Agricultural Land Evaluation Report For Energy Projects

Alberta Utilities Commission

Prepared for:

Alberta Utilities Commission

Submitted By:

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Definitions

Admixing	The mixing of subsoil horizons with topsoil layers. Generally, an undesirable result of poorly handled soil. Admixing of up to 20% is generally accepted as an unavoidable result of the soil disturbance process.
Agricultural land	Land that is arable and used for crops, hay, pasture, food production, and rearing of animals.
Agricultural Region of Alberta Soil Inventory Database	A spatial database for the soils of Alberta's agricultural area that is ideal for regional, and field scale, land use assessment and decision making.
Agrivoltaic systems	A system allowing for the coexistence of solar panels with agricultural crops on the same piece of land. Systems can take the form of greenhouse, annual crop, livestock, or forage production. Solar panels are elevated to allow space underneath for agricultural activities.
Annual crop production	An agricultural system under which plants are grown and harvested within a single growing season.
Bulk density (soils)	Bulk density is an indicator of soil compaction. It is calculated as the dry weight of soil divided by its volume. This volume includes the volume of soil particles and the volume of pores among soil particles. Bulk density is typically expressed in g/cm3.
C3 cereals	Cereal crops, such as wheat and barley, that utilize the C3 photosynthetic pathway.
C3 species	Plants adapted to cool, wet environments, as opposed to C4 species, which are adapted to warmer conditions.
Canadian Land Inventory	A comprehensive multi-disciplinary land inventory of rural Canada that covers over 2.5 million square kilometers and provides information on land capability for multiple resource users like agriculture, forestry, wildlife, and recreation.
Canadian Soil Information Service	An authoritative source of soil data and land resource information for Canada.
Carbonates	Compounds within soil that result from the weathering of original minerals rich in calcium. In addition to buffering soil pH against acidification, soil carbonates are also important for sequestering heavy metals.
Drought conditions	A prolonged period of unusually dry weather resulting in a depletion of both natural and man-made sources of water.
Ecosite	A distinctive kind of land with specific physical characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation (Adams et al., 2016).
Electrical grid	Network of electrical transmission lines that transfer power from where it is generated to the end user.
Environmental Protection Plan	A plan that outlines standard measures and best management practices to prevent or mitigate environmental impacts from the construction of a project.
Erosion	The wearing away of the land surface by geological agents, such as water, wind, or ice, which transport soil material from one location to another.

Geothermal energy	Heat that is contained within the earth subsurface.
Green area	A land use designation used in Alberta to generally describe land that is under the authority of the provincial Crown, in unsettled areas of the province, with land uses that include timber production, oil and gas, tourism, recreation, conservation, watershed protection, and wildlife habitat.
Healthy	A scoring used when evaluating the health of grasslands, modified grasslands, tame pasture, and forests where a score of ≥75% is given as the ecosystem is functional, healthy, and providing the expected goods and services it produces.
Healthy with Problems	A scoring used when evaluating the health of grasslands, modified grasslands, tame pasture, and forests where a score of <75% to >50% is given, where moderate to heavy disturbance or grazing has compromised the integrity of the ecosystem. The ecosystem is no longer performing all of its key functions.
Horticulture	The cultivation of plants in either indoor or outdoor greenhouses.
Hydraulic properties (soil)	Soil hydraulic properties determine the rate at which water and other fluids move through soils. It also determines their water holding capacity, microbial activity, and biogeochemical processes.
Hydro-electric	Hydroelectric energy, also called hydroelectric power or hydroelectricity, is a form of energy that harnesses the power of water in motion—such as water flowing over a waterfall—to generate electricity.
Interim Reclamation	interim reclamation is the reclamation that occurs immediately following construction to bring the land back to equivalent land capability post construction. The sooner interim reclamation is performed the higher its chances of success.
Inundation (water)	A flood or being flooded with water.
Land Capability Class	Land classification depicting the varying potential of lands for agricultural production, as outlined in the Canada Land Inventory (Government of Canada, 2019)
Land Equivalent Ratio	The land equivalent ratio is a concept in agriculture that describes the relative land area required under sole cropping to produce the same yield as under intercropping. Generally, a LER value of 1.0 indicates no difference in yield between the intercrop and the sole crop, while a value of greater than 1.0 indicates a yield advantage for intercrop, and LER values of less than 1.0 indicates a disadvantage of the intercrop.
Land Suitability Rating System	Procedure for rating the sustainability of land for agricultural spring-seeded small grain and hardy oil seeds, based on the climate-soil-landscape potential. This tool replaces the Canadian Land Inventory Tool in Alberta.
Leaching	Leaching is the loss or extraction of certain materials from a carrier into a liquid (usually, but not always a solvent). and may refer to: Leaching (agriculture), the loss of water-soluble plant nutrients from the soil; or applying a small amount of excess irrigation to avoid soil salinity.

