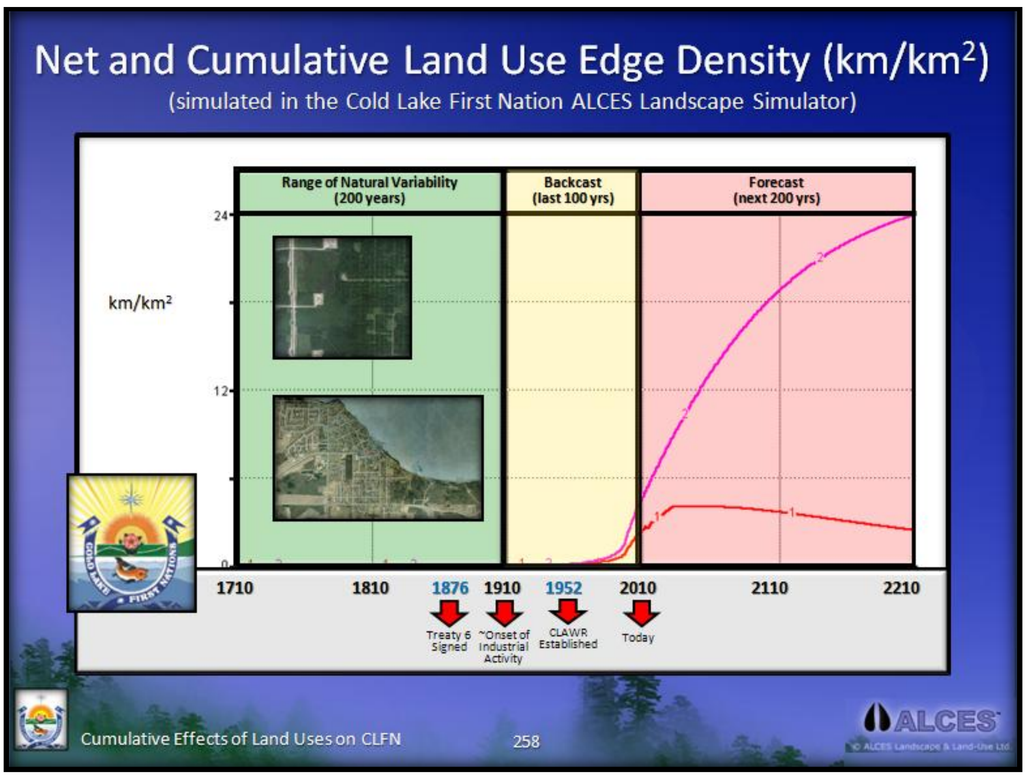


Figure 147. Changes in net land-use footprint edge (km/km^2) in CLFN SA. Edge includes the boundaries of all footprint types from each land-uses of energy, agriculture, transportation, and settlements.

Figure 148. Example of edge density created by footprints associate with the extraction of bitumen and heavy oil in CLFN SA. Source: Google Earth.

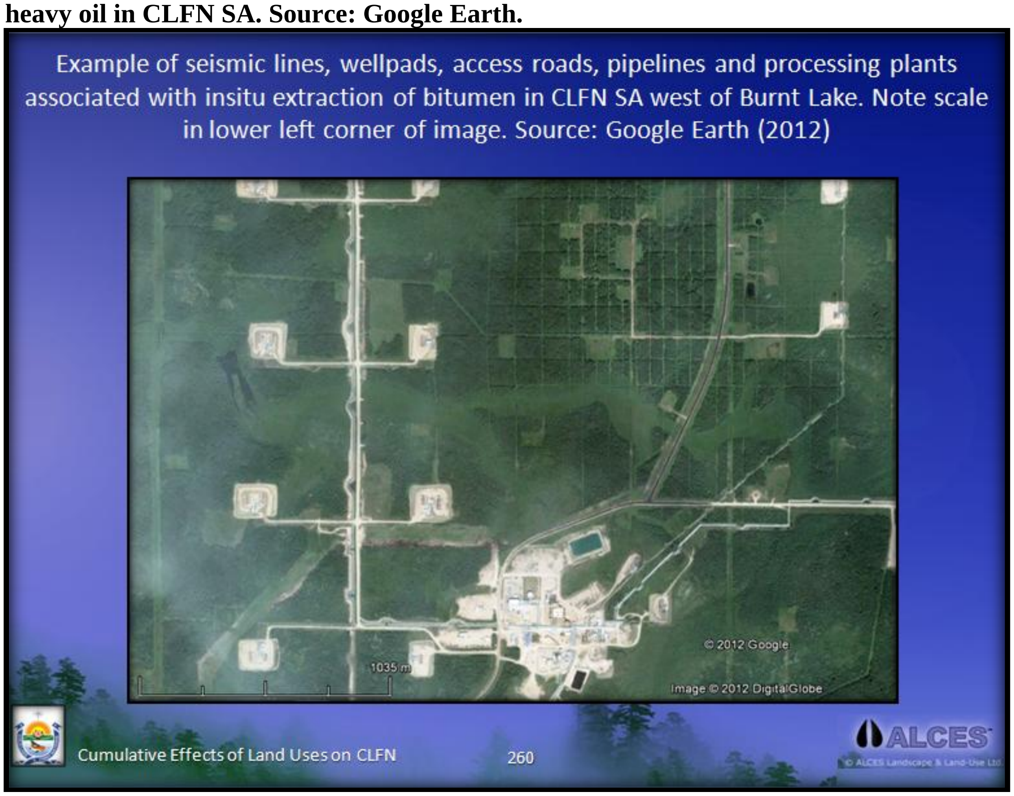


Figure 149. Example of edge density created by footprints associate with the extraction of bitumen and heavy oil in CLFN SA. Source: Google Earth.

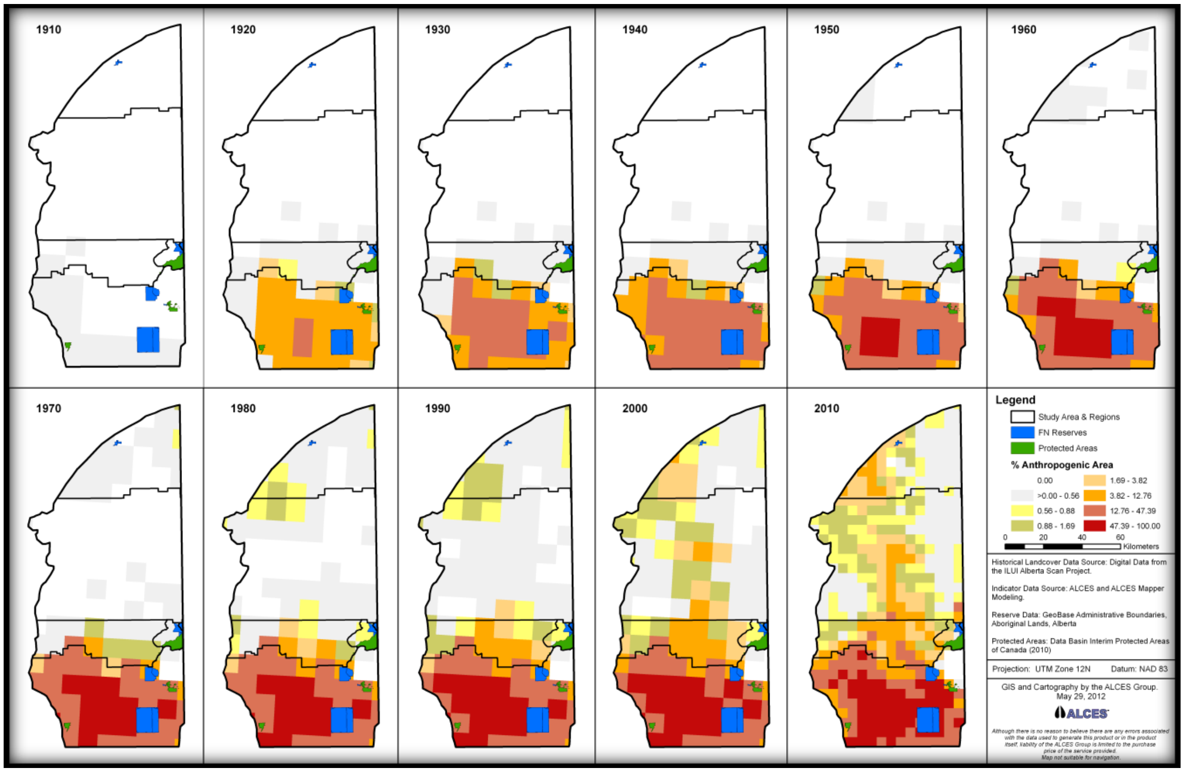


Figure 150. Historical change in anthropogenic area (%) on CLFN SA.

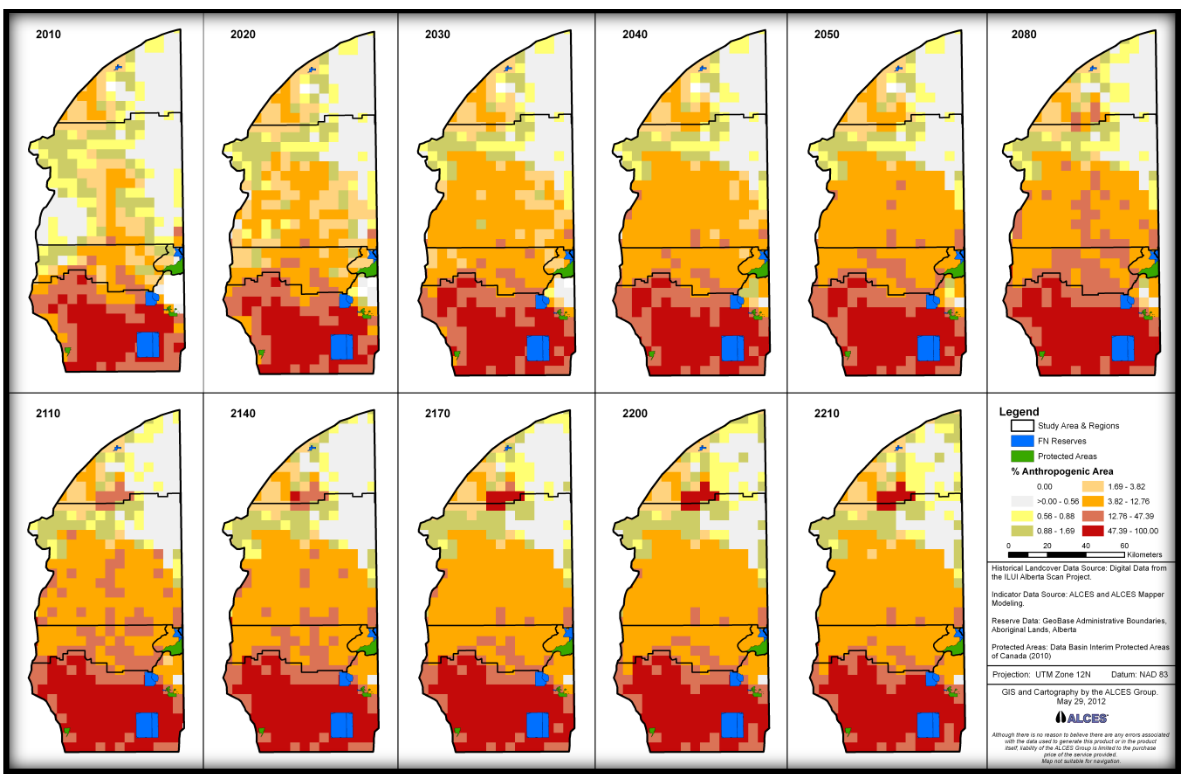


Figure 151. Future change in anthropogenic area (%) of CLFN SA.

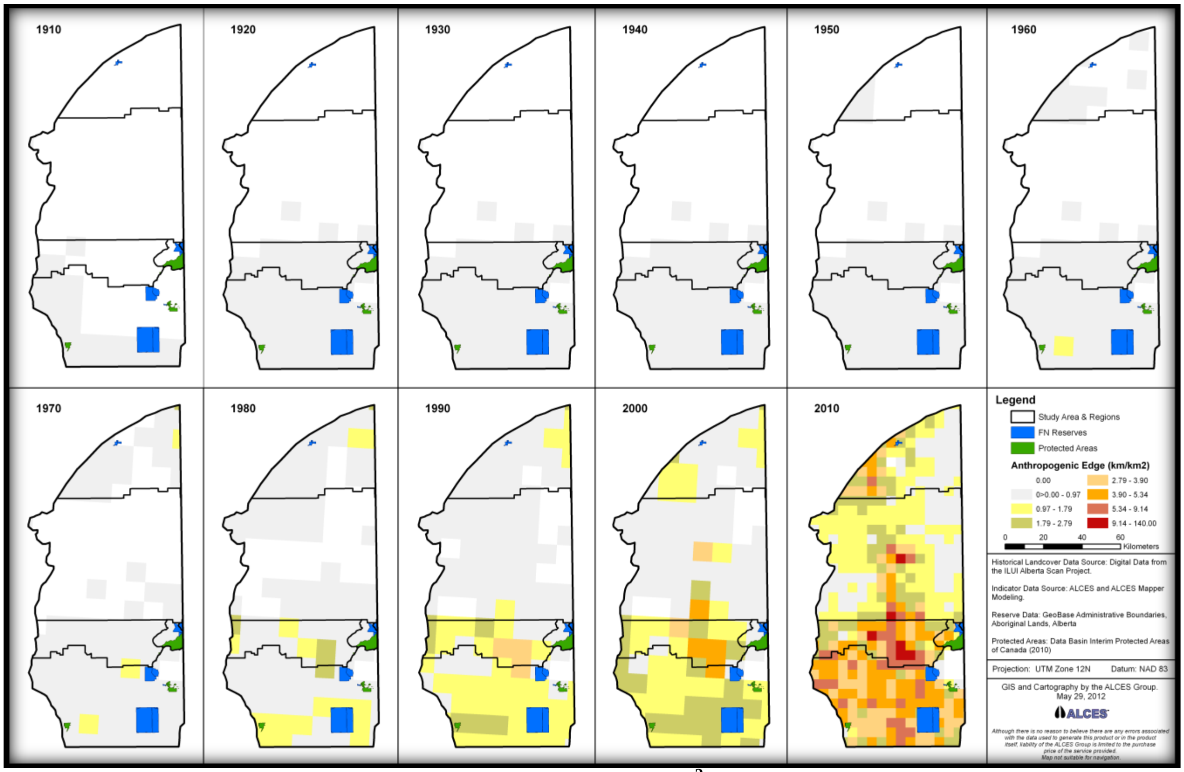


Figure 152. Historical change in anthropogenic edge (km/km^2) on CLFN SA.

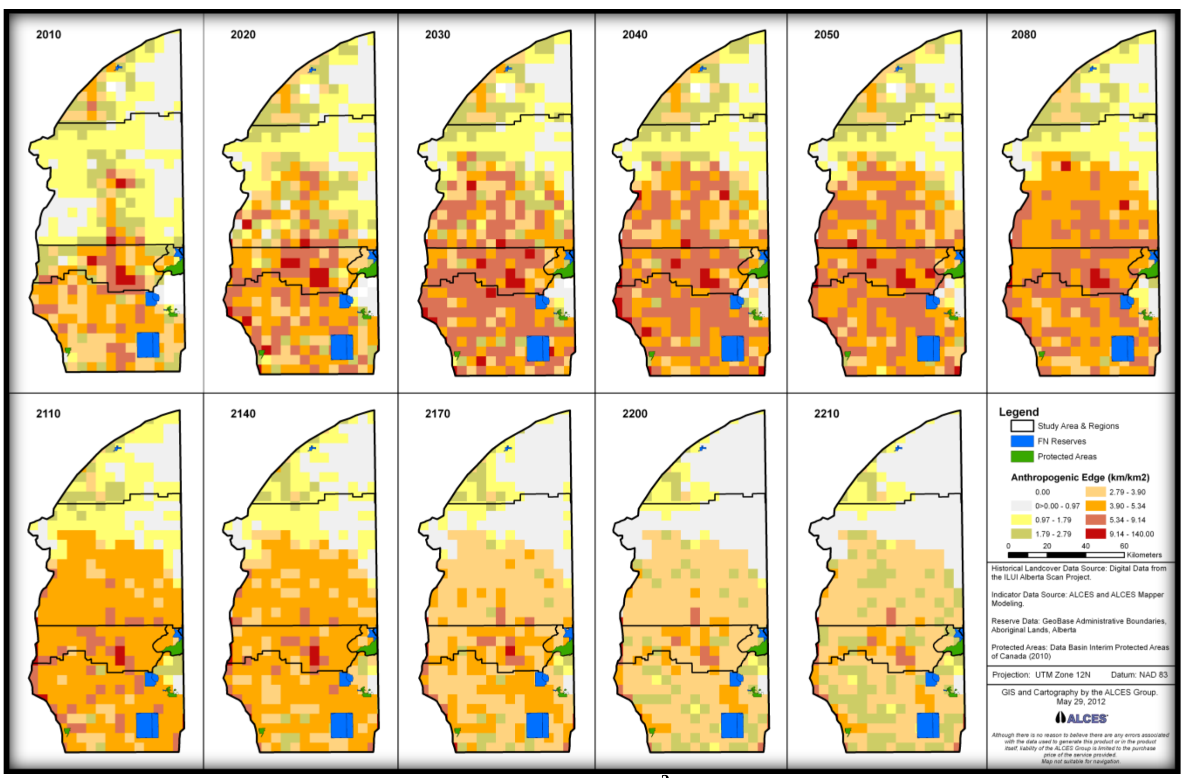


Figure 153. Future change in anthropogenic edge (km/km^2) on CLFN SA.