National Soil Database	A collection of geospatial datasets which contain soil, landscape, and climatic data for all of Canada, serving as the national archive for land resources information that was collected by federal and provincial field surveys, or created by analysts. Included in this database is the National Ecological Framework, Soil Landscapes of Canada, the Canadian Land Inventory, Detailed Soil Surveys, National Pedon Database, and soil name and profile data.
Paratillage	Paratilling is a form of non-inversion deep tillage sought after by producers for its effectiveness at loosening soil structure without compromising the soil conservation practices that are already employed.
Parent material (soil)	Patent material is the base layer of soil below the topsoil and subsoil. Typically weathering of parent material creates the surface soils above it and its physical characteristics affect the surface soil layers.
Park effect	The park effect is the process where wind turbines will shade one another from the wind, thus energy is lost if wind turbines are spaced too closely.
Photovoltaic panels	A device (commonly called a solar panel) that converts solar energy into electricity.
Primary agriculture	Work that is performed within the boundaries of a farm, nursery, or greenhouse.
Public land	Another term to describe the green area in Alberta, more specifically, land that is owned by the provincial Crown.
Pulse Crops	Annual crops that yield between one and 12 grains or seeds.
Referral report	Desktop siting and pre-application wildlife surveys conducted by a developer to determine a renewable projects risk to wildlife resources. The Referral Report is reviewed by Alberta Wildlife Biologists prior to project approval.
Rig matting	Rig mats are sometimes known as swamp mats or access mats. Rig mats are primarily used for extremely heavy loads. They are typically built out of layer of wood.
Ripping	A ripper aerates and loosens soil while leaving the organic matter at the soil top, a ripper is used for tillage.
Run-of-river hydroelectricity	Run-of-river hydropower: a facility that channels flowing water from a river through a canal or penstock to spin a turbine. Typically, a run-of-river project will have little or no storage facility.
Salinity	Soils with amounts of soluble salts sufficient to have an adverse affect on growth.
Silage Crops	silage crops are forage plants such as corn (maize), legumes, and grasses that have been chopped and stored in tower silos, pits, or trenches for use as animal feed.
Sodicity	Soils which have exchangeable sodium sufficient to have adverse effects on soil structure and/or growth
Soil Landscape Model	A conceptual entity that summarizes characteristics of several areas of land by amalgamation of the soil model (composite of dominant or codominant and significant soils found in a polygon) and landscape model (composite of morphology, genesis, relief, slope class, surface form modifiers).

Soil Porosity	Soil porosity refers to the number of pores, or open space, between soil particles. Pore spaces may be formed due to the movement of roots, worms, and insects; expanding gases trapped within these spaces by groundwater; and/or the dissolution of the soil parent material. Soil texture can also affect soil porosity.
Subsoil	Subsoil refers to the stratum of soil immediately below the surface soil or topsoil. It typically has been modified by biological activity and physical weathering to be different than parent materials (Mahmoudi, 2020).
Tillage	Tillage is the manipulation of the soil into a desired condition by mechanical means; tools are employed to achieve some desired effect (such as pulverization, cutting, or movement).
Topsoil	topsoil is the surface layer of soil that has been modified through weathering and biological activities. This layer of soil is typically known for providing high levels of fertility, water holding capacity and is full of biological life
Unhealthy	A scoring used when evaluating the health of grasslands, modified grasslands, tame pasture, and forests where a score of ≤50% is given, where long term heavy disturbance has significantly compromised the integrity of the ecosystem. It may enter a modified state that can never regain the function it has prior to disturbance.
White area	Most of the privately owned land are within the white area of the province, where agricultural use is primarily concentrated

Acronyms

ac	Acre
AGRASID	Agricultural Region of Alberta Soil Inventory Database
ALQM	Agriculture Land Quality Model
ALSA	Alberta Land Stewardship Act
AUC	Alberta Utilities Commission
AVI	Alberta Vegetation Inventory
BMPs	Best Management Practices
C&R	Conservation and Reclamation
C&R	Closure & Reclamation Plan
CanSIS	Canadian Soil Information Service
CLI	Canadian Land Inventory
cm	Centimeters
CSP	Concentrated Solar Power
DRA	Desktop Review Assessment
EC	Electrical conductivity
ELC	Equivalent land capability
EPA	Environmental Protection Agency
EPP	Environmental Protection Plan
EPP	Environmental Protection Plan
GDP	Gross Domestic Product
GVI	Grassland Vegetation Inventory
GWh	Gigawatt hour
ha	Hectare
II	Irrigation Infrastructure
IL	Irrigation Land
ILR	Irrigation Land Ranking
LER	Land Equivalent Ratio
LSRS	Land Suitability Rating System
LUIE	Land Use Intensity of Electricity
m	Meters
MGA	Municipal Government Act
MW	Megawatt
MWh	Megawatt hour
NPC	Native Plant Communities
NSDB	National Soils Database
PDSA	Pre-disturbance Site Assessment
PLVI	Primary Land and Vegetation Inventory
PV Panel	Photovoltaic Panel
REO	Renewable Energy Operator
RHA	Range Health Assessment
RMA	Rural Municipalities of Alberta

RoW	Right of Way
SAR	Sodium adsorption ratio
SOC	Soil Organic Carbon
SQC	Soil Quality Criteria
SSRP	South Saskatchewan Regional Plan
TWh	Terawatt-hour

Executive Summary

Understanding agricultural land and productive capacity within Alberta is an essential step to transitioning to a net zero system that benefits all Albertans. The expansion of our renewable energy sector should consider high value agricultural lands. The numerous publicly available soil and vegetation datasets in the province can be used to assess, and ultimately protect agricultural lands. Currently, there are no data sources that are aggregated to show comprehensive agricultural land value within Alberta. The creation of a database addressing this gap would facilitate consistent planning and uniform assessment of agricultural lands impacted by energy developments. The development of an Agriculture Land Quality Model (ALQM) capable of identifying high quality agriculture land is proposed to inform agricultural land valuation. The ALQM would provide stakeholders with a standardized way to assess agricultural land value for agricultural land conservation.

An agriculture first approach has been proposed to mitigate energy development impacts on the agricultural sector. Requirements for agricultural production minimums for all projects sited on agricultural land should be legislated to protect Albertas primary producers. To facilitate this, a four-tiered approach was proposed corresponding with specific requirements for maintaining agricultural land productivity for power plant siting and planning purposes. These are: Tier 1 (Very high to high value land), Tier 2 (Moderate to high value land), Tier 3 (Low to moderate value land), and Tier 4 (low to very low value land). The higher the value of agricultural land the tighter the restrictions and mitigations would be for energy projects sited on them. This approach will support continued production from valued agricultural land, while promoting power plant development through clear regulatory pathways. The mechanism, which acts as a novel engineering control, should be combined with standardizing construction best management practices to protect our agricultural communities.