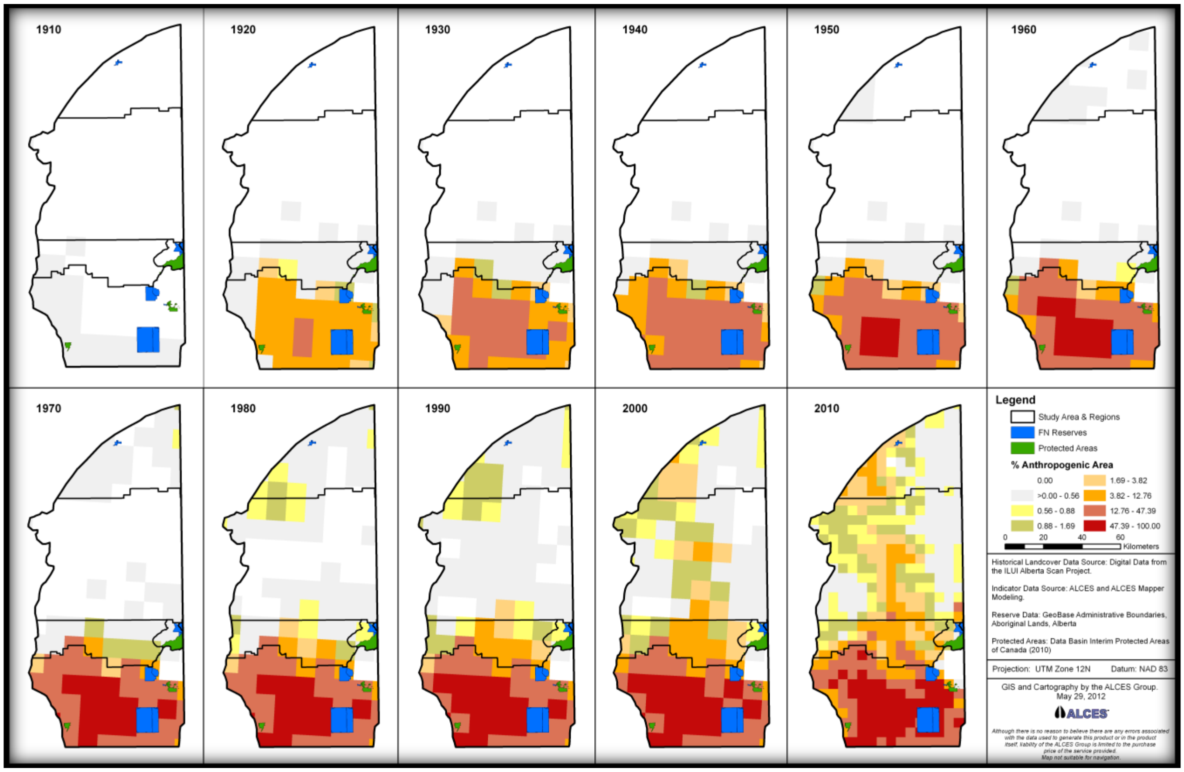


Figure 154. Historical change in footprint area (%) in CLFN SA with reclamation rates set at 0.

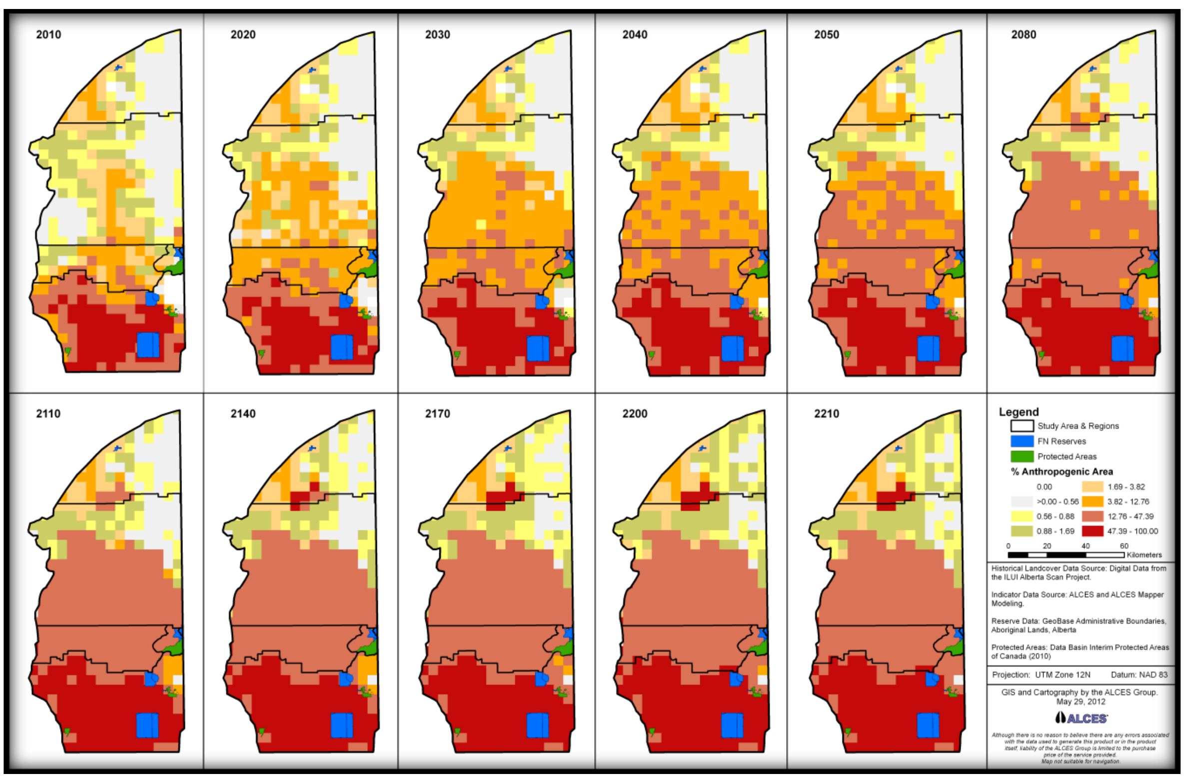


Figure 155. Simulated future change in land-use footprint area (%) in CLFN SA if reclamation rates are set at 0.

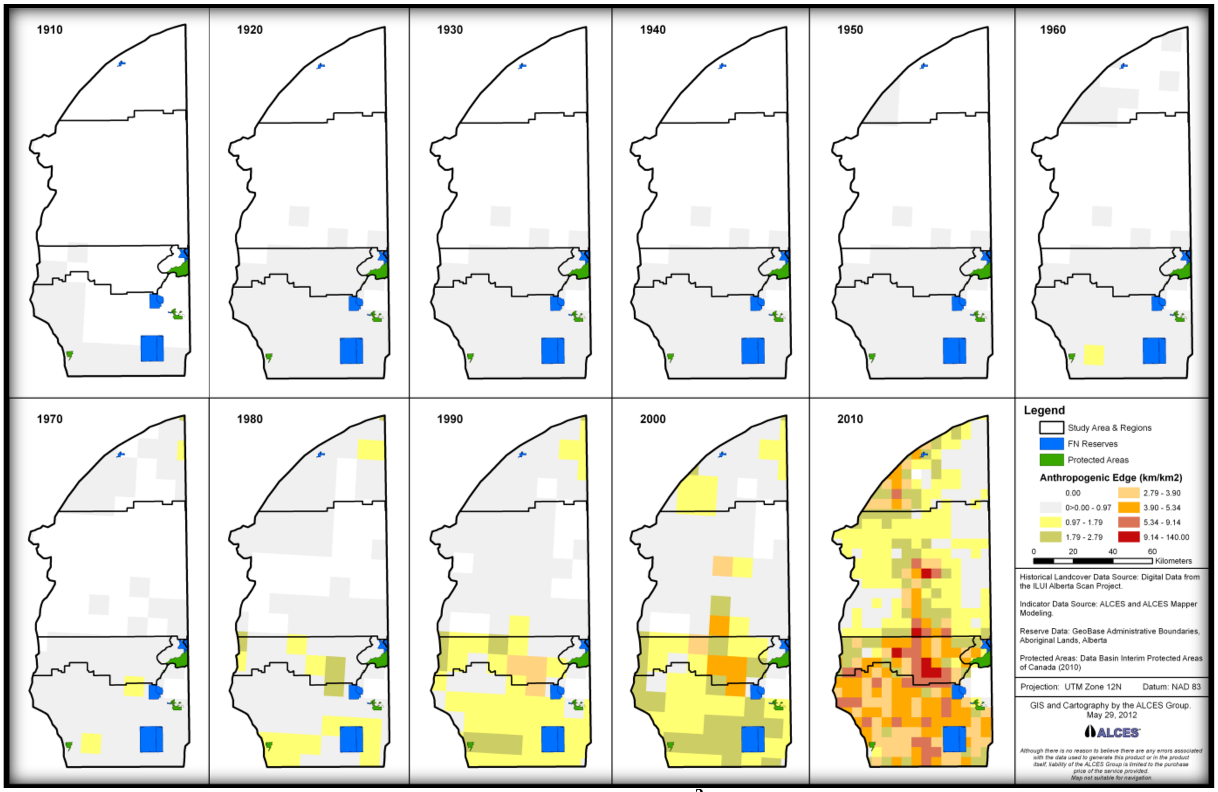


Figure 156. Historical change in anthropogenic edge (km/km^2) in CLFN SA without reclamation.

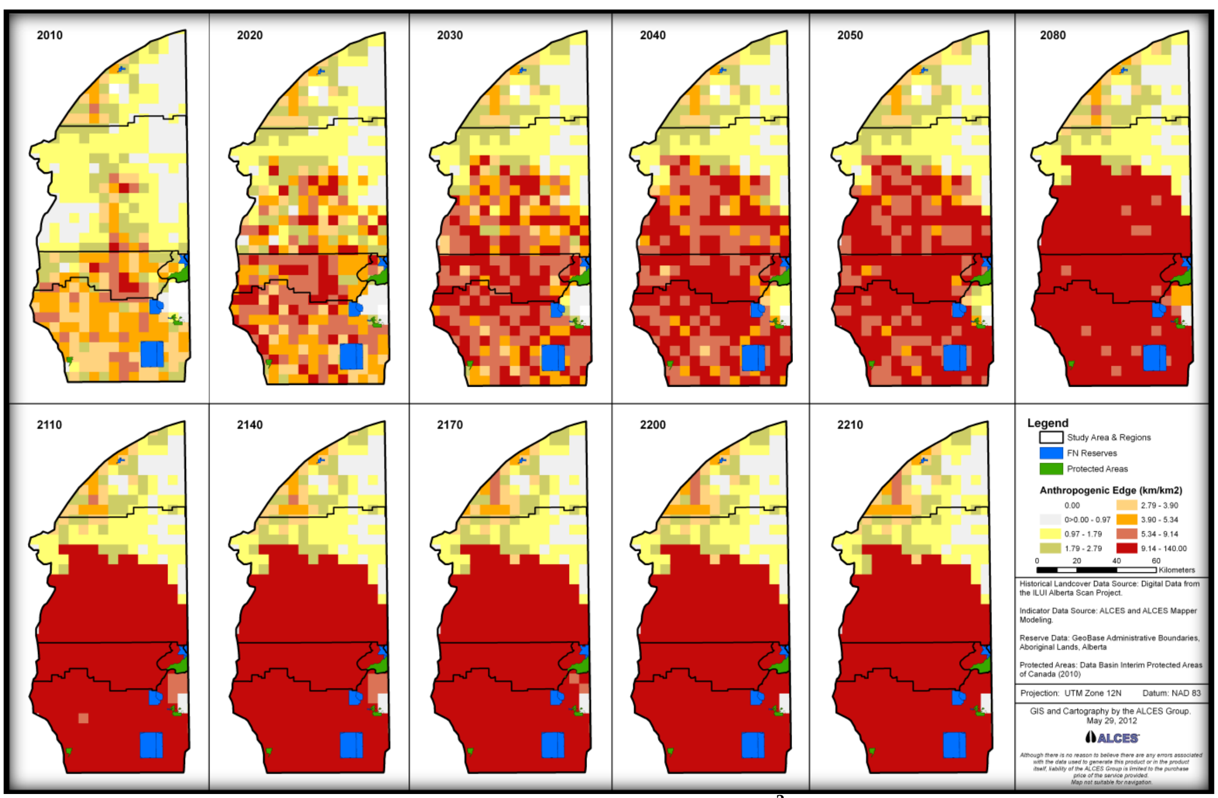


Figure 157. Simulated future change in anthropogenic edge (km/km^2) in CLFN SA without reclamation.

9.3.2 Water Quality

The index of water quality used in these analyses is based on change in the runoff rates of nitrogen, phosphorus and sediment relative to RNV (range of natural variability) levels. Since the water quality index represents an inverse reciprocal of nutrient and sediment loading, lower values reflect increasing levels of nutrient loading. This methodology for computing relative water quality index is the same one adopted by the Cumulative Environmental Management Association (CEMA) and the Alberta Land-use Framework when using the ALCES simulator.

All boreal landscapes have natural runoff of N, P, and sediment, and indeed these elements are required to maintain ecological function of terrestrial and aquatic ecosystems. That said, excessive runoff rates associated with a suite of land-uses (Figure 158) can have a significant and adverse effect on ecosystems through the process of eutrophication and by altering the structure of lentic and lotic substrates.

Simulation results of CLFN SA indicate a significant decline in the relative index of water quality during the past 100 years (Figure 159). The greatest historical contributor to increased loading is the nutrient and sediment runoff associated with croplands (Figure 160). To a lesser degree, increasing loading in the non-agricultural regions were associated with energy sector footprints (seismic lines, wellsites, pipelines, processing plants) and the transportation networks that lead to wellpads and rural residential.

The water quality of CLFN SA is projected to worsen in upcoming decades (Figure 161). This degrading pattern will be caused by multiple factors that include:

1. Increasing energy sector footprint (seismic lines, wellpads, pipelines, processing plants) that have elevated levels of N, P, and sediment runoff.

2. Continued expansion of the cropland matrix in the White Area on remaining soils of agricultural potential.

3. An expanding rural residential network that includes roads and yards.

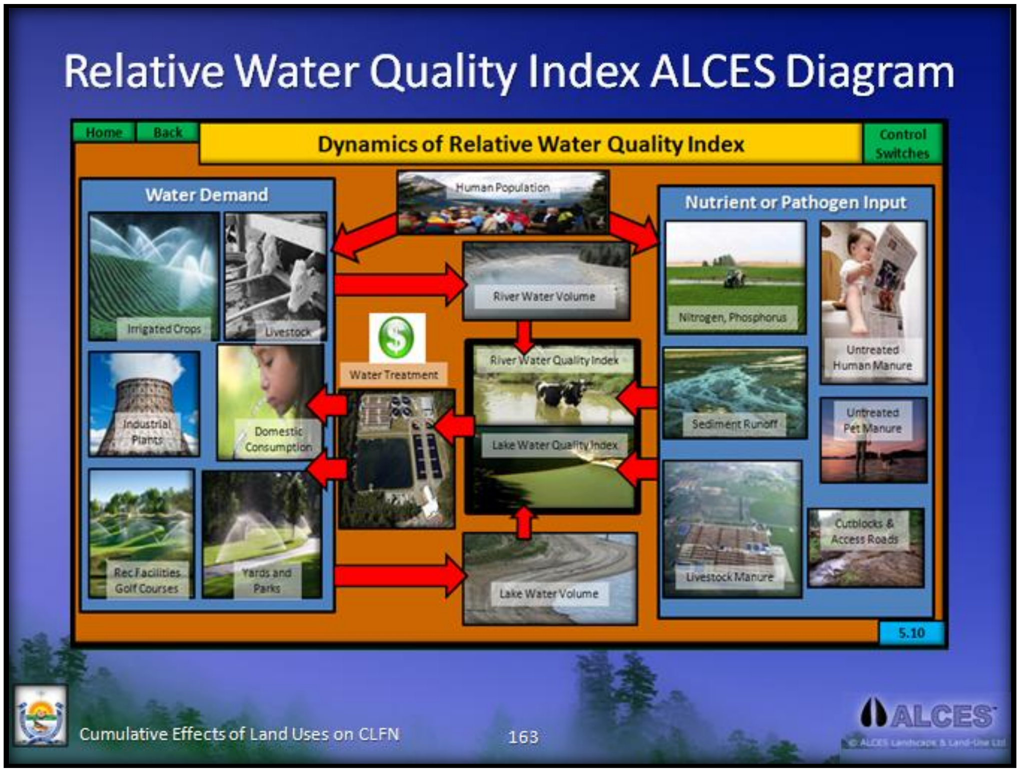


Figure 158. Diagram of relative water quality index used in the CLFN ALCES model.

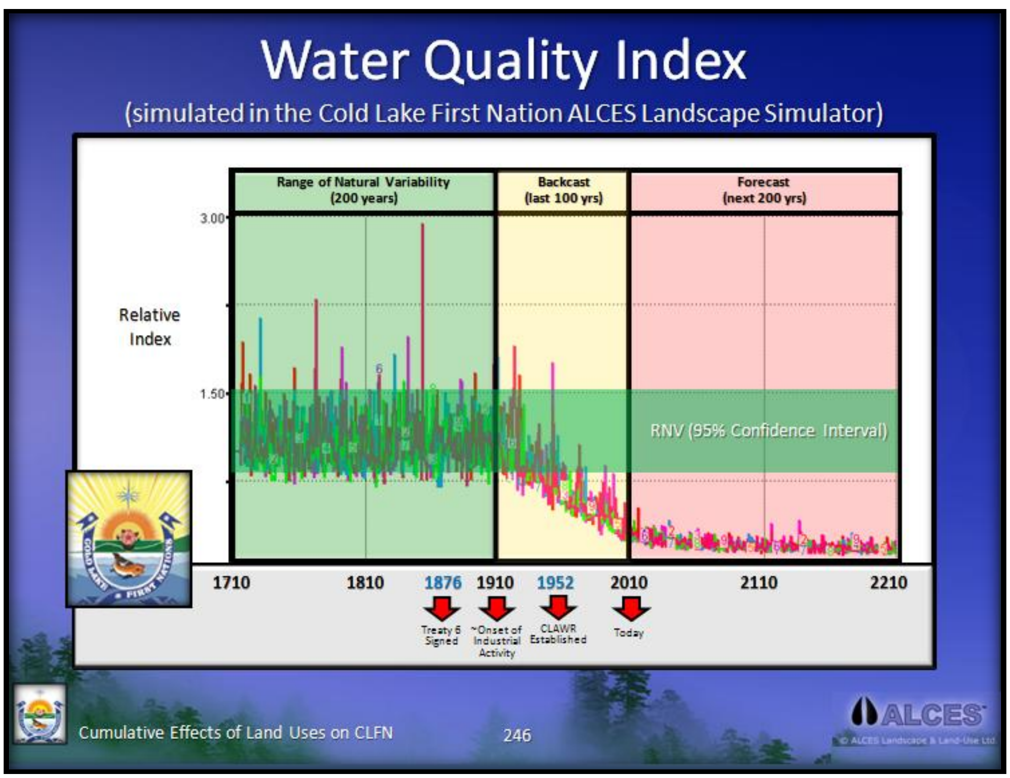


Figure 159. Historical, current and future changes in relative water quality in CLFN SA.