An agricultural directive for power plants is recommended, with detailed guidance on protecting agricultural resources, particularly for renewable energy development. The document should outline minimum production yield requirements for each tier of agricultural land, required pre-approval soil and vegetation surveys, appropriate construction and reclamation requirements to ensure equivalent land capability is reached, and monitoring and assessment requirements for interim and final reclamation. Specific data related to soil and vegetation collected during pre-approval field surveys will inform the design process and demonstrate that due diligence has been applied. The interim and final reclamation requirements outlined in the directive will focus on the level of effort required to maintain agricultural production following construction. Adoption of techniques such as agrivoltaics should be considered within high value agricultural land and be accompanied by minimum requirements for types of crops and crop yields instead of prohibition of development on high value lands. If energy projects are compatible with agricultural production they should be encouraged.

Reclamation requirements to meet equivalent land capability are relatively well understood in Alberta by other parts of the energy sector, like oil and gas. Many of the physical impacts to land within the renewable energy sector are the same as those within oil and gas. Therefore, it is possible to leverage the decades of research and public engagement that the oil and gas sector has conducted to amend the existing renewable C&R directive to provide a uniform standard for reclamation assessment and certification for all energy projects to follow. Utilizing best management practices in soil handling, erosion control, minimal disturbance techniques and mitigating compaction it is possible to maximize our ability to bring land back to equivalent land capability.

1.0 Introduction

Two major sectors in Alberta are agriculture and energy production. While oil and gas are the most prominent part of the Alberta energy sector, the sector has seen a dramatic change in the last decade through the push for a more sustainable electrical grid. This energy transition will bring Alberta to a carbon neutral state by 2050 and require the adoption and acceptance of new technologies. The *Renewable Electricity Act* outlines Alberta's commitment to increasing the amount of green energy produced in the province, including a legislated target of 30.0% renewable electricity by 2030. Renewable energy comes from naturally occurring and sustainable sources, such as geothermal, hydro, solar, sustainable biomass, and wind. Agriculture is the backbone of the rural economy in much of Alberta and plays a key role in supplying raw materials to a thriving agri-food industry in Alberta and Canada. Both the agriculture and energy sectors are changing and, as they do, it is important to ensure that these changes are to the benefit of all Albertans.

1.1 Energy Production and Needs

Historically, Alberta has been powered by coal, hydro-electric power, and natural gas. With increasing demands for low carbon renewable energy sources, wind and solar energy have become key interests in Alberta. The AUC recorded an annual use of 87 terawatt-hours (TWh) in 2022 (Alberta Utilities Commission, 2023). Of this required electrical demand, Alberta produced 83 TWh in 2022 (Alberta Utilities Commission, 2023). The future energy needs in Alberta are likely to change significantly as the energy transition continues to progress and as our population grows. Historic trends in energy usage offer a glimpse into what future energy demands may be. The current energy needs within Alberta have roughly doubled in the past 30 years (Alberta Utilities Commission, 2023). Increasing energy demands are leading to competition for a finite amount of land. To mitigate the potential for conflict a new approach to energy development is required that avoids, minimizes, and mitigates impacts to the agricultural sector while producing the energy required to power Alberta's grid.

1.2 Importance of Agriculture to Alberta and Canada

Agriculture and agri-food generated $143.8 billion, or about 7.0% of Canada's gross domestic product (GDP) in 2022 while employing around 2.3 million people (Government of Canada, 2023). Primary agriculture contributed to $33.7 billion of GDP illustrated in Figure 1-1, with a total of 189,874 farms covering 62.2 million acres (ac) or approximately 6.0% of Canada's land area (Government of Canada, 2023). Crop production totals $30.6 billion of GDP with export markets primarily going to China, Japan, and the United States and key crops being grain and cereals. Animal production totals $5.7 billion and employs 109,300 people and food and beverage totals $33.7 billion and employs 323,000 people (Government of Canada, 2023).

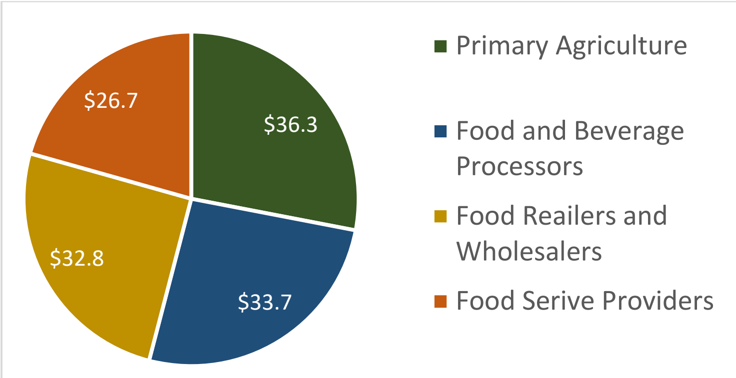

Figure 1-1: GDP of Agriculture and Agri-food in Canada per sector (in billions of dollars).

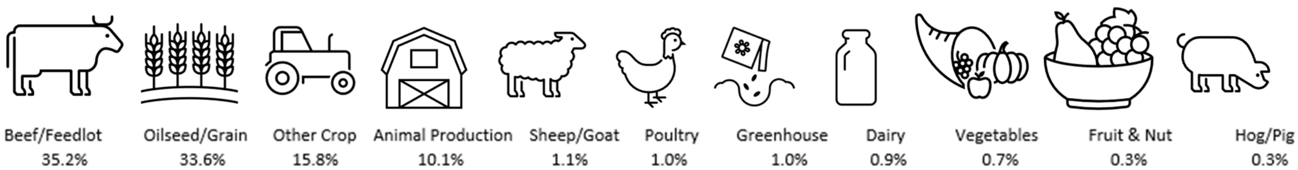

Figure 1-2: Schematic of proportion of farms by farm type in Alberta.

Alberta has the second largest number of farms in Canada at 41,500, or 22.0% of Canada (Alberta Water Portal Society, 2023) after Ontario, and the second largest farmed area at 32.0% 49.2 million ac (Alberta Water Portal Society, 2023; St. Pierre & McComb, 2023) after Saskatchewan (Begam & Adilu, 2017). In 2022, the sector employed around 69,000 people within Alberta (Government of Alberta, 2023b). Alberta has the largest number of beef cattle of all the provinces, totalling 44.0% of the Canadian herd (St. Pierre & McComb, 2023), and has the largest proportion of farms in Alberta, at 35.2% as summarized in Figure 1-2 (St. Pierre & McComb, 2023).

In Alberta, agriculture makes up $22.2 billion in operating revenues as of 2020 which comprises 25.5% of the farm revenues within Canada’s agricultural sector (St. Pierre & McComb, 2023). While this only makes up around 2.2% of Alberta’s GDP, it influences many other sectors including retail, construction, real-estate, manufacturing, and transportation. The profits from this portion of the GDP are more likely to remain within the provincial economy, as the majority of primary producers are based in Alberta. Agriculture is a major export industry with $16.2 billion in exports in 2022 (Government of Alberta, 2023b). Alberta is continuing to expand base agricultural production and value-added agricultural products within the province (Government of Alberta, 2023b). While the percentage of GDP is small relative to other industries (e.g., energy), the importance of agriculture is not uniform across Alberta. In many rural communities, agriculture is one the most important economic drivers and the backbone of their economies (Lee et al., 2018).

Alberta Agriculture leads in the applications of technology with the third highest adoption of auto-steer technology at 31.1%, which is higher than the natural average at 26.8%. Alberta is the third highest in the adoption of drones on farms at 4.2% in 2020 and Alberta farms report above average solar energy production at 8.7% in 2021 (St. Pierre & McComb, 2023).