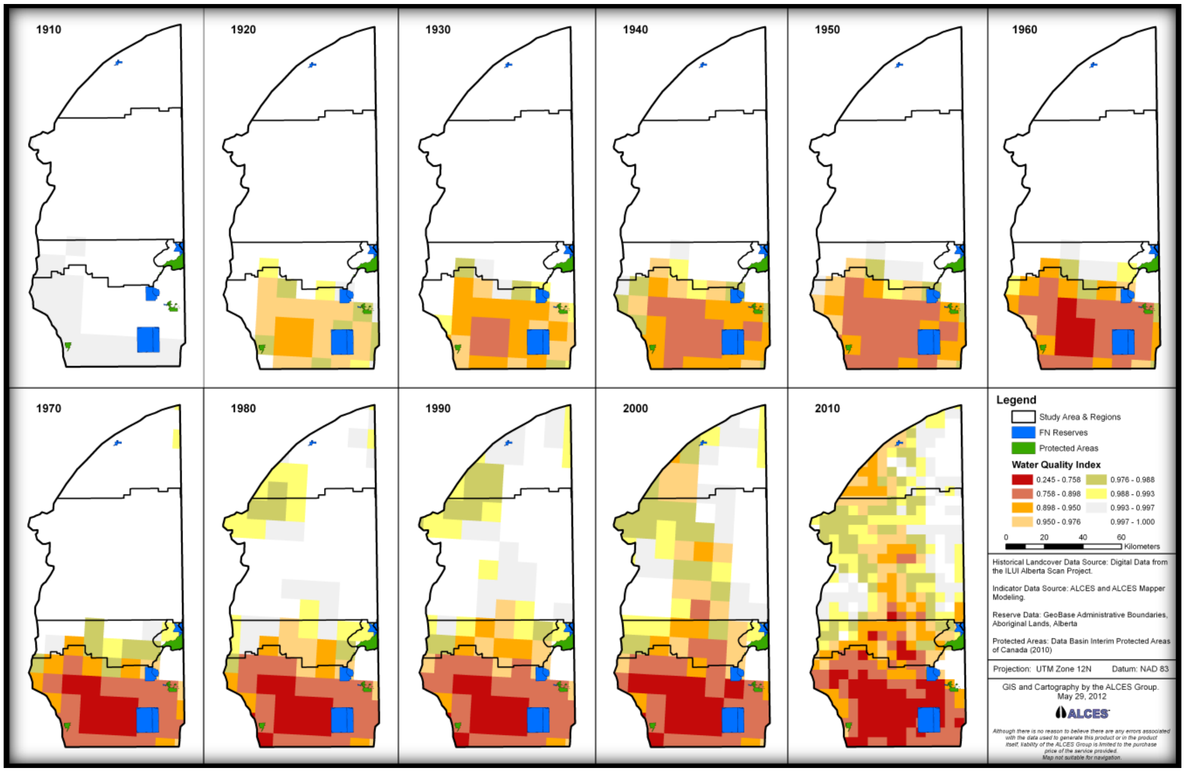


Figure 160. Historical changes in relative water quality index in CLFN SA.

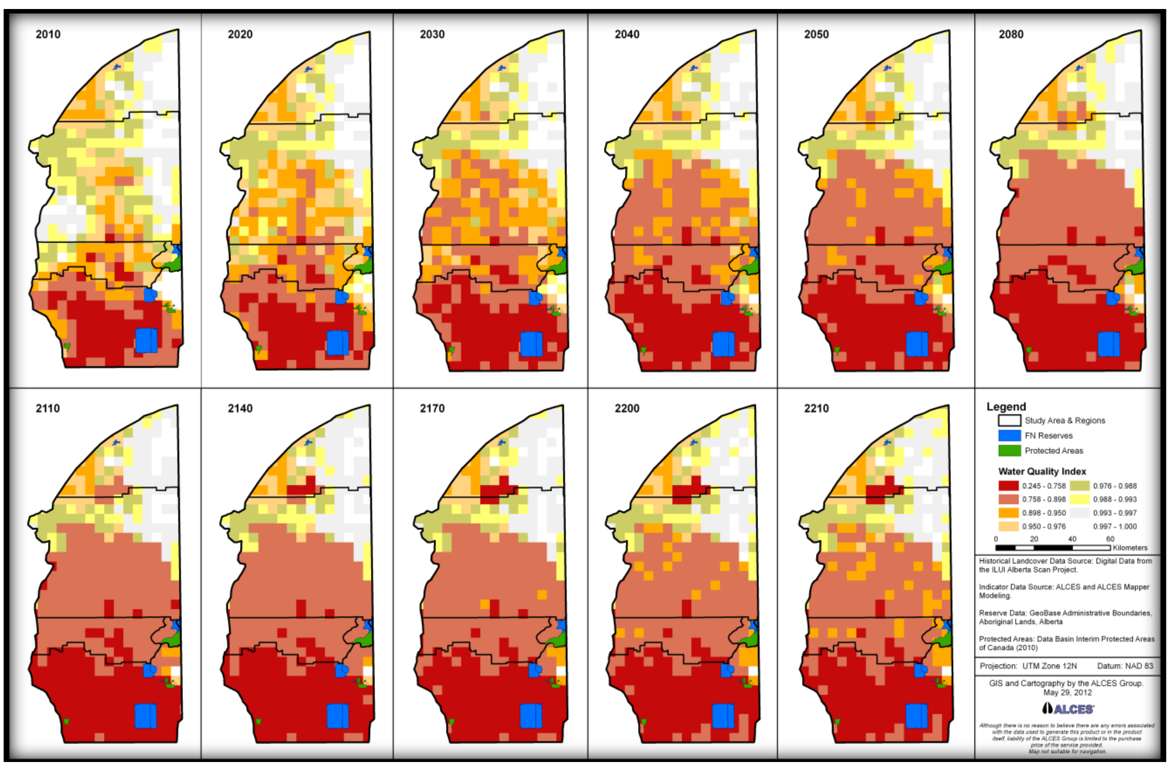


Figure 161. Simulated future changes in future relative water quality index in CLFN SA.

9.3.3 Forest Demography

Forest age is an important element of forest ecosystems and one that explains considerable spatial and temporal variation in the abundance and distribution of many species of biota that prefer (or avoid) old forests.

The average age of forests in CLFN SA has a natural variance of 45-105 years (Figure 162), a variation that is caused by the episodic nature of large fire events (Figure 14). Average forest age is projected to become moderately younger during the next 100 years, and this shift is caused by the significant amount of young forest created by reclaiming energy sector footprint .

The fraction of the forested portion of CLFN SA that is old (>100 years since last disturbance event) generally ranges from ~15% to 45% (Figure 163) and is highly variable through time. This inter-annual variation is also caused by the episodic nature of the fire regime. The simulated results do not indicate a reduction in the average fraction of the forest landscape that is old, as the fire disturbance regime is not projected to change, and there is no significant level of logging occurring on the study area.

The analyses of forest demography in CLFN SA are different than results reported in projects such as CEMA SEWG, where average forest age and contributions of old forests are projected to decline significantly. The major reason for this discrepancy is the absence of commercial forestry in CLFN SA, and hence the absence of additive disturbances (fire and logging) that collectively shape forest age class structure.

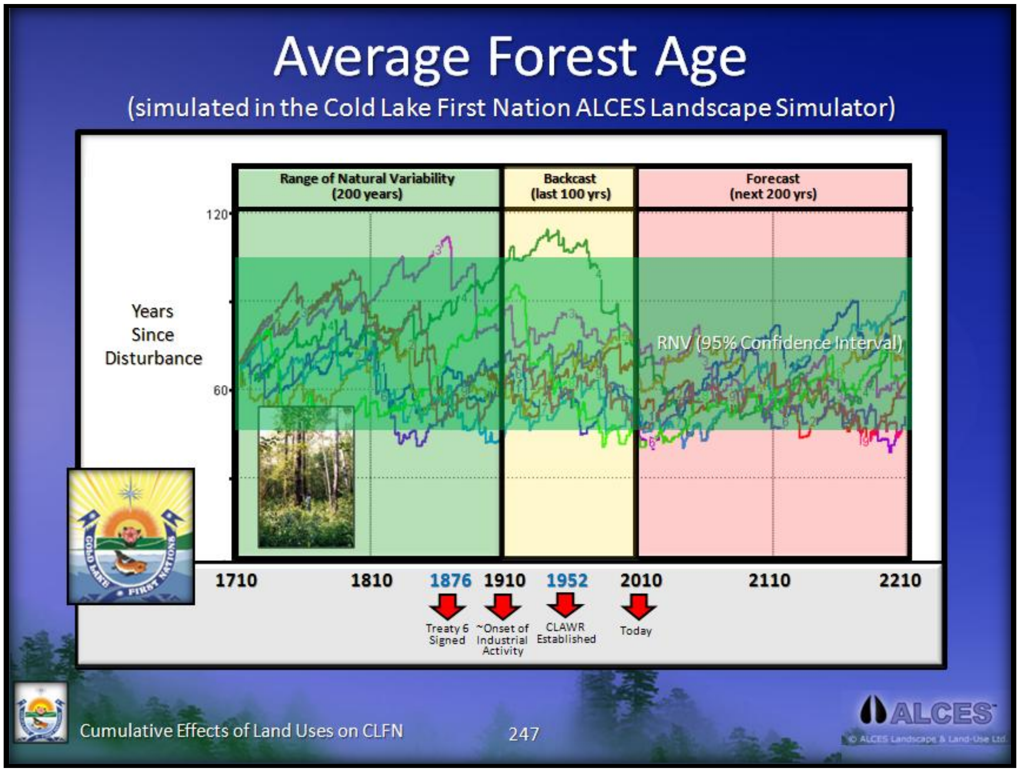


Figure 162. Average forest age in CLFN SA.

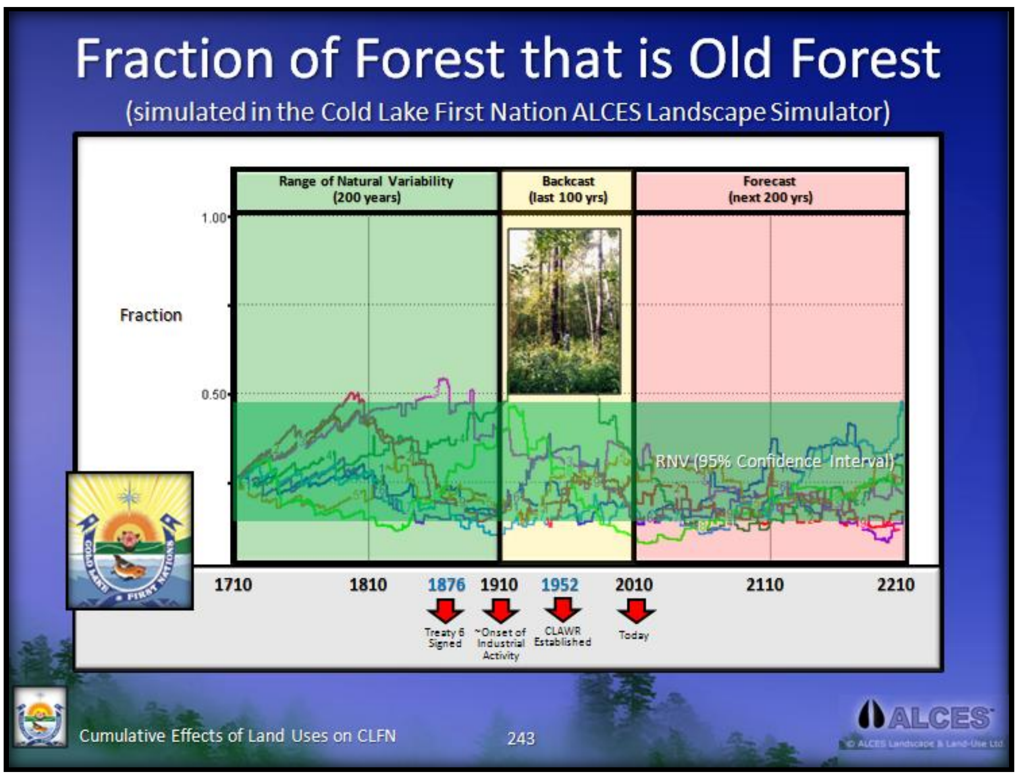


Figure 163. Simulated changes in average forest age on CLFN SA.

9.3.4 Moose Habitat Effectiveness

Moose habitat effectiveness index in CLFN SA varied in the RNV era between 0.35 and 0.5, indicating that not all landscape types are of maximum value or remain in an optimal age class structure. During the past 100 years, the quality of moose habitat has declined appreciably (Figure 164), and the majority of this decline has occurred in the cultivated regions to the south and in those townships where human population and the energy sector footprint is highest. The combination of high human and edge density reflects an elevated mortality factor and a concomitant decline in habitat effectiveness.

Relative to other regions, the generally improved status of moose habitat effectiveness in CLAWR (Figure 165) is caused by the general exclusion of both hunting and firearms in this subregion. In a modeling context, the linear features within CLAWR do not carry the same habitat discount factor as similar land-use footprint in regions where hunting is not prohibited.

Moose habitat quality is projected to decline modestly in the next few decades (Figure 164, Figure 165) in regions where agriculture expands or linear features become denser. The major reason that moose habitat does not decline further toward zero in the next few decades can be explained by two observations:

1. No/minimal hunting of moose occurs in CLAWR.

2. Areas that can be hunted and have linear features are unlikely to be further discounted by the construction of new linear features, because edge density is already high and further discounting in not possible.

Results of our simulations suggest that moose population in CLFN SA would have fluctuated in RNV era between 2000-3000 individuals. Inter-annual and inter-decadal variation would have been caused by temporal variation in forest age class structure and snowpack depth, both of which would have affected food availability to moose.

Assuming that per capita moose consumption of CLFN peoples would have been similar to those rates published by Tanner et al. (2001), the annual demand for moose harvest would have been ~1600 individuals. This value is ~ twice as high as a sustainable moose harvest would be from CLFN SA.

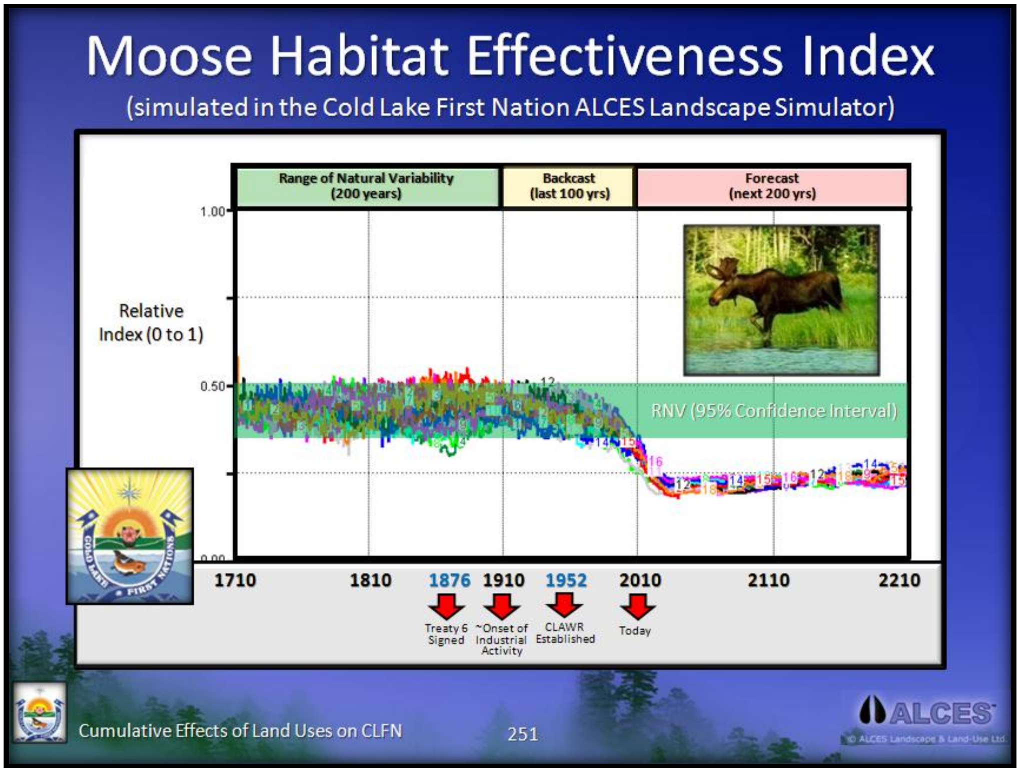


Figure 164. Historical, current and future changes in moose habitat effectiveness for CLFN SA.

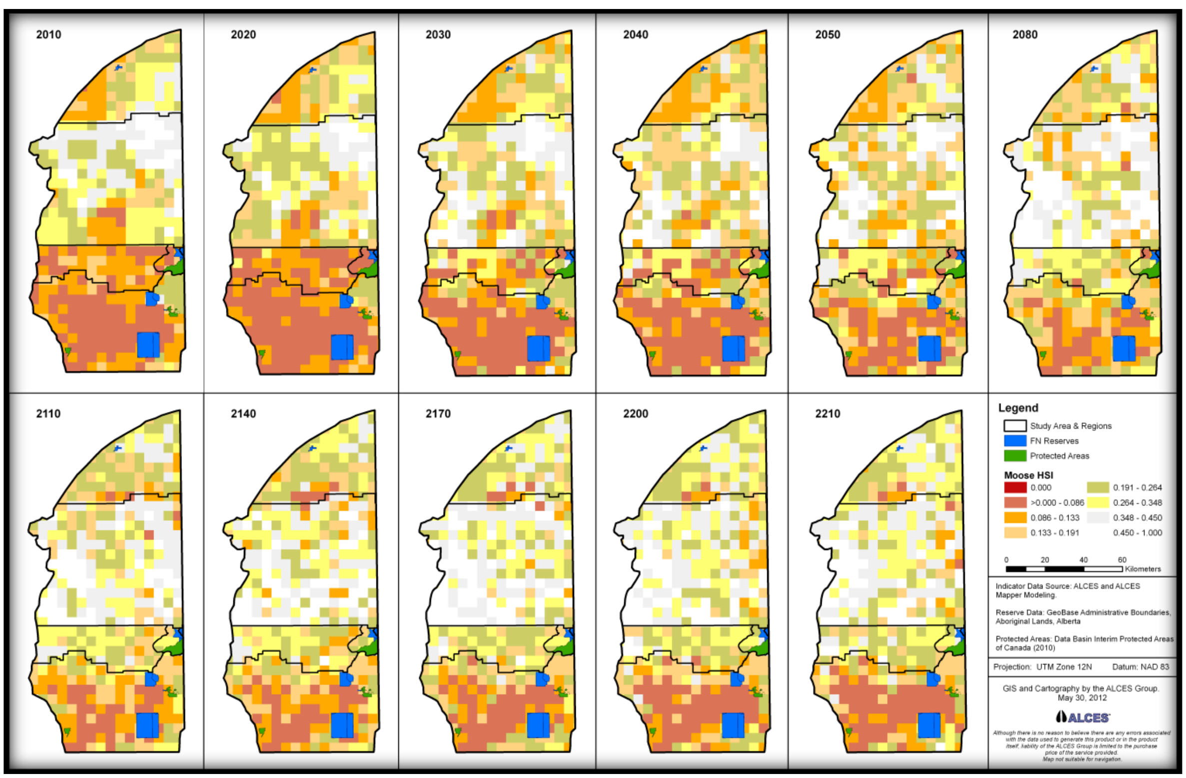


Figure 165. Projected future change in moose habitat effectiveness on CLFN SA.

9.3.5 Moose Populations and Harvest

The general structure for computing moose harvest levels is outlined in Figure 166. RNV simulations indicated that moose populations would have fluctuated between 2000-3000 individuals based on fire and snowpack history and habitat effectiveness (Figure 167). During this period, moose demand would have averaged ~1600 individuals (based on average annual per capita moose demand of 1.40; Tanner et al. 2001) and the resident population could have supported ~500-700 based on the logic outlined in Figure 166. These results suggest that it is likely that CLFN would have ranged beyond the borders of CLFN SA to satisfy their moose meat requirements. The portion of the CLFN Traditional Territory that is in Saskatchewan is approximately the same size as that of CLFN SA, and this eastern half of their Traditional Territory would have likely met the deficit between supply and demand.

Backcast simulations indicate that moose populations have declined during the past century in response to loss of habitat (e.g., cultivated lands, settlements, roads) and increased harvest mortality from aboriginal and non-aboriginal hunters (Figure 167; also see Figure 106, Figure 107, Figure 108). It is highly likely that loss of access to the majority of the Traditional Territory by CLFN would have lead to elevated hunting pressure on the remaining portion of the landbase that remained accessible.

The moose population dynamics model suggests that the population will continue its decline to levels ~50% of RNV values and might incrementally increase to levels of ~1500 moose as the footprint of the energy sector reclaims.

It is important to state that land-use footprint reclamation will not likely result in increased moose populations if issues relating to local overharvest of moose are not addressed.

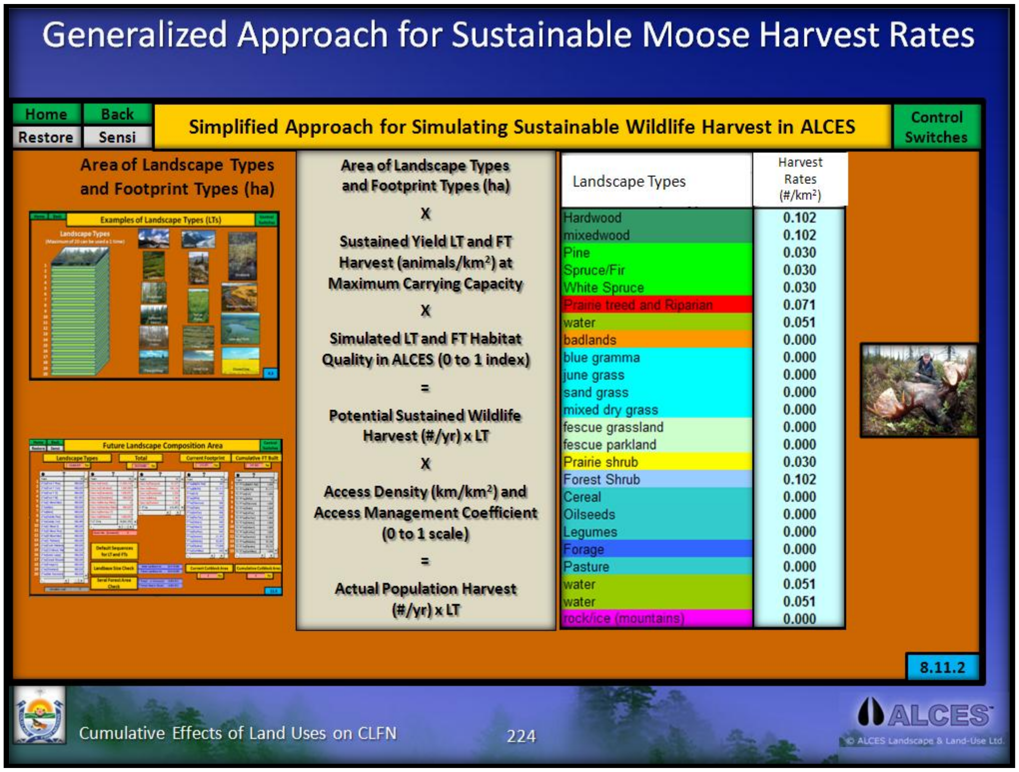


Figure 166. General approach in the CLFN ALCES model for simulating moose harvest.

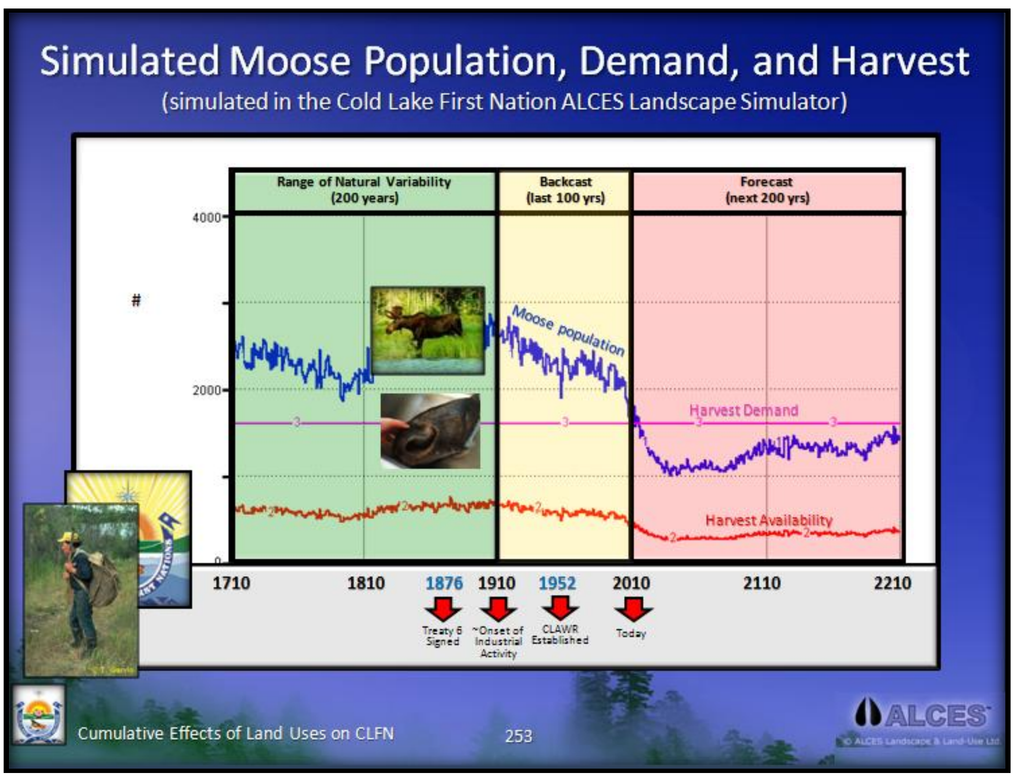


Figure 167. Simulated change in moose populations, harvest demand and harvest availability.

9.3.6 Fisher Habitat Effectiveness

Fisher are sensitive to landscape types, forest age and linear features. They are also vulnerable to excessive trapping pressure. Fisher habitat effectiveness index in CLFN SA varied in the RNV era between 0.15 and 0.28, indicating that not all landscape types are of maximum value or remain in an optimal age class structure. During the past 50 years, the quality of fisher habitat has declined significantly (Figure 168), and the majority of this decline has occurred in the cultivated regions to the south, and in those townships where access associated with the energy sector is highest. The combination of high human and edge density reflects an elevated mortality factor and a concomitant decline in habitat effectiveness.

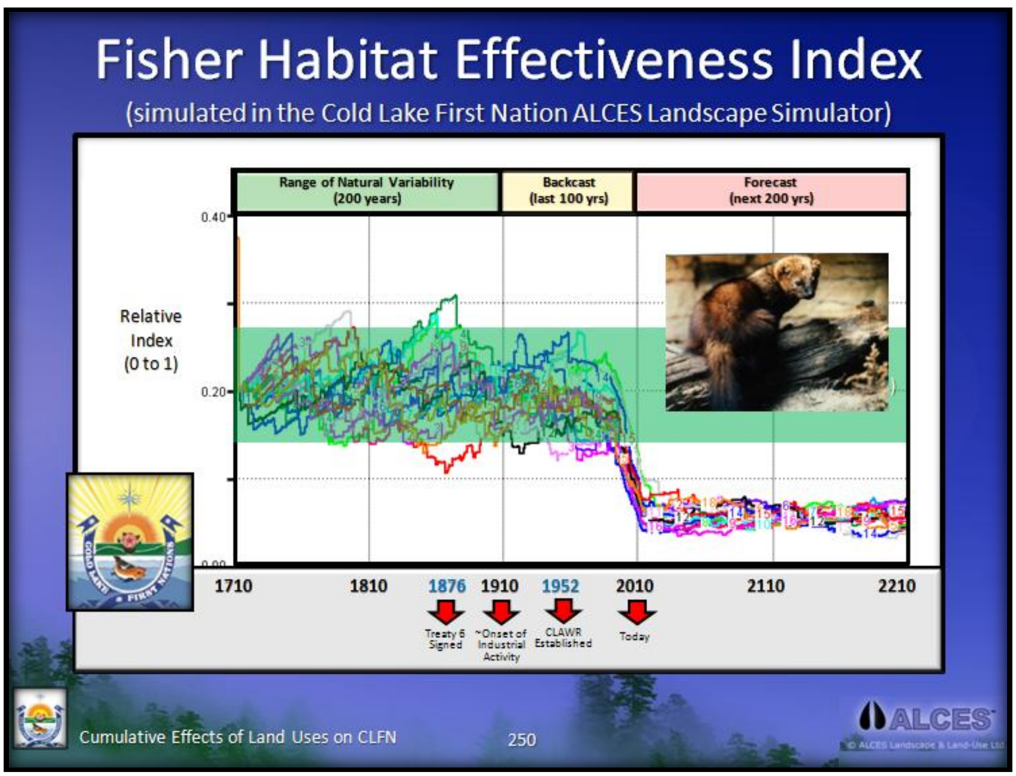


Figure 168. Changes in Fisher Habitat Effectiveness. Source: CLFN ALCES Simulations

9.3.7 Index of Native Fish Integrity (INFI)

RNV simulations indicated that the index of fish integrity would have fluctuated between 0.75 and 1.00 based on inter-annual variation in precipitation, temperature and sediment discharge into lakes and rivers. CLFN harvesters would have been a contributing factor to population fluctuations, but it is likely that their effects on populations would have been local and transient. It is generally accepted that the nomadic movements of pre-European CLFN communities would have been driven by local food scarcity, and that these continuous movements would have allowed locally reduced populations to recover.

Backcast simulations indicate that the INFI index has declined during the past several decades in response to direct loss of surface water habitat (headwater streams and ponds) and elevated nutrient inputs to surface water from cultivated lands, settlements, roads and the footprint of the energy sector. An expanding network of access roads to wellpads and rural residential has also contributed to loss of watershed continuity through the process of "hung" culverts caused during flood years (Park et al., 2008). Perhaps the greatest factor leading to loss of fish community integrity was the combination of elevated human populations (non-aboriginal and aboriginal) and abundant access features (roads, trails, pipelines). This combination allowed the recreational and commercial fishermen to readily access all major lakes and rivers and impose elevated and unsustainable harvest rates on desired fish species (grayling, walleye, pike). The arrival of CLAWR, while having a negative effect on access by the fishing community, has also created refugia in which angling pressure is lower and fish communities have higher levels of integrity (Sullivan, 2003, 2011).

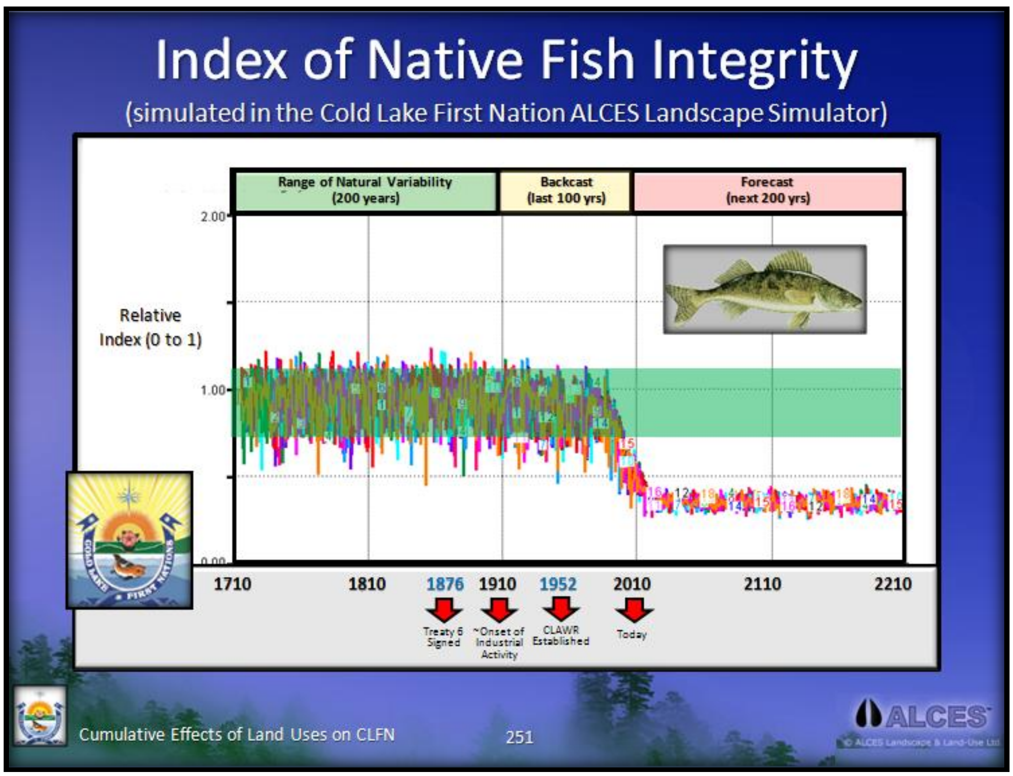


Figure 169. Changes in Index of Native Fish Integrity.

9.3.8 Sulphur Emissions

The annual production of $S0_2$ follows an emission trajectory similar in shape to that of bitumen production (Figure 170, Figure 131). The annual and cumulative emission of $S0_2$ in CLFN SA will be significantly affected by the scale of operations used to extract bitumen. If no sulphur removals are required, such as currently allowed by small operators, a cumulative emission loading of 1.37 M tonne of $S0_2$ will occur during the full production trajectory examined in these analyses (Figure 171). Over the full production life of bitumen production in CLFN SA, this equals an area-weighted average cumulative loading of 1.22 tonne of $S0_2$ being emitted (and presumably) deposited for each hectare. This approach does not account for upwind $S0_2$ being deposited in CLFN SA or the recognition that some of the $S0_2$ produced in the study area will be deposited down-wind of the CLFN SA. These high potential loadings of sulphur on the landscape underscore the need to minimize the emission of this atmospheric contaminant and adverse effects of $S0_2$ on soil, water and other ecological processes.

In the small-scale facility scenario, maximum annual S02 emission rates would occur in ~40 years at a rate of ~10,000 tonne/yr. As illustrated clearly in Figure 170and Figure 171, annual and cumulative loading of $S0_2$ can be reduced by 70% and 90% by relying on medium or large facilities, respectively. Alternatively, smaller-scaled bitumen facilities could be required to adopt more stringent $S0_2$ recovery technologies.

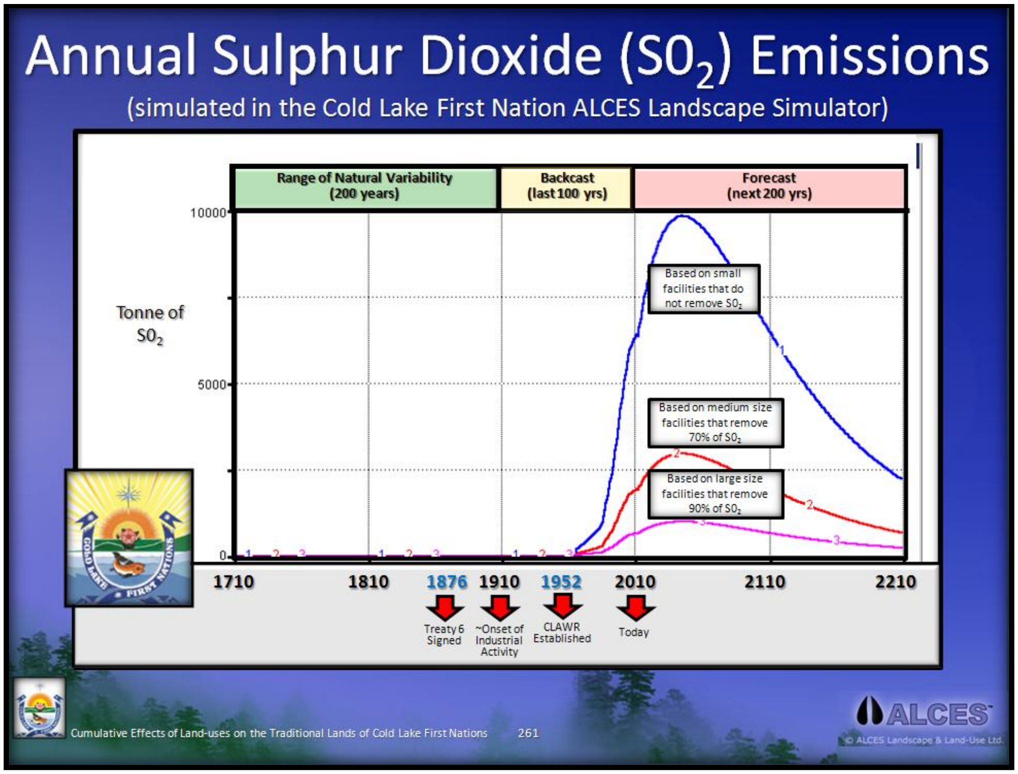


Figure 170. Simulated changes in annual production of sulphur dioxide (S02) in CLFN SA based on recovery of bitumen using small, medium and large sized facilities.