1.3 Agricultural Land Evaluation Report Objectives

The objective of this report is to:

1) Create a process to identify agricultural land throughout Alberta and assign an appropriate value to this land. The process will create a planning tool to allow for all land to be assessed for its agricultural value and help maintain the productivity of prime farmland within Alberta.
2) Identify the impacts to agriculture caused by energy development projects.
3) Identify appropriate mitigation measures to protect agricultural land from impacts of energy development.
4) Identify the appropriate reclamation requirements necessary to ensure that agricultural land is brought back to equivalent land capability at the end of an energy projects life (i.e., during operation as well as after decommissioning of the projects).

2.0 Inventory of Agricultural Land in Alberta

Agricultural land in Alberta can be subdivided in several ways. Two of the most valuable ways to look at agricultural land is through the lens of potential productivity of the land by using soils/geology, topography, climatic conditions, growing degree days and access to water, and its current land use such as crop type, land use, and land amendments. The ability of land to maximize agricultural outputs incorporates not only its potential, but also the cost to reach that potential. If it is too expensive to operate a parcel of land to its maximum potential at the current time, then it may not meet its potential output.

2.1 Location of Agricultural Land

In 1948, the provincial government split Alberta into white and green areas which has shaped land use decision making since then (Province of Alberta, 2008). The green area of the province makes up 61.0% of the total land base, owned by the provincial Crown and commonly referred to as Crown land, the forestry, or public land as illustrated in Table 2-1. Public land is managed for resource development, grazing, conservation, and recreation as shown in Table 2-1 (Province of Alberta, 2008). About ten percent of both the green and white area of the province is controlled by the federal government as parks and protected areas (Province of Alberta, 2008). Most of the privately owned land are within the white area of the province, where agricultural use is primarily concentrated. Generally, landowners do not have rights to subsurface and non-renewable natural resources on private land, as ownership rights apply to the land surface (Province of Alberta, 2008).

Figure 2-1: Green and white areas of Alberta from (Province of Alberta, 2008).

Table 2-1: Summary of white and green area characteristics used in land-use framework.

White Area	Green Area
Settled areas	Unsettled areas
39.0% of Alberta	61.0% of Alberta
Populated south and central region, Peace River, and MacKenzie County.	Primarily in unsettled northern areas and some areas of the foothills and mountains.
Land uses include settlements, oil and gas, tourism, recreation, conservation, habitat, and agriculture.	Land uses include timber production, oil and gas, tourism, recreation, conservation, watershed production, wildlife habitat.
Municipal government oversees private land. provincial government oversees crown land.	Authority with provincial government.

2.2 Quantity and Quality of Agricultural Land in Alberta

Alberta's total land base is 64.0 million hectares (ha; 158.7 million ac), of which 33.0% or 21.0 million ha (52.0 million ac) is used for Agriculture. In 2013 (Glen, 2013), agricultural land was primarily under cultivation accounting for 62.0% of the land base, or 12.9 million ha (32.0 million ac). Grazing accounted for 38.0% of the land base, or 8.1 million ha (20.0 million ac). Of the cultivated land annual crop accounted for 72.0% of the land base, or 9.3 million ha (23.0 million ac). Hay and tame pasture accounted for 22.0% of the land base, or 2.8 million ha (7.0 million ac), and finally, 6.0% of the land base or 0.8 million ha (2.0 million ac) was in summer fallow as illustrated Figure 2-2.