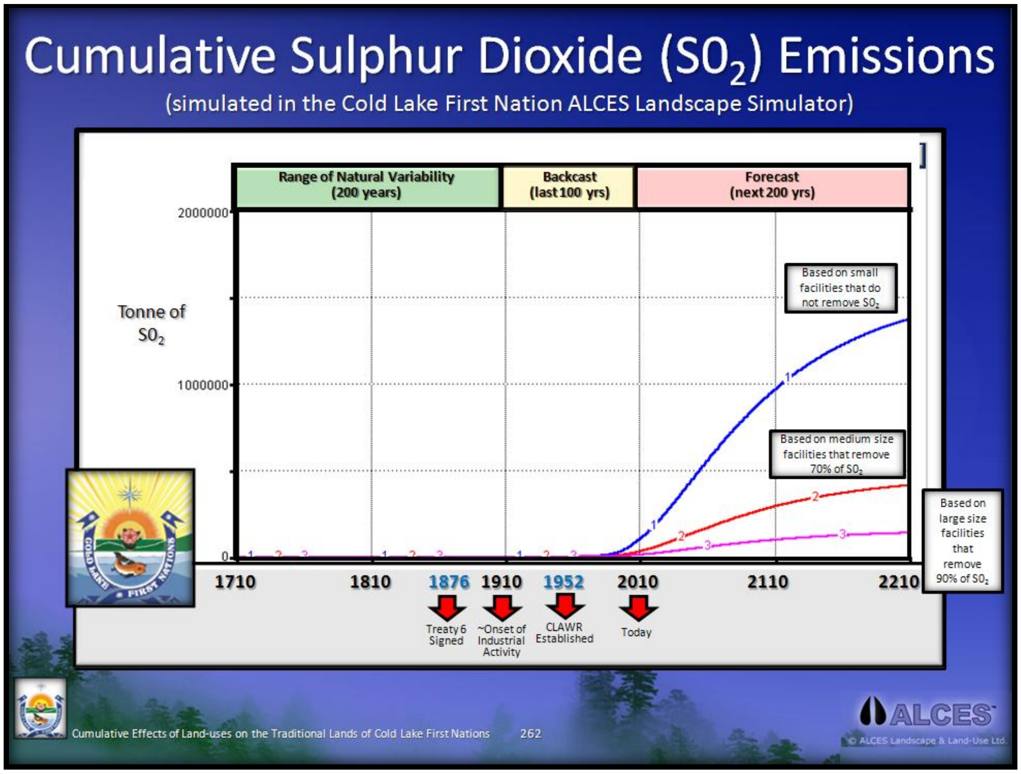


Figure 171. Simulated changes in cumulative production of sulphur dioxide (S02) in CLFN SA based on recovery of bitumen using small, medium and large sized facilities.

9.3.9 Edible Berries

The amount and quality of habitat for edible berries varies during the RNV period (Figure 172) because of inter-annual variation in climate and fire regimes, which in turn, creates variation in forest age class structure.

First Nation communities describe that berry integrity (quantity and quality of edible berries) is reduced by industrial features and activities. One example would be the emission and deposition of dust associated with a high density road network that carries a heavy vehicle transit load (Figure 173). Based on simulations completed in the CLFN ALCES model using buffer setbacks provided by the Integral Ecology Group (Figure 174), the integrity of edible berry habitat has declined in CLFN SA during the past century because of direct loss of forest habitat from crops, settlements, roads and the footprint of the energy sector. An indirect loss to berry habitat has also occurred and has been caused by roads which create dust buffers that influence berry productivity. Roads, and other linear features, also increase access of harvesters to berries and can lead to reductions in berry prevalence.

Significant future direct and indirect loss of edible berry habitat is projected to occur, and these losses are attributed to an increase in density of linear features such as wellpad access roads.

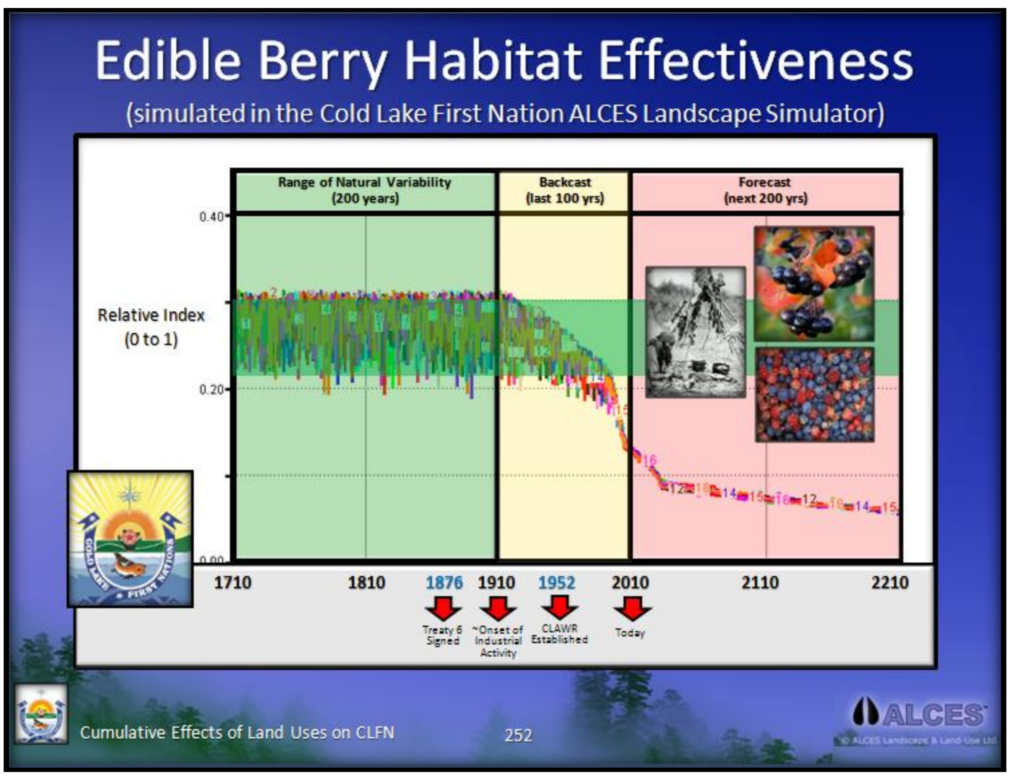


Figure 172. Historical and future projected changes in integrity of edible berry habitat.

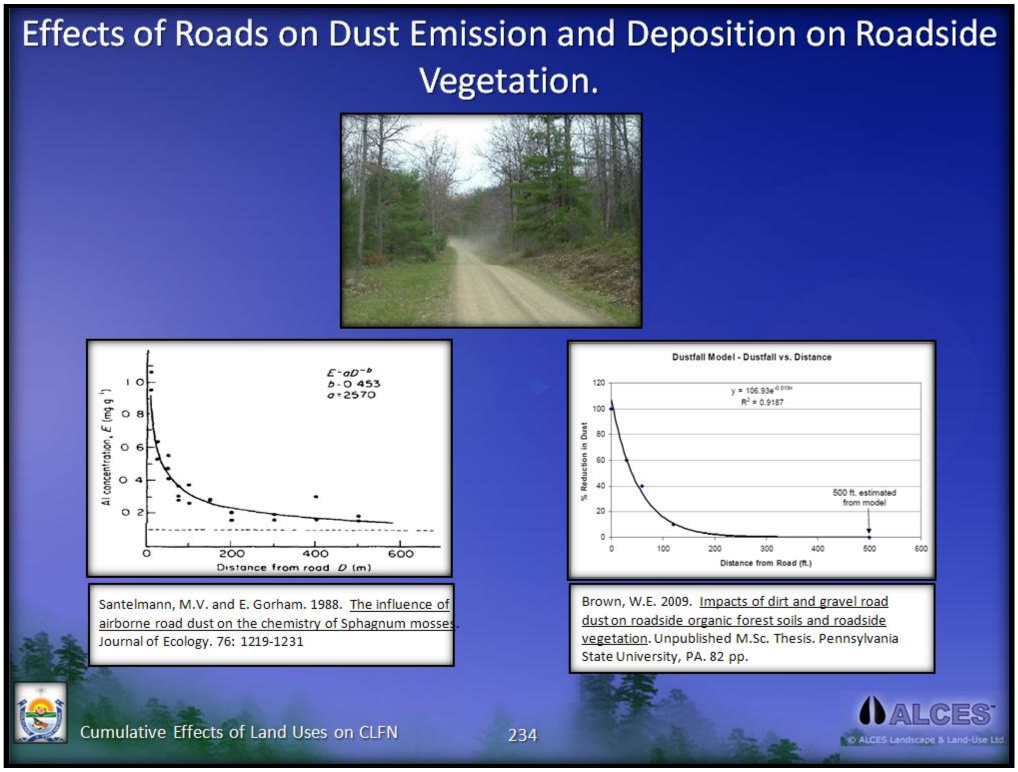
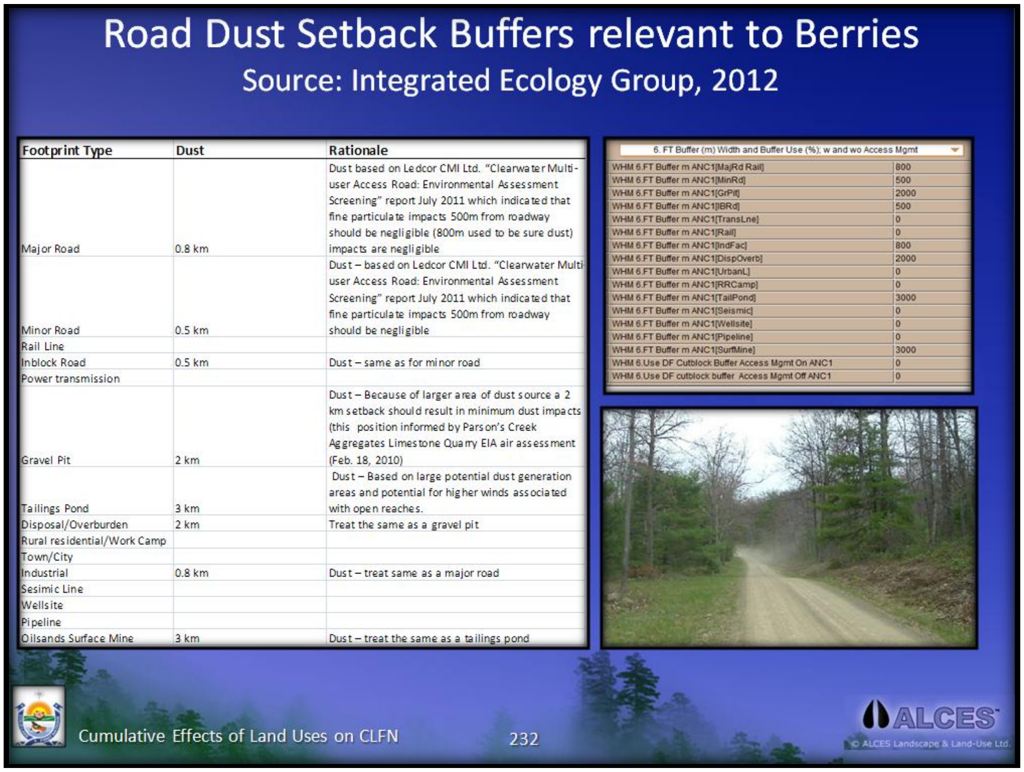


Figure 173. Examples of research illustrating relationship between road proximity and dust deposition. Sources: Santelmann and Gorham 1988 and Brown, 2009.



Footprint Type	Dust	Rationale
Major Road	0.8 km	Dust based on Ledcor CMI Ltd. "Clearwater Multi-user Access Road: Environmental Assessment Screening" report July 2011 which indicated that fine particulate impacts 500m from roadway should be negligible (800m used to be sure dust) impacts are negligible
Minor Road	0.5 km	Dust – based on Ledcor CMI Ltd. "Clearwater Multi-user Access Road: Environmental Assessment Screening" report July 2011 which indicated that fine particulate impacts 500m from roadway should be negligible
Rail Line		
Inblock Road	0.5 km	Dust – same as for minor road
Power transmission		
Gravel Pit	2 km	Dust – Because of larger area of dust source a 2 km setback should result in minimum dust impacts (this position informed by Parson's Creek Aggregates Limestone Quarry EIA air assessment (Feb. 18, 2010)
Tailings Pond	3 km	Dust – Based on large potential dust generation areas and potential for higher winds associated with open reaches.
Disposal/Overburden	2 km	Treat the same as a gravel pit
Rural residential/Work Camp		
Town/City		
Industrial	0.8 km	Dust – treat same as a major road
Sesimic Line		
Wellsite		
Pipeline		
Oilsands Surface Mine	3 km	Dust – treat the same as a tailings pond

6. FT Buffer (m) Width and Buffer Use (%); w and wo Access Mgmt	
WHM 6.FT Buffer m ANC1[MajRd Rail]	800
WHM 6.FT Buffer m ANC1[MinRd]	500
WHM 6.FT Buffer m ANC1[GrPit]	2000
WHM 6.FT Buffer m ANC1[IBRd]	500
WHM 6.FT Buffer m ANC1[TransLne]	0
WHM 6.FT Buffer m ANC1[Rail]	0
WHM 6.FT Buffer m ANC1[IndFac]	800
WHM 6.FT Buffer m ANC1[DispOverb]	2000
WHM 6.FT Buffer m ANC1[UrbanL]	0
WHM 6.FT Buffer m ANC1[RRCamp]	0
WHM 6.FT Buffer m ANC1[TailPond]	3000
WHM 6.FT Buffer m ANC1[Seismic]	0
WHM 6.FT Buffer m ANC1[Wellsite]	0
WHM 6.FT Buffer m ANC1[Pipeline]	0
WHM 6.FT Buffer m ANC1[SurfMine]	3000
WHM 6.Use DF Cutblock Buffer Access Mgmt On ANC1	0
WHM 6.Use DF cutblock buffer Access Mgmt Off ANC1	0

Figure 174. Estimates of roadside buffers distances that may adversely affect integrity of edible berries. Source: Integrated Ecology Group (IEG), 2012. Based on work completed by IEG for Fort McKay First Nations.

9.4 CULTURAL AND SOCIAL

9.4.1 Access of CLFN to CLFN SA

During the pre-European era, CLFN had the ability to access all areas within the CLFN SA for traditional activities (hunting, fishing, gathering). That is not to say that all regions would have been frequented during any given year, for the nomadic nature of their lifestyle would have enabled CLFN to focus their presence in those regions that best satisfied their resource requirements.

During the past century (1912 to 2012), access to CLFN SA by CLFN for purposes of traditional activities has been reduced by several land uses including:

- Expansion of cultivated lands
    - currently 117,000 ha; 10.4% of CLFN SA
- Expansion of settlements
    - Currently 8,700 ha; 0.8 % of CLFN SA
- Establishment of CLAWR in 1952
    - 469,577 ha; 41.7% of CLFN SA
- Effective inaccessibility of regions north of CLAWR in 1952
    - 185,481 ha; 16.6% of CLFN SA
- Establishments of Provincial Parks during the 1960s
    - 6,463 ha; 0.6% of CLFN SA

Collectively these contemporary direct losses of natural landscape, or restriction to access of natural landscapes amount to 787,221 ha or 70.3% of CLFN SA (Figure 175). These geographic restrictions do not include any lands outside of the above features that are restricted because of infrastructure of the energy sector.

Participation in traditional activities can be compromised by proximity to infrastructure of the energy sector such as processing plants, wellpads, pipelines, or access roads. In many cases, access roads to wellpads and other energy sector infrastructure are gated. If a 100 m buffer is placed on those energy sector features occurring between CLAWR and the agricultural regions to the south, then the effective loss of natural landscape for traditional activities is further increased to ~80% of CLFN SA.

Future simulations indicate that the fraction of the natural landscape accessible to traditional activities will continue to decline because of a rapid expansion in the infrastructure of the bitumen and heavy oil sector. Future levels of access to natural landscapes for traditional activities will continue at very low levels for the next 80-100 years and will only increase once the footprint of the energy sector experiences a significant level of reclamation. This description assumes that access by CLFN to regions north of CLAWR remains difficult.

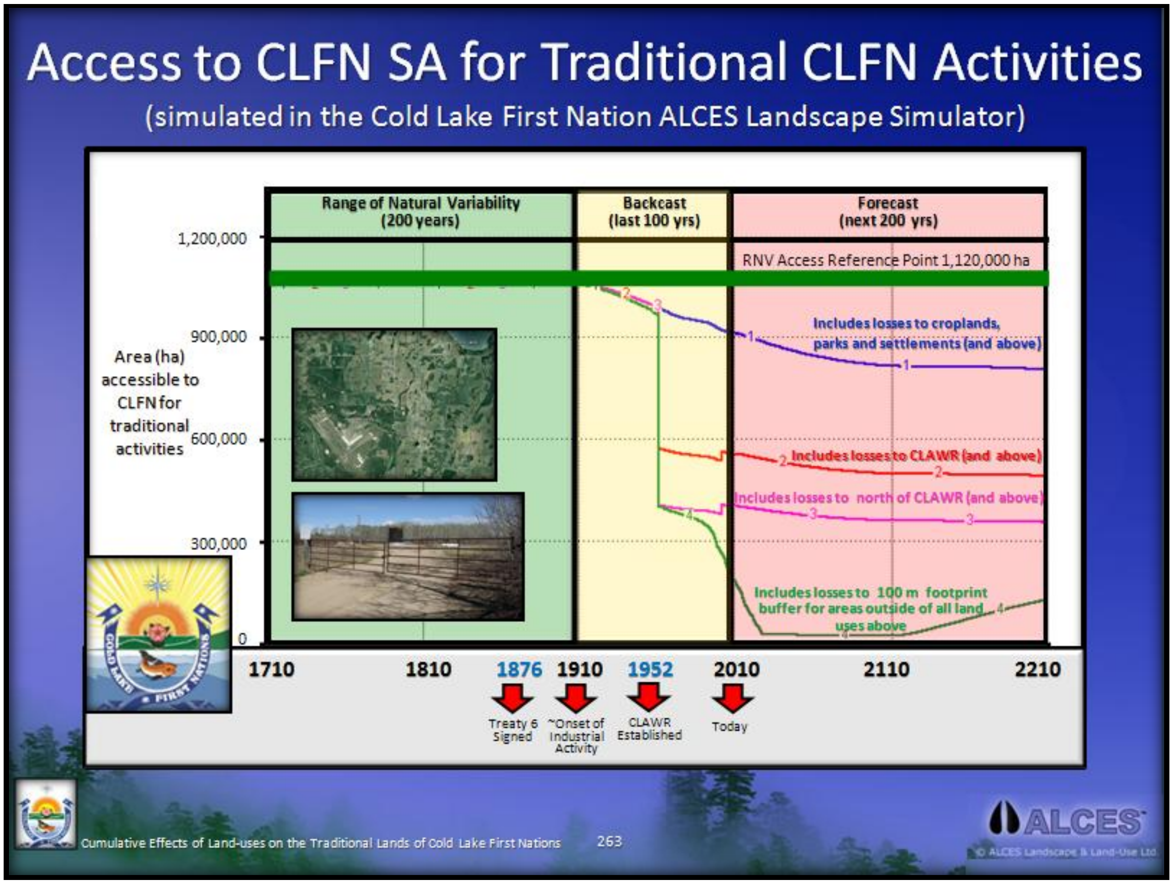


Figure 175. Simulated historical, current, and future changes in access by CLFN to the CLFN SA for purposes of traditional activities.

10. CONCLUSIONS

The historical, current and future analyses of the CLFN ALCES simulator chronicle the changes to an important and dynamic boreal landscape of east central Alberta. For the vast majority of the past 10,000 years since glacial ice sheets retreated, the major architects of these boreal ecosystems were natural disturbances (fires, insect outbreaks, variance in climate) and the First Nation communities whose nomadic lifestyle was driven by the need to locate, harvest, eat and utilize natural resources (such as moose, fish, berries, trees, etc.) for all of their subsistence, spiritual and cultural needs.

During the past 100 years CLFN, and the boreal forest landscape on which they pursue their traditional activities, have experienced a transformation that can only be described as profound. The physical features of the landscape and the cultural fabric of native peoples have been altered by a suite of consecutive land-use trajectories that include trapping, European religions, agriculture, residential schooling, transportation, non-aboriginal settlements, military, and the hydrocarbon sector.

As the past century has unfolded, the ability of CLFN to participate meaningfully in traditional activities has been substantively eroded. Some land-uses, such as croplands and parks, are partially available to CLFN, but are not conducive to traditional activities. Others, such as the military (CLAWR) and the energy sector, create impediments or barriers that prevent CLFN from accessing vestiges of natural landscapes. When considered in total, these overlapping land-uses have restricted the CLFN community to a very small fraction of their original Traditional Territory.

The adaptive nature of the CLFN people to their pre-European boreal landscape was based on the key elements of "meaningful" space and time. They required an extensive landscape over which to seek and use resources. No single portion of their Traditional Territory met their full seasonal and annual requirements for fish, moose, berries, and other resources. As a result, family clans would have been highly mobile, residing in regions until local foods were depleted, and then moving to new locations to allow for resource recovery. Some of these patterns would have been seasonal; other movements might reflect decadal periods. The spatial-temporal system that defined the CLFN people for millennia no longer exists. Hemmed in by croplands to the south and an air weapons range to the north, the CLFN community of today has very few remaining areas on which to participate in traditional activities. Not surprisingly, these natural landscape remnants experience high levels of traditional resource use and may be readily over-exploited. No longer able to access their traditional lands extensively, CLFN have few remaining venues to satisfy the existing appetite for traditional activity.

However, time is not standing still and neither is land-use. As much as the CLFN Traditional Territory has changed during the past 100 years, current plans for future land-use reveal expansion of croplands onto those remaining forests with arable soils to the south, expanding towns and rural residential, and a rapidly growing network of seismic lines, wellpads, access roads, pipelines and processing plants as the hydrocarbon sector delineates, extracts, processes and translocates bitumen and heavy oil to southern markets. In a cumulative sense, the boreal landscape of CLFN Traditional Territory will continue its transformation, incrementally losing what remains of its “naturalness”, incrementally becoming more industrialized with each passing year.

The focus of most EIAs is myopic in space and time and fails stakeholders by not contributing to an informed dialogue about both the benefits and liabilities that attend land-use. Clearly CLFN feel they are subject to a constrained regulatory view of resource allocation, and have been unable to adequately express their concerns within a framework that is structured for the specific detail of individual projects, but largely blind to the bigger picture.

As resource managers, we can and must do better in the arena of land-use assessment and resource allocation between industry and First Nations, for we are no longer constrained by technology or knowledge. Our only constraints are political leadership and regulatory vision.

11. LIMITATIONS AND IMPORTANT CONSIDERATIONS

11.1 FUTURE CONDITIONS

Future land-use projections can have high levels of uncertainty. The land-use scenarios examined for CLFN SA are based on specific assumptions about the rate, location and operating practices of various land-use activities. Government policy, global commodity prices, trends in energy supply and transportation infrastructure, and technological innovation all have significant effects on the intensity and location of future land-use activities. It is highly probable that the land-use assumptions upon which the scenario modelling is based will become less robust as the future simulation period unfolds.

While changing future conditions are a near certainty, examining plausible futures based on current assumptions allows stakeholders to better understand potential benefits and risks that attend defined alternative land management options. For the various governing bodies (Canada, Alberta, CLFN) that are relevant to this region, a decision-making framework is critical to developing and implementing sustainable land management strategies that can be re-evaluated as circumstances change. Similar to the precautionary principle, uncertainty about future land-use activities should not prevent informed decision-making today.

11.2 IMPACT PREDICTION AND SIGNIFICANCE

Projected wildlife and fish status under different development assumptions is compared to simulated RNV to provide some information on the ecological risk associated with projected changes. This approach assumes that risk is minimal where indicator status is within the RNV, and increases as indicator status moves further away from 'natural' conditions. The risk management categories presented here were utilized for land-use planning by the Government of Alberta in northeast Alberta as part of the Alberta Land-use Management Framework. Because risk tolerance of resource managers and communities can vary, these risk rankings may not reflect “made-for-CLFN” socio-cultural perspectives. Such perspectives should be considered when discussing and evaluating potential land-use impacts, particularly in the context of establishing limits of acceptable change.

12. REFERENCES

Alberta Environment, 2006. Cold Lake Beaver River; Surface water quality state of the basin report. Alberta Environment; in partnership with Lakeland Industry and Community Association and the Cold Lake, Beaver River Basin Advisory Committee.

Alberta Forest Service, 1985. Alberta phase 3 forest inventory: an overview. Energy and Natural Resources Report I/86, Alberta Energy and Natural Resources, Edmonton, AB.

Alberta Forest Service, 1985. Alberta phase 3 forest inventory: an overview. Energy and Natural Resources

Alberta Land and Forest Services 1994. Status of Alberta's timber supply. Canadian Council of Forest Ministers Timber Supply Conference. November 16–18, 1994. Kananaskis, AB.

Anderson, Anne-Marie. 1994. Effects of wastewater effluence discharges on the water quality of the Beaver River. Alberta Environmental Protection.

Anonymous. 1993. Primrose Air Weapons Range Report. Indian Claims Commission.

ASRD (Alberta Sustainable Resource Development). 2002. Northern Moose Management Program – Progress Report. Alberta Sustainable Resource Development, Edmonton, AB. Online [URL]: http://www.srd.gov.ab.ca/fishwildlife/livingwith/huntingalberta/northernmoosemanagement/default.aspx

Attiwill, P.M. 1994. The disturbance of forest ecosystems: the ecological basis for conservative management. Forest Ecology and Management 63:247–300.

Axys Environmental Consulting Ltd. 2003. Winter Wildlife Surveys; Field Technical Report.

Barney, R.J.; Stocks, B.J. 1983. Fire frequencies during the suppression period. pp. 45–62. In: The role of fire in northern circumpolar ecosystems. Wein, R.W.; MacLean, D.A. (editors). John Wiley and Sons, Toronto, ON.

Bergeron, Y. 1991. The influence of island and mainland lakeshore landscapes on the boreal forest fire regime. Ecology 72:1980–1992.

Berry, S. and Brink. J. 2005. Aboriginal cultures in Alberta. Provincial Museum of Alberta. Pp 22.

Boer, A.H. 1992. Fecundity of North American moose *(Alces alces)*: a review. ALCES (Supplement 1): 1-10.

Bradshaw, R.; Zackrisson, O. 1990. A two thousand year history of a northern Swedish boreal forest stand. Journal of Vegetation Science 1:519–528.

Burton, P.J.; Cumming, S.G.; Joy, M.; Klinkenberg, B.; Schmiegelow, F.K.A.; Smith, J.N.M. 1994. Experimental habitat fragmentation and simulation of landscape dynamics in the boreal mixedwood: a pilot study. C.A.P.A.I.F. publication, Edmonton, AB.

CEMA (Cumulative Effects Management Association). 2008. Terrestrial Ecosystem Management Framework for the Regional Municipality of Wood Buffalo. Online [URL]: http://www.cemaonline.ca/content/view/75/148/.

Clark, J.S. 1990. Fire and climate change during the last 750 years in northwestern Minnesota. Ecological Monograph 60:135–159.

Clissold, R.J.; Tress, R.G. 1974. Pinehurst-Seibert-Touchwood Lake Area biophysical resource inventory. Prepared for Lands and Forests, Government of Alberta, Edmonton, AB.

Dancik, B.; Brace, L; Stelfox, J.; Udell, B. 1990. Forest management in Alberta. Report of the expert review panel. Department of Alberta Energy, Forestry, Lands and Wildlife, Edmonton, AB. 128 pp.

Danks, H.V.; Foottit, R.G. 1989. Insects of the boreal zone of Canada. The Canadian Entomologist 121:626–677.

Eberhart, K.E.; Woodard, P.M. 1987. Distribution of residual vegetation associated with large fires in Alberta. Canadian Journal of Forest Research 17:1207–1212.

Engelmark, O.; Bradshaw, R.; Bergeron, Y. 1993. Disturbance dynamics in boreal forest. Journal of Vegetation Science 3:729–732.

Fedirchuk, McCullough and Associates Ltd. 2001. Historical Resources Impact Assessment; Cold Lake First Nations Consultation and Traditional Site Survey; Encana Corporation Foster Creek SAGD Expansion Project, Cold Lake Air Weapons Range, Twp 70, Rges 3-4, W4M.

Ferguson, S.H., A.R. Bisset, and F. Messier. 2000. The influences of density on growth and reproduction in moose *Alces alces.* Wildlife Biology. 6: 31-39.

Forman, R.T.T. and L.E. Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics. 29: 207-231.

Francis, J.; Lumbis, K. 1979. Habitat relationships and management of terrestrial birds in northeastern Alberta. Alberta Environment and Environment Canada. AOSERP Report No. 78.

Franzmann, A.W. and C.C. Schwartz. 1985. Moose twinning rates: a possible population condition assessment. Journal of Wildlife Management. 49: 394-396.

Gaillard, J-M. 2007. Are moose only a large deer?: some life history considerations. ALCES. 43: 1-11.

Gasaway, W. C., R. D. Boertje, D. V. Grangaard, D. G. Kelleyhouse, R. 0. Stephenson, and D. G. Larsen. 1992. The role of predation in limiting moose at low densities in Alaska and Yukon and implications for conservation. Wildlife Monographs 120:1-59.

Holling, C. S. 1973. Resilience and stability of ecological systems. Annual Review of Ecology and Systematics 4: 1-23.

Johnson, E.A. 1992. Fire and vegetation dynamics—studies from the North American boreal forest. Cambridge University Press, Cambridge, U.K.

Johnson, E.A.; Larsen, D.P.S. 1991. Climatically induced change in fire frequency in the southern Canadian Rockies. Ecology 72:194–201.

Kabzems, A.; Kosowan, A.L.; Harris, W.C. 1976. Mixedwood section in an ecological perspective. Technical Bulletin 8, Forestry Branch, Saskatchewan Department of Tourism and Renewable Resources, Regina, SK.

Kelsall, J.P.; Telfer, E.S.; Wright, T.D. 1977. The effects of fire on the ecology of boreal forest, with particular reference to the Canadian north; a review and selected bibliography. Canadian Wildlife Service, Occasional Paper No. 32, Edmonton, AB.

Kocaoglu, S.S. 1975. Reconnaissance soil survey of the Sand River area (73L). University of Alberta. Bulletin No. SS–15. Edmonton, AB.

Kocaoglu, S.S.; Bennett, K.E. 1983. An integrated resource inventory of the Special Lakeland area, physical land and forage classifications. Alberta Energy and Natural Resources, Edmonton, AB. ENR Report Number T/48.

Longley, R.W. 1970. Climatic classification for Alberta forestry. pp. 147–153. In: Proceedings of the Third Forest Microclimate Symposium. Powell, J.M.; Nolasco, C.F. (editors). Seebe, Alberta, September 23–26, 1969. Canadian Department of Fisheries and Forestry, Canadian Forestry Service, Forest Research Lab, Calgary, AB.

Maser, C. 1994. Sustainable forestry; philosophy, science and economics. St. Lucie Press, Delray Beach, FL.

McCullough, Annette. 2011. Cold Lake First Nations Traditional Knowledge Study. FMA Heritage/Nu Nenne-Stantec Inc.

Messier, F. 1994. Ungulate population models with predation: a case study with the North American moose. Ecology. 75: 478-488.

Messier, F., and M. Crete. 1985. Moose-wolf dynamics and the natural regulation of moose populations. Oecologia. 65: 503-5 12.

Moss, E.H. 1983. Flora of Alberta. A manual of flowering plants, conifers, ferns and fern allies found growing without cultivation in the province of Alberta, Canada. 2nd edition. Revised by Packer, J.G. University of Toronto Press, Toronto, ON.

Murphy, P.J. 1985. History of forest and prairie fire control policy in Alberta. Report T/77, Alberta Energy and Natural Resources, Edmonton, AB.

Nelson, J.S.; Paetz, M.J. 1992. The fishes of Alberta. 2nd edition. University of Alberta Press, Edmonton, AB.

Oliver, C.D. 1992. Similarities of stand structures and stand development processes throughout the world – some evidence and applications to silviculture through adaptive management. pp. 11–26. In: The ecology and silviculture of mixed-species forests. Kelty, M.J. (editor). Kluwer Academic Publishers, Dordrecht, The Netherlands.

Osko, T.J., M.N. Hiltz, R.J. Hudson, and S.M. Wasel. 2004. Moose habitat preferences in response to changing availability. Journal of Wildlife Management. 68: 576-584.

Pattie, L.D.; Hoffmann, R.S. 1992. Mammals of the North American parks and prairies. 2nd edition. 11762–106 Street, Edmonton, AB.

Payette, S.; Morneau, C.; Sirois, L.; Desponts, M. 1989. Recent fire history of the northern Quebec biomes. Ecology 70:656–673.

Personal Communication. Michael Sullivan. Provincial Fisheries Biologist. Government of Alberta, Edmonton

Peterson, E.B.; Peterson, N.M. 1992. Ecology, management and use of aspen and balsam poplar in the prairie provinces. Special Report 1, Forestry Canada, Edmonton, AB.

Pickett, S.T.A.; White P.S. 1985. The ecology of natural disturbance and patch dynamics. Academic Press. New York, N.Y.

Pyc, C.D. 1999. Resource management in Wood Buffalo National Park: striving for cooperation. Unpublished M.Sc. Thesis., University of Calgary, Calgary, AB. 144 pp.

Rowe, J.S. 1972. Forest regions of Canada. Canadian Department of Fisheries and Environment, Canadian Forest Service, Ottawa, ON. Publication 1300.

Rowe, J.S.; Scotter, G.W. 1973. Fire in the boreal forest. Quaternary Research 3:444–464.

Russell, A.P.; Bauer, A.M. 1993. The amphibians and reptiles of Alberta. University of Calgary Press, Calgary, AB.

Schneider, R.R. and S.M. Wasel. 2000. The effect of human settlement on the density of moose in northern Alberta. Journal of Wildlife Management. 64: 513-520.

Schwartz, C.C. 1992. Reproductive biology of North American moose. Alces. 28: 165-173.

Semenchuk, G.P. 1992. The atlas of breeding birds of Alberta. Federation of Alberta Naturalists, Edmonton, AB.

Smith, H.C. 1993. Alberta mammals. An atlas and guide. Provincial Museum of Alberta, Edmonton, AB. 239 pp.

Stelfox, J. B. 1995. Relationships between stand age, stand structure, and biodiversity in aspen mixedwood forests in Alberta. Alberta Environmental Centre, Vegreville, AB.

Stelfox, J.B. and S.M. Wasel. 1993. Hunting and harvest. pp. 91-106. *In* J.B. Stelfox, ed., *Hoofed Mammals of Alberta*. Lone Pine Publishing. Edmonton, AB.

Sullivan, M. 2011. Conceptual Framework for Public Motorized Access Management Strategies for Cumulative Effects Modelling. Alberta Sustainable Resource Development.

Sullivan, M.G. 2003. Active management of walleye fisheries in Alberta: Dilemmas of managing recovering fisheries. North American Journal of Fisheries Management. Volume 23, Issue 4, 2003.

Syncrude Canada and Birch Mountain Resources. Ancient hunters of the Athabasca lowlands. Syncrude Canada and Birch Mountain Resources.

Telfer, E.S., and J.P. Kelsall. 1984. Adaptation of some large North American mammals for survival in snow. Ecology. 65: 1828-1834.

Thomas, J.W.; Anderson, R.B.; Maser, C.; Bull, E.L. 1979. Snags. pp. 60–70. In: Wildlife habitats in managed forests, the Blue Mountains of Oregon and Washington. Thomas, J.W. (editor). United States Forest Service, Department of Agriculture.

Thomas, J.W.; Ruggiero, L.F.; Mannan, R.W.; Schoen, J.W.; Lancia, R.A. 1988. Management and conservation of old-growth forests in the United States. Wildlife Society Bulletin 16:252–262.

Thorpe, P.T. 1992. Patterns of diversity in the boreal forest. pp. 65–79. In: The ecology and silviculture of mixed-species forests. Kelty, M.J. (editor). Kluwer Academic Publishers, Dordrecht, The Netherlands.

Trombulak, S. C., and C. A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14(1): 18–30.

Vitt, D.H.; Marsh, J.E.; Bovey, R.B. 1988. Mosses, lichens and ferns of Northwest North America. Lone Pine Press, Edmonton, AB.

Wein, E.E., J.H. Sabry, and F.T. Evers. 1991. Food consumption patterns and use of country foods by native Canadians near Wood Buffalo National Park, Canada. Arctic. 44: 196-205.

Wilson, B., et al. 2008. Methodologies of the Sustainable Ecosystems Management Framework (TEMF). Data analysis of the Sustainable Ecosystem Working Group (SEWG). CEMA.

Wynnyk, A.; Lindsay, J.D.; Heringa, P.K.; Odynsky, W. 1963. Exploratory soil survey of Alberta Map Sheet 83–O, 83–P, and 73–M, Research Council of Alberta, Preliminary soil survey report 64–1, Alberta Soil Survey. Edmonton, AB.

GENERAL REFERENCES

(S&T)2 Consultants Inc. 2010. The Addition of Unconventional Natural Gas Supply to GHGenuis. Natural Resources Canada, Ottawa, Canada.

Alberta Environment. 2007. Current and future water use in Alberta. Available online at http://www.albertawater.com/index.php?option=com_content&view=article&id=80&Itemid=78.

Alberta Municipal Affairs and Housing. 2010. Official Alberta Population Lists. Available online: http://www.municipalaffairs.alberta.ca/mc_offical_populations.cfm.

Alberta-Pacific Forest Industries Inc. 2008. Alberta-Pacific FMA Area Forest Management Plan (Revised) September 2007 (Approved September 2008). Alberta-Pacific Forest Industries, Boyle, AB.

ALCES Group. 2011. Cumulative Effects Assessment for Alberta Pacific Forest Industries. Unpublished report prepared for Alberta Pacific Forest Industries.

Alexander, M. D., L. Qian, T. A. Ryan, and J. Herron. 2011. Considerations for Responsible Gas Development of the Frederick Brook Shale in New Brunswick. Fundy Engineering and Atlantica Centre for Energy.

Anonymous. 1993. The state of Canada's forest 1993. Canadian Forest Service, Hull, QB.