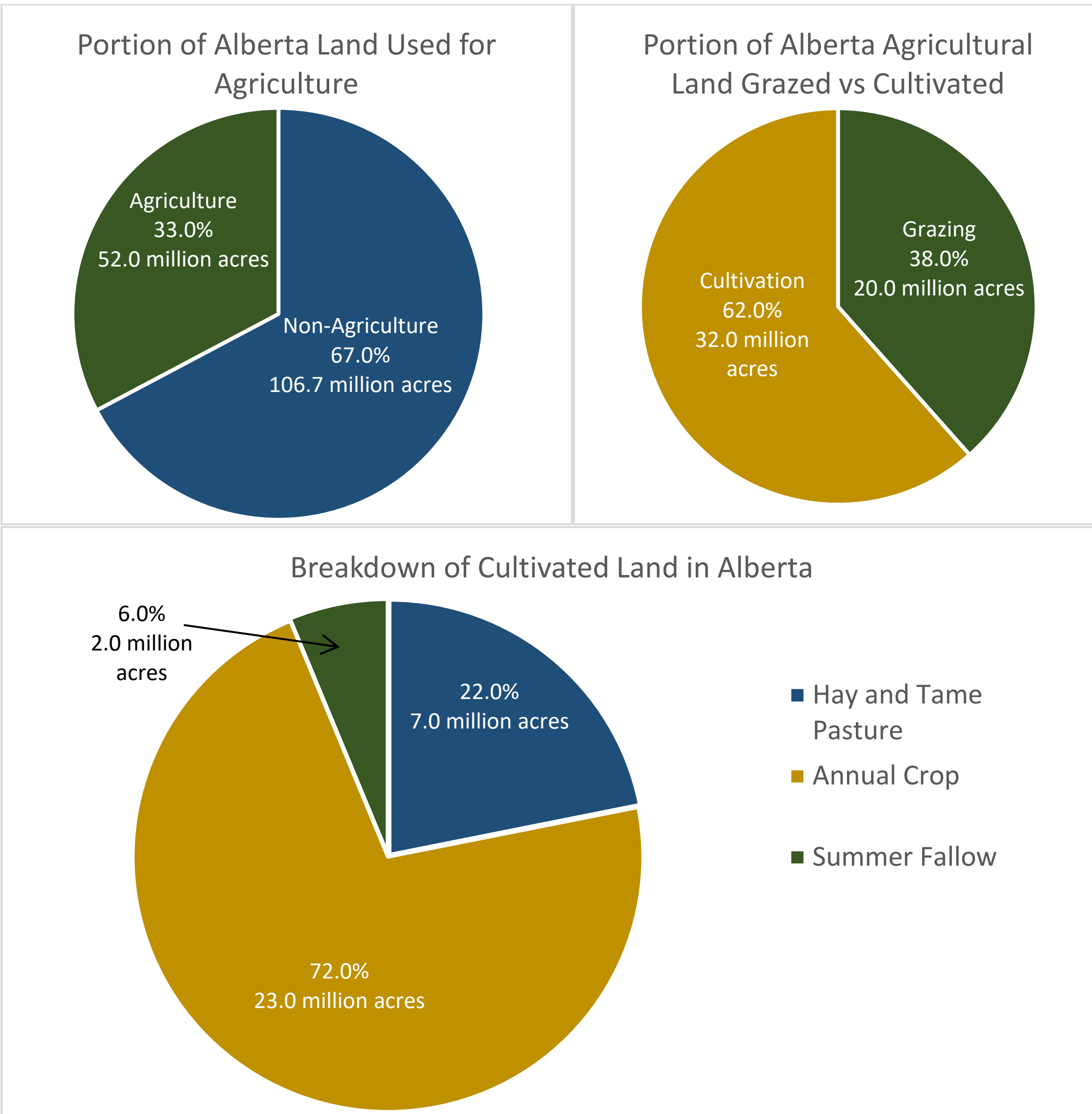

Figure 2-2: Schematic showing the amount of agricultural land in Alberta and its land use class.

In 2021, Alberta's total farm area fell from 21.0 million ha (52 million ac) to 19.9 million ha (49.2 million ac). Cropland has been increasing since 2016, but natural land for pasture decreased by 297,433.0 ha (734,974 ac) in 2021 (St. Pierre & McComb, 2023).

2.3 Quality of Agricultural Land

There are several different metrics that are used to rank the quality of agricultural land in Canada, and on a refined scale in Alberta. One important information source lies with the Canadian Soil Information Service (CanSIS), which is an authoritative source of soil data and land resource information in Canada. Within CanSIS, the National Soil Database (NSDB) serves as the Canadian archive for field surveys and data created by analysts (Government of Canada, 2022). The Canada Land Inventory (CLI) is a comprehensive inventory of rural Canada that designates capability for multi-disciplinary uses that is considered widely valid for land-use planning. There are seven classes under the CLI used to rate land capability, with Class 1 lands having the highest capability, and Class 7 lands having the lowest capability (Government of Canada, 2019a) as shown in Table 2-2. The Land Suitability Rating System (LSRS), which is Alberta's equivalent, uses the same criteria as the CLI but provides more refined mapping (Government of Alberta, 2023d, 2023b).

Table 2-2: Land capability classes in the Canadian Land Inventory tool.

Classes	Description
Class 1	Soils in this class have no significant limitations in use for crop.
Class 2	Soils in this class have moderate limitations that restrict the range of crops or require moderate conservation practices.
Class 3	Soils in this class have moderately severe limitations that restrict the range of crops or require special conservation practices.
Class 4	Soils in this class have severe limitations that restrict the range of crops or require special conservation practices.
Class 5	Soils in this class gave very severe limitations that restrict their capability in producing perennial forage crops, and improvement practices are feasible.
Class 6	Soils in this class are capable only of producing perennial forage crops, and improvement practices are not feasible.
Class 7	Soils in this class have no capacity for arable culture or permanent pasture.
Class 0	Organic soils (not placed in capability classes).

In addition to these metrics, there are other mapping resources specific to Alberta that provide ecological or agronomic criteria that will be discussed in detail below. Soil inventory data includes Agricultural Region of Alberta Soil Inventory Database (AGRASID). The Irrigation Land Ranking (ILR) tools divides the province into areas based on the physical and chemical characteristics affecting its suitability for sustained production under irrigated agriculture. Mapping resources used for vegetation level mapping include the Grassland Vegetation Inventory (GVI), the Agricultural Vegetation Inventory (AVI), or the Primary Land and Vegetation Inventory (PLVI).

2.3.1 Soil Based Classification Systems

When considering the classification of land quality for agriculture, decision making is based heavily on soil properties with consideration given to climate as well as landscape. For this reason, both the federal CLI and the provincial LSRS are based off soil mapping. Soils are influenced by landscape factors and consideration should include both a local level as well as a provincial level. This project considers the provincial scale which uses AGRASID and already imbeds information from the LSRS in its data layers. Both tools are discussed below in detail with examples on how a viewer can harness their data for decision making.

2.3.1.1 Alberta Land Suitability Rating System

The Alberta Land Suitability Rating System (LSRS) is the most detailed and comprehensive resource for the classification of agricultural land in Alberta, intended to replace the use of the CLI as it addressed several limitations identified in the CLI (Agronomic Interpretations Working Group, 1995). The LSRS provides a specific procedure for rating the agricultural potential of land for spring-seeded small grains and hardy oilseeds. The LSRS system is interpretive and recognizes three major factors for determination of crop suitability which are climate, soils, and landscape (Agronomic Interpretations Working Group, 1995).

The LSRS has two categories. “Classes” split based on the degree of limitation for production of crops, and “subclasses” split based on the kind of limitation (Agronomic Interpretations Working Group, 1995). The seven-class system used by CLI was retained in the development of the LSRS, with Class 1 being the highest quality, and Class 7 being the most restricted (Begam & Adilu, 2017) shown in Table 2-3. It is important to note that Alberta does not have any land that is considered Class 1 suitability.

Table 2-3: Classes, or the degree of limitation