ArborVitae Environmental Services. 2004. Estimating Future Carbon Losses from Deforestation in Canada. Unpublished report submitted to Canadian Forest Service, Natural Resources Canada.

Armstrong, G.W. 1999. A stochastic characterisation of the natural disturbance regime of the boreal mixedwood forest with implications for sustainable forest management. Canadian Journal of Forest Research 29: 424–433.

Armstrong, G.W. 1999. A stochastic characterisation of the natural disturbance regime of the boreal mixedwood forest with implications for sustainable forest management. Canadian Journal of Forest Research 29: 424–433.

Athabasca Landscape Team. 2009. Athabasca Caribou Landscape Management Options Report. Unpublished report submitted to the Alberta Caribou Committee Governance Board. Available online: http://www.albertacariboucommittee.ca/PDF/Athabasca-Caribou.pdf.

Atmospheric Environment. 1981. Canadian climate normals. Temperature and precipitation. 1951–1980. Environment Canada, Atmospheric Service, Downsview, ON.

Blaustein, A.R.; Beatty, J.J.; Olson, D.H.; Storm, R.M. 1995. The biology of amphibians and reptiles in old-growth forests in the Pacific Northwest. United States Department of Agriculture, Forest Service, Pacific Northwest Research Station. General Technical Report PNW–GTR–337.

Boutin, S. and C. Arienti. 2008. Boreal Caribou Committee (BCC) equation reanalysis, Final Report – November 26, 2008. Unpublished report prepared for the Alberta Caribou Committee Research and Monitoring Subcommittee by University of Alberta Integrated Land Management Laboratory. Edmonton, AB. 20 pp.

British Columbia Ministry of Energy and Mines and National Energy Board. 2011. Ultimate Potential for Unconventional Natural Gas in Northeastern British Columbia's Horn River Bain. Oil and Gas Reports 2011-1.

Burton, P.J.; Balisky, A.C.; Coward, L.P.; Cumming, S.G.; Kneeshaw, D.D. 1992. The value of managing for biodiversity. The Forestry Chronicle 68 (2):225–237.

Butler, J. 1993. Forestry related threats to wildlife in the boreal forests. Alberta Game Warden, Spring 1993:29–32.

Butler, J. 1994. The Eco-tourism potential..... Western Canada Wilderness Committee, Alberta Branch Educational Report. Volume 13, No. 3 Spring 1994.

Canada Land Inventory. 1976. Land Capability for Agriculture. Environment Canada.

Canadian Association of Petroleum Producers. 2010. Responsible Canadian Energy Oil Sands Progress Report for the Year Ended December 31, 2009. Canadian Association of Petroleum Producers, Calgary, AB.

Canadian Association of Petroleum Producers. 2011. CAPP Statistical Handbook. Available online: http://www.capp.ca/library/statistics/handbook/Pages/default.aspx#nurEHFMGTBBF.

Canadian Council of Forest Ministers. 2011. National Forestry Database. Available online at: http://nfdp.ccfm.org/index_e.php.

Carey, A.B. 1989. Wildlife associated with old-growth forests in the Pacific Northwest. Natural Areas Journal 9:151–162.

Carlson, M., E. Bayne, and B. Stelfox. 2007. Seeking a Balance: Assessing the Future Impacts of Conservation and Development in the Mackenzie Watershed. Canadian Boreal Initiative, Ottawa, ON.

Carlson, M., J. Chen, S. Elgie, C. Henschel, A. Montenegro, N. Roulet, N. Scott, C. Tarnocai, and J. Wells. 2010. Maintaining the role of Canada's forests and peatlands in climate regulation. Forestry Chronicle 86(4): 434–443.

Centre for Topographic Information. 2004. National Hydro Network, Canada, Level 1 Product Specifications Edition 1.0. Natural Resources Canada, Sherbrooke, Quebec.

Centre for Topographic Information. 2007a. National Road Network Data Product Specifications. Edition 2.0. Natural Resources Canada, Sherbrooke, Quebec. Available online: http://www.geobase.ca/geobase/en/data/nrn/description.html.

Centre for Topographic Information. 2007b. National Road Network Feature Catalogue. Edition 2.0. Natural Resources Canada, Sherbrooke, Quebec. Available online: http://www.geobase.ca/geobase/en/data/nrn/description.html.

Centre for Topographic Information. 2009a. Land Cover, circa 2000-Vector Data Product Specifications. Natural Resources Canada, Sherbrooke, Quebec.

Centre for Topographic Information. 2009b. Land Cover, circa 2000-Vector Feature Catalogue. Natural Resources Canada, Sherbrooke, Quebec.

Centre for Topographic Information. 2010a. CanVec Data Product Specifications Edition 1.1. Natural Resources Canada, Sherbrooke, Quebec.

Centre for Topographic Information. 2010b. CanVec Feature catalogue 1.1.0. Natural Resources Canada, Sherbrooke, Quebec.

Chen, J. M., W. Ju, J. Cihlar, D. Price, J. Liu, W. Chen, J. Pan, T. A. Black, and A. Barr. 2003. Spatial distribution of carbon sources and sinks in Canada's forests. Tellus B 55(2): 622-642.

Cleary, J., N. T. Roulet, T. R. Moore. 2005. Greenhouse gas emissions from Canadian peat extraction, 1990-2000: a life-cycle analysis. Ambio 34(6): 456-461.

Collyer, D. 2010. BC's Energy Future Climate Policy and Energy Policy – Where do they meet? Presentation to the BCBC & BC Chamber of Commerce BC Energy Conference. October 27, 2010. Vancouver, BC. Available online: http://www.capp.ca/getdoc.aspx?dt=PDF&docID=180185.

Cumming, S. G. 2005. Effective fire suppression in boreal forests. Canadian Journal of Forest Research 35: 772-786.

Cumming, S.G. 2001. Forest type and wildfire in the Alberta boreal mixedwood: what do fires burns? Ecological Applications 11(1):97-110.

Dehcho Land-use Planning Committee. 2006. Respect for the Land: The Dehcho Land-use Plan Background Report.

Delisle, G.P.; Hall, R.J. 1987. Forest fire history maps of Alberta, 1931–1983. Technical report, Forestry Canada, Northern Forestry Centre, Edmonton, AB.

DeLong, C. 1988. A field guide for identification and interpretation of seral aspen ecosystems of the BWBSC1, Prince George Forest Region. B.C. Ministry of Forests Research Branch. Victoria, B.C. Land Management Handbook 16.

Dempsey, H.A.I. 1974. People of the boreal forest Chipewyan and Cree. pp. 33–44. In. The land of Peter Pond. Chalmers, J.W. (editor). Boreal Institute for Northern Studies Occasional Publication No. 12, University of Alberta, Edmonton, AB.

Dix, R.L.; Swan, J.M.A. 1971. The roles of disturbance and succession in upland forest at Candle Lake, Saskatchewan. Canadian Journal of Botany 49:657–676.

Duinker, P.N. and L.A. Greig. 2007. Scenario analysis in environmental impact assessment: Improving explorations of the future. Environmental Impact Assessment Review. 27: 206-219.

Ecological Stratification Working Group. 1995. A National Ecological Framework for Canada. Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Resources Research and Environment Canada, State of the Environment Directorate, Ecozone Analysis Branch, Ottawa/Hull.

Energy Resources Conservation Board (ERCB). 2010. Alberta's Energy Reserves 2009 and Supply/Demand Outlook 2010-2019. ST98-2010. Energy Resources Conservation Board, Calgary, AB.

Environment Canada. 2010. National Inventory Report 1990-2008: Greenhouse Gas Sources and Sinks in Canada.

Flack, J.A. 1976. Bird populations of aspen forests in western North America. Ornithological Monographs No. 19.

Flannigan M.D., K.A. Logan, and B.D. Amiro. 2005. Future area burned in Canada. Climatic Change (72): 1-16.

Forrest, R.D. 1993. AL-PAC; A new stand for big. Papermaker, July:18–25.

Gerdes, K. J., and T. J. Skone. 2009. An Evaluation of the Extraction, Transport and Refining of Imported Crude Oils and the Impact on Life Cycle Greenhouse Gas Emissions. National Energy Technology Laboratory.

Gosseline, P., S.E. Hrudey, M.A. Naeth, A. Plourde, R. Therrien, G. Van Der Kraak, and Z. Xu. 2010. Environmental and Health Impacts of Canada's Oil Sands Industry. The Royal Society of Canada, Ottawa, ON.

Griffiths, M., and S. Dyer. 2008. Upgrader Alley: Oil Sands Fever Strikes Edmonton. The Pembina Institute, Drayton Valley, AB.

Hammond, H.E.J. 1995. The arthropod diversity of *Populus* spp. coarse woody material in aspen mixedwood forests of north-central Alberta: a progress report for Alberta Environmental Research Trust. Edmonton, AB.

Hansen, A.J.; Spies, T A.; Swanson, F.J.; Ohmann, J.L. 1991. Conserving biodiversity in managed forests. BioScience 41:382–392.

Hawksworth, D.L. 1991. The fungal dimension of biodiversity: magnitude, significance and conservation. Mycological Research 95:641–655.

Hayden, J. and D. Pursell. 2005. The Barnett Shale: Visitors Guide to the Hottest Gas Play in the US. Pickering Energy Partners, Inc.

Johnson, E. A., K. Miyanishi, and J. M. H. Weir. 1998. Wildfires in the western Canadian boreal forest: landscape patterns and ecosystem management. Journal of Vegetation Science 9(4): 603-610.

Juday, G.P., V. Barber, P. Duffy, H. Linderhorm, S. Rupp, S. Sparrow, E. Vaganov and J.Yarie. 2005. Forests, Land Management and Agriculture. Chapter 14. Arctic Climate Impact Assessment: Scientific Report. Cambridge University Press, UK.

Karaim, B.W.; Wengert, E.M.; Szabo, T. 1990. Opportunities for aspen and balsam poplar production in Alberta. pp. 253–274. In: Aspen symposium '89. Adams, R.D. (editor). Duluth, MI. U.S. Department of Agriculture, Forest Service, North Central Forest Experimental Station, St. Paul, MI. General Technical Report. NC–140.

Kirk, D.A., J.T. Fisher, and B. Eaton. 2009. Wildlife indicators for the Lower Athabasca Region of Alberta: building models to develop coefficients for simulations. Prepared for the Lower Athabasca Regional Plan by the Species Modelling Team, Government of Alberta.

Kochtubajda B., M.D. Flannigan, J.R. Gyakum, R.E. Stewart, K.A. Logan, and T.V. Nguyen. 2006. Lightning and fires in the Northwest Territories and responses to future climate change. Arctic 59(2): 211-221.

Kull, S. J., W. A. Kurz, G. J. Rampley, G. E. Banfield, R. K. Schivatcheva, and M. J. Apps. 2007. Operational-Scale Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) Version 1.0: Users Guide. Canadian Forest Service, Edmonton, AB.

Kurz, W. A. et al. 2009. CBM-CFS3: A model of carbon-dynamics in forestry and land-use change implementing IPCC standards. Ecological Modelling 220: 480-504.

La Roi, G.H.; Ostafichuk, M. 1982. Structural dynamics of boreal forest ecosystems on three habitat types in the Hondo-Lesser Slave Lake area of north central Alberta in 1981. Research Management Division Report. Alberta Environment, RMD/35A.

Lagimodiere, M. and B. Eaton. 2009. Fish and Fish Habitat Indicators for the Lower Athabasca Regional Plan (LARP): Description, Rationale and Modelling Coefficients. Prepared for the Lower Athabasca Regional Plan by the Fish Element Team, Government of Alberta.

Larsen, C.P.S. 1994. Spatial and Temporal Variations in Forest Fire Frequency in the Boreal Forest of Northern Alberta. Ph.D. Thesis, McMaster University, Hamilton, ON.

Lee, P. and R. Cheng. 2009. Bitumen and Biocarbon: Land-use Conversions and Loss of Biological Carbon due to Bitumen Operations in the Boreal Forests of Alberta, Canada. Global Forest Watch Canada, Edmonton, AB.

Lee, P. and S. Boutin. 2006. Persistence and development transition of wide seismic lines in the western Boreal Plains of Canada. Journal of Environmental Management 78:240-250.

Lee, P., Z. Stanojevic, and J. D. Gysbers. 2004. Canada's Commercial Forest Tenures, 2003. Global Forest Watch Canada, Edmonton, AB.

Levins, R. 1968. Evolution in changing environments. Princeton University Press. Princeton, N.J.

MacArthur, R.H.; MacArthur, J.W.; Preer, J. 1962. On bird species diversity. II. Prediction of bird census from habitat measurements. American Naturalist 96:167–174.

MacFarlane, A. 1999. Revegetation of Wellsites and Seismic Lines in the Boreal Forest. University of Alberta Department of Biological Science Honour's Thesis.

Mahmoud M., Y. Liu, H. Hartmann, S. Stewart, T. Wagener, D. Semmens, R. Stewart, H. Gupta, D. Dominguez, F. Dominguez, D. Hulse, R. Letcher, B. Rashleigh, C. Smith, R. Street, J. Ticehurst, M. Twery, H. van Delden, R. Waldick, and D. White. 2009. A formal framework for scenario development in support of environmental decision-making. Environmental Modeling and Software 24:798-808.

Maser, C.; Trappe, J.M. 1985. Food habits of the northern flying squirrel (*Glaucomys sabrinus*) in Oregon. Canadian Journal of Zoology 63:1084–1088.

May, R.M. 1975. Patterns of species abundance and diversity. pp. 81–120. In: Chapter 4. Ecology and evolution of communities. Cody, M.L.; Diamond, J.M. (editors). Harvard University Press, Cambridge, MA.

McCulloch, M., M. Raynolds, and R. Wong. 2006. Carbon Neutral 2020: A Leadership Opportunity in Canada's Oil Sands. The Pembina Institute, Drayton Valley, AB.

McInnis, J. 1994. Northern Alberta. pp. 19–25. In: The taiga; a treasure or timber and trash. Taiga Rescue Network. 5th edition.

McKenzie-Brown, P. 1993. The greening of Al-Pac. Canadian Resources Review, November–December: 9–11.

Meslow, C.E. 1978. The relationship of birds to habitat structure: plant communities and successional stages. pp. 12–18. In: Proceedings of Workshop on Non-game Bird Habitat Management in the Coniferous Forest of the western United States. De Graff, R.M. (editor). February 7–9, 1977. Portland, OR. U.S. Dept. Agriculture Forest Service, Pacific NW Forest Range Experimental Station, General Technical Report PNW–69.

Millington, D., and M. Mei. 2011. Canadian Oil Sands Supply Costs and Development Projects (2010-2044). Canadian Energy Research Institute, Calgary, AB.

Mossop, G., and I. Shetsen. 1994. Geological Atlas of the Western Canada Sedimentary Basin. Available online: http://www.ags.gov.ab.ca/publications/wcsb_atlas/atlas.html.

National Energy Board (NEB). 2003. Canada's Energy Future: Scenarios for Supply and Demand to 2025. National Energy Board, Calgary, AB.

National Energy Board (NEB). 2009. A Primer for Understanding Canadian Shale Gas. National Energy Board, Calgary, AB.

Natural Resources Canada. 2008. Canadian Natural Gas: Review of 2007/08 & Outlook to 2020. Natural Gas Division, Petroleum Resources Branch, Natural Resources Canada, Ottawa, ON.

Nikiforuk, A.; Struzik, E. 1989. The great forest sell-off. The Globe and Mail Report on Business, November 1989.

Nishi, J. S., and T. Antoniuk. 2010. Cumulative Effect Thresholds and Natural Gas Development Scenarios in the Southern Dehcho. Unpublished report prepared for Indian and Northern Affairs Canada and Department of Environment and Natural Resources, Government of the Northwest Territories.

North Saskatchewan Watershed Alliance (NSWA). 2009. Cumulative Effects Assessment of the North Saskatchewan River Watershed using ALCES. 32 pp + app. Submitted by Dr. M.G. Sullivan, ALCES Group. Edmonton, Alberta: The North Saskatchewan Watershed Alliance Society. Available on the internet at http://nswa.ab.ca/cumulative_effects.

Olson, D.M. 1992. The northern spotted owl conservation strategy: implications for Pacific Northwest forest invertebrates and associated ecosystem processes. Final report to the Northern Spotted Owl EIS Team, U.S. Department of Agriculture, Forest Service, OR. 51 pp.

PACTeam Canada. 2003. A Spatial Analysis and Literature Review of Timber Potential in the Deh Cho Territory, NWT. Unpublished report prepared for the Deh Cho Land-use Planning Committee.

Park, D., M. Sullivan, E. Bayne, and G. Scrimgeour. 2008. Landscape-level stream fragmentation caused by hanging culverts along roads in Alberta's boreal forest. Canadian Journal of Forest Research 38:566-675.

Pettapiece, W.W. 1986. Physiographic subdivision of Alberta. Agriculture Canada, Alberta Institute of Pedology, Edmonton, AB.

Pollard, D.F.W. 1971. Mortality and annual changes in distribution of above-ground biomass in an aspen sucker stand. Canadian Journal of Forest Research 1:262–266.

Power, K.; Gillis, M.D. 2006. Canada's forest inventory 2001. Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C., Information Report BC-X-408E. 100 p.

Pratt, L.; Urquhart, I. 1994. The last great forest; Japanese multinationals and Alberta's northern forests. NeWest Press Edmonton, AB.

Prebble, P., A. Coxworth, T. Simieritsch, S. Dyer, M. Huot, and H. Walsh. 2009. Carbon Copy: Preventing Oil Sands Fever in Saskatchewan. The Pembina Institute, Saskatchewan Environmental Society, and Canadian Parks and Wilderness Society.

PriceWaterhouseCoopers. 2009. Alberta Industry Sector Performance and Prospects. PriceWaterhouseCoopers.

Probst, J.R.; Rakstad, D.S. 1987. Small mammal communities in three aspen stand-age classes. Canadian Field Naturalist 101:362–368.

Rainey, W.E.; Pierson, E.D.; Colbert, M.; Barclay, J.H. 1992. Bats in hollow redwoods: seasonal use and role in nutrient transfer into old-growth communities. Bat Research News 33:71.

Schieck, J., and S. J. Song. 2006. Changes in bird communities throughout succession following fire and harvest in boreal forests of western North America: literature review and meta-analyses. Canadian Journal of Forest Research 36: 1299–1318.

Schneider, R. R., G. Hauer, W. L. Adamowicz, and S. Boutin. 2010. Triage for conserving populations of threatened species: the case of woodland caribou in Alberta. Biological Conservation 143: 1603-1611.

Schneider, R., and S. Dyer. 2006. Death by a Thousand Cuts: Impacts of In Situ Oil Sands Development on Alberta's Boreal Forest. Canadian Parks and Wilderness Society and The Pembina Institute.

Schneider, R.R. 2002. Alternative Futures: Alberta's Boreal Forest as the Crossroads. The Federation of Alberta Naturalists and The Alberta Centre for Boreal Research, Edmonton, Alberta.

Spence, J.; Langor, D. 1994. Effects of forestry practices on biodiversity of litter-dwelling beetles in aspen forests. Final report to Alberta Forest Research Development Trust Fund, Edmonton, AB.

Statistics Canada. 2001a. 2001 Census of Agriculture. Available online at http://www.statcan.ca/english/agcensus2001/index.htm.

Statistics Canada. 2001b. 2001 Census of Population. Available online at http://www12.statcan.ca/english/census01/home/Index.cfm.

Statistics Canada. 2006a. 2006 Census of Agriculture. Available online at http://www.statcan.gc.ca/ca-ra2006/index-eng.htm.

Statistics Canada. 2006b. 2006 Census of Population. Available online at http://www12.statcan.ca/census-recensement/2006/dp-pd/index-eng.cfm.

Stevenson, S. 1993. It is all systems go for Alberta-Pacific. Pulp & Paper Canada 94(11):13–18.

Stocks, B.J. et al. 2002. Large forest fires in Canada, 1959-1997. Journal of Geophysical Research 107: 8149 doi:10.1029/2001JD000494.

Strong, W.; Leggat, K.R. 1992. Ecoregions of Alberta. Prepared for Alberta Forestry, Lands and Wildlife, Land Information Services Division, Resource Information Branch. Publication Number T:245.

Sullivan, M. 2006. CEMA INFI Indicator Criteria. Presentation to CEMA SEWG.

Swan, J.M.A.; Dix R.L. 1966. The phytosociological structure of upland forest at Candle Lake, Saskatchewan. Journal of Ecology 54:13–40.

Tarnocai, C. 2006. The effect of climate change on carbon in Canadian peatlands. Global Planet. Change 53:222-232.

Thomas, J.W. (editor) 1979. Wildlife habitat in managed forests. The Blue Mountains of Oregon and Washington. Agricultural Handbook No. 553. Department of Agriculture, Forest Service, Washington, D.C.

Thomas, J.W. (editor) 1993. Forest ecosystem management: an ecological, economic, and social assessment. Report of the Forest Ecosystem Management Assessment Team. U.S. Department of Agriculture, Forest Service.

Thomson, N. and A. Shaw. 2011. Fracking in BC: Integrating Climate Change Issues. Pacific Institute for Climate Solutions Briefing Note 2011-29.

Timilsina, G.R., N. LeBlanc, and T. Walden. 2005. Economic Impacts of Alberta's Oilsands. Canadian Energy Research Institute, Calgary, AB.

Tolko High Level Lumber Division and Footner Forest Products Ltd. 2003. Integrated Detailed Forest Management Plan.

TransCanada. 2011. National Energy Board Approves Horn River Pipeline Project B.C. Shale Gas Production Projected to Rise Significantly. February 4 2011 News Release. Available online: http://www.transcanada.com/5639.html.

Turetsky, M., and V. St. Louis. 2006. Disturbance in boreal peatlands. Ecological Studies 188: 359-379.

Turetsky, M., K. Wieder, L. Halsey, and D. Vitt. 2002. Current disturbance and the diminishing peatland carbon sink. Geophysical Research Letters 29(11).

Turunen, J. 2008. Development of Finnish peatland area and carbon storage 1950-2000. Boreal Environment Research 13:319-334.

Upton, B., R. Miner, and K. Vice. 2007. The Greenhouse Gas and Carbon Profile of the Canadian Forest Products Industry. Special Report No. 07-09. National Council for Air and Stream Improvement, Inc., Research Triangle Park, NC.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Journal of Wildlife Management 47:893–901.

Van Wanger, C.E. 1978. Age-class distribution and the forest fire cycle. Canadian Journal of Forest Research 8: 220-227.

Vitt, D. H., L. A. Halsey, I. E. Bauer, and c. Campbell. 2000. Spatial and temporal trends in carbon storage of peatlands of continental western Canada through the Holocene. Canadian Journal of Earth Sciences 37: 683-693.

Westworth D.A.; Brusnyk, L.M.; Burns, G.R. 1984. Impact on wildlife of short-rotation management of boreal aspen stands. D.A. Westworth and Associates Ltd. Edmonton, AB. 134 pp.

Westworth, D.A.; Telfer, E.S. 1993. Summer and winter bird populations associated with five age-classes of aspen forests in Alberta. Canadian Journal of Forest Research 23:1830–1836.

Wiken, E., J. Cinq-Mars, M. Padilla, and C. Latsch. 2003. The state of Canadian wetlands: Building a conservation strategy. In: C. D. A. Rubec (ed.), Wetland Stewardship in Canada: Contributed Papers from the Conference on Canadian Wetlands Stewardship, Feb 3-5 2003, Ottawa, ON. North American Wetlands Conservation Council Canada.

Willis, J. Evolving water use regulations in British Columbia's Emerging Shale Gas Regions. Presentation at WaterTech 2011, April 13-15 2011 Banff, Alberta. Environmental Services Association of Alberta. Available online: http://www.esaa-events.com/watertech/2011/default.htm.

Wilson, B., J. B. Stelfox, and M. Patriquin. 2008. SEWG Workplan Facilitation and Modelling Project: Data Inputs and Assumptions. Unpublished report prepared for the Cumulative Effects Management Association. Available online: www.cemaonline.ca.

Wilson, E.O. 1992. The diversity of life. The Belknap Press of Harvard University Press, Cambridge, MA.

Young, J. 1993. Alberta-Pacific's bleached kraft market pulp mill sets for startup. Pulp & Paper July:67–75.

APPENDICES

12.1 APPENDIX A. CLFN ALCES TECHNICAL MANUAL

This appendix is lengthy and is provided as a separate document.

12.2 APPENDIX B. REPORT ON HYDROCARBON VOLUMES AND RECOVERY FACTORS FOR ALCES COLD LAKE FIRST NATIONS PROJECT

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Dated May 31st 2012

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Introduction

This report has been undertaken at the request of Witten LLP Inc., who is working with Dr. Brad Stelfox of ALCES Group in assessing the impact of oil sands development on the Cold Lake First Nations area.

Scope

The scope for this report is as follows:

- Gather and verify the resource numbers pertaining to the Cold Lake Area from ERCB public database and reports
- Subdivide the resource by deposit and by recovery methods currently/historically employed
- Assign recovery factors to each deposit
- Determine remaining amount of recoverable oil through existing methods (attached)
- Estimate Natural Gas coming out of solution from production of Bitumen
- Estimate SO_2 emissions from production of Bitumen as a function of recovery method

The outputs from this report will form part of the input for ALCES simulation model to determine future environmental, ecological and economic impact of developing those resources.

Methodology and Sources of Data

The methodology in this report primarily uses publicly available data through the ERCB's website, and technical reports and papers available for download. We have also drawn upon previous experience from working on oil sands projects in the Cold Lake area and have made certain assumptions, which are highlighted in the report.

Sources of data are found in the reference section at the end of the report.

Resource estimates

The Resource numbers are summarized below in Table 1.

Table 1: Heavy Oil & Bitumen in place in the Cold Lake Oil sands area

	Primary Extraction of Heavy Oil	**Cyclic Steam Stimulation (CSS)**	**Steam-Assisted Gravity Drainage (SAGD)**	**Total Heavy Oil & Oilsands Volume**
In-Place	Billion m^3	Billion m^3	Billion m^3	Billion m^3
Grand Rapids (Upper & Lower)	10.25	2.56	2.56	15.38
Clearwater	0	7.54	1.88	9.42
Wabiskaw/ Ft. McMurray	0	4.29	0	4.29
Total	**10.25**	**14.39**	**4.44**	**29.09**
Recoverable Fraction	5%	25%	50%	
Recoverable	Billion m^3	Billion m^3	Billion m^3	Billion m^3
Grand Rapids (Upper & Lower)	0.51	0.64	1.28	2.43
Clearwater	0	1.89	0.94	2.82
Wabiskaw/ Ft. McMurray	0	1.07	0	1.07
Total	**0.51**	**3.60**	**2.22**	**6.32**
				21.7% Overall

The In-place numbers and the Recoverable fraction in the above table are taken from ERCB's report: **ST98-2011: Alberta's Energy Reserves 2010 and Supply/Demand Outlook 2011-2020** dated June 2011[1].

Table 3.3 from this report is reproduced below to demonstrate the Cold Lake Oil sands deposit to be estimated at 29.09 billion m^3 of bitumen and heavy oil.

Table 3.3 Initial in-place volumes of crude bitumen as of December 31, 2010

Oil sands area Oil sands deposit	Initial volume in place (10^6 m^3)	Area (10^3 ha*)	Average pay thickness (m)	Average bitumen saturation: Mass (%)	Average bitumen saturation: Pore volume (%)	Average porosity (%)
Athabasca						
Grand Rapids	8 678	527	9.6	6.5	57	30
Wabiskaw-McMurray (mineable)	20 823	375	25.9	10.1	76	28
Wabiskaw-McMurray (in situ)	131 609	4 694	13.1	10.2	73	29
Nisku	10 330	499	8.0	5.7	63	21
Grosmont	64 537	1 766	23.8	6.6	79	20
Subtotal	**235 977**					
Cold Lake						
Upper Grand Rapids	5 377	612	4.8	9.0	65	28
Lower Grand Rapids	10 004	658	7.8	9.2	65	30
Clearwater	9 422	433	11.8	8.9	59	31
Wabiskaw-McMurray	4 287	485	5.1	8.1	62	28
Subtotal	**29 090**					
Peace River						
Bluesky-Gething	10 968	1 016	6.1	8.1	68	26
Belloy	282	26	8.0	7.8	64	27
Debolt	7 800	258	25.3	5.1	66	18
Shunda	2 510	143	14.0	5.3	52	23
Subtotal	**21 560**					
Total	**286 627**					

*ha—hectare.

<u>Recovery Factors</u>
The recovery factors for Primary Cold Heavy Oil Production, Cyclic Steam Stimulation (CSS), and Steam Assisted Gravity Drainage (SAGD) have been taken respectively as 5%, 25% and 50% in line with ERCB's estimates[1]. A brief description follows for each Recovery method.

Primary Recovery
ERCB estimates the Primary Recovery factor in the Cold Lake Area to be 5%. This is borne out by empirical evidence from primary projects operating in the area as represented in Table 3.5 on the following page which is extracted from the ST98-2011[1] report. This number appears reasonable based on >500 million barrels of oil cumulatively recovered by the end of December 2010 through primary methods. This number does not explicitly indicate potential recovery from Enhanced recovery methods such as waterflooding, polymer flooding, or CO_2 injection which can raise the recovery factor in the range of 8 -10%. For the purpose of this report we have aimed to be conservative in estimates of recoverable oil, therefore 5% is taken as an overall recovery factor for primary production from Cold Lake oil sands deposit.

Table 3.5 In situ crude bitumen reserves[a] in areas under active development as of December 31, 2010

Development	Initial volume in place (10^6 m^3)	Recovery factor (%)	Initial established reserves (10^6 m^3)	Cumulative production[b] (10^6 m^3)	Remaining established reserves (10^6 m^3)
Peace River Oil Sands Area					
Thermal commercial projects	55.8	40	22.3	10.8	11.5
Primary recovery schemes	160.8	10	16.1	10.2	5.9
Subtotal[c]	**216.6**		**38.4**	**21.0**	**17.4**
Athabasca Oil Sands Area					
Thermal commercial projects	313.7	50	156.9	68.0	88.9
Primary recovery schemes	1 026.2	5	51.3	22.5	28.8
Enhanced recovery schemes[d]	(289.0)[e]	10	28.9	15.9	13.0
Subtotal[c]	**1 339.9**		**237.1**	**106.4**	**130.7**
Cold Lake Oil Sands Area					
Thermal commercial (CSS)[f]	1 212.8	25	303.2	211.5	91.7
Thermal commercial (SAGD)[g]	33.8	50	16.9	1.9	15.0
Primary recovery schemes	6 257.5	5	313.0	84.3	228.7
Subtotal[c]	**7 504.1**		**633.0**	**297.7**	**335.4**
Total[c]	**9 060.7**		**908.5**	**425.1**	**483.5**

[a] Thermal reserves reported in this table are assigned only for lands on which thermal recovery is approved and drilling development has occurred.
[b] Cumulative production to December 31, 2010, includes amendments to production reports.
[c] Any discrepancies are due to rounding.
[d] Schemes currently on polymer or waterflood in the Brintnell-Pelican area. Previous primary production is included under primary schemes.
[e] The in-place number is that part of the primary number above that will see incremental production due to polymer or waterflooding.
[f] Cyclic steam simulation projects.
[g] Steam-assisted gravity drainage projects.

In-situ thermal recovery – Cyclic Steam Stimulation
As can be seen from the table above, more than 1.3 billion barrels of oil have been recovered from the Cold Lake area through Cyclic Steam Stimulation (CSS). The in-situ performance report[2] from the major operator of CSS in the Cold Lake Area (Imperial Oil) reveals that Imperial is forecasting recoveries in the range of 30-40% on some CSS pads, a part of which is anticipated through their LASER (Liquid Addition to Steam for Enhancing Recovery) process. Imperial estimates that LASER can enhance recovery by >5% of the estimated bitumen in place.

CNRL's insitu performance presentation for Wolf Lake[3] estimates CSS recovery factor to be 21 – 26% for Valley fill CSS area and 25 – 28% for C3 sand.

Similar to the approach used for primary recovery factor, we have taken the conservative route by following the ERCB accepted recovery factors of 25% for CSS operations throughout the Cold Lake Area.

In-situ thermal recovery – Steam Assisted Gravity Drainage
The cumulative recovery to date from SAGD operations in the Cold Lake Area has been relatively minor compared to CSS. Various operators including Shell at Orion[4], Husky at Tucker Lake[5], and CNRL at Wolf Lake and Burnt Lake[3], have estimated targeted ultimate recovery from SAGD operations in the range of 45–55%.

A couple of wells in Shell's Hilda Lake Pilot[4], and CNRL's Wolf Lake Pad SD9[3] are exhibiting Recovery factors to date in excess of 40% which supports the estimated ultimate recovery of 50% from SAGD operations.

Though the realistic recovery factors can be expected to be >50% on most SAGD projects, we have consistently tried to err on the side of caution in this report so as not to overstate the volumes of recoverable bitumen, and have accepted ERCB's estimate of recovery factor of 50% for SAGD as being reasonable.

Gas Oil Ratio – GOR

The gases produced with bitumen in In-situ thermal operations are for the most part a mixture of methane, CO_2, and H_2S. For the purpose of this report the GOR discussions are confined to the ratio of methane to bitumen volumetrically on a m^3/m^3 basis.

The solubility of Methane has been discussed in the technical literature in reasonable detail. Svrcek and Mehrotra[6] have discussed binary gas mixtures of CO_2 and CH_4. Dr. Harald Thimm has created a body of work on gas solubility and production in SAGD operations[7] and has predicted the range of GOR to be between 1 and 16. There has been some empirical evidence from operating projects in the Cold Lake area that the natural gas (methane) production ratio to bitumen is ~10:1.

The author has crosschecked solubility of Methane in Bitumen against the equation provided in Roger Butler's text on thermal recovery of bitumen and heavy oil[8] by assuming reservoir pressure of 3,500 kPa and reservoir temperature of 15 deg C and has come up with a number of 9.55 m^3/m^3 for the methane to bitumen ratio which is very close to the assumed ratio of 10.

SO_2 emissions

Dr. Harald Thimm's work[7] on prediction of GOR and H_2S concentrations gives a range of H2S from 1,000 to 30,000 ppm. As H_2S is a product of aquathermolysis in thermal In-situ operations, it is predicted that as temperature goes higher and higher more H_2S will be produced hence the large range of H_2S prediction covers low pressure operations as well as high pressure due to the fact that in thermal operations utilizing steam the saturation temperature is a direct function of pressure.

In examining the contents from Husky's in-situ performance presentation to the ERCB, Shell's report and Imperial's report on Cold Lake operations, the following observations and calculations were made:

Husky's Tucker Lake operations - SAGD

At Husky Tucker Lake the produced SO2 has been reported in the range of 0.4 T/d through February to May 2011 for a corresponding Bitumen production rate of ~1,000 m^3/d[5] which comes out to a ratio of 0.0004 T/ m^3 of bitumen. More recently the SO_2 rate has been anecdotally quoted in excess of 1.0 T/d for a corresponding Bitumen production rate of ~1,600 m^3/d which comes out to be 0.000625 T/m3.

Shell's Orion operations - SAGD

At Shell's Orion project the SO2 numbers reported for the period Oct – Dec 2010 are 0.4 T/d for a corresponding Bitumen production rate of ~650 m^3/d[4] which corresponds to a ratio of 0.000615 T/ m^3. This ratio is very close to the recent estimates at Husky's SAGD operations in the same Clearwater formation.

Imperial's Cold Lake - CSS

At Imperial's Cold Lake operations the SO_2 numbers reported are an average 694 Tons per month for the period Oct to Dec 2010[2] and the corresponding average monthly bitumen production is reported as 723,066 m^3, therefore the ratio of SO_2 to bitumen is 0.00095 T/m3. This higher ratio for Imperial's CSS operations is explained by the higher pressure and correspondingly higher saturation temperature at which CSS is operated compared to SAGD.

Primary Recovery

There is very little evidence of any H2S production in cold Heavy Oil production operations in the Cold Lake Area therefore for Primary production this ratio can be assumed to be zero.
In summary for the purpose of providing input to ALCES, the SO_2 to Bitumen ratio has been estimated to be 0.000625 T/m3 for SAGD operations, 0.0009 T/ m^3 for CSS, and zero for Primary recovery.

List of References

1. ENERGY RESOURCES CONSERVATION BOARD, ST98-2011: Alberta's Energy Reserves 2010 and Supply/Demand Outlook 2011-2020, June 2011.
2. ESSO Imperial Oil, Cold Lake Approvals 8558 and 4510 Annual Performance Review 2011.
3. Canadian Natural Resources Ltd., 2011 Primrose, Wolf Lake, and Burnt Lake Annual Presentation to the ERCB, Subsurface Issues related to Resource Evaluation and Recovery, January 25, 2012.
4. Shell Canada Ltd., In Situ Oil Sands Progress Presentation, Hilda Lake Pilot 8093 Orion 10103, April 21st 2011.
5. Husky Oil Operations Ltd., Tucker Thermal Project, Commercial Scheme #9835, Annual Performance Presentation, Energy Resources Conservation Board, June 27, 2011.
6. A.K. Mehrotra and W.Y. Svrcek, "Correlation and Prediction of Gas Solubility in Cold Lake Bitumen", The Canadian Journal of Chemical Engineering, Vol 66, August 1988.
7. Harald F. Thimm, "Overview of SAGD Operations: Gas, Solvents and Water", Canadian Heavy Oil Association Dec 2006.
8. Roger Butler, "Thermal Recovery of Oil and Bitumen", equation 2 Pg. 510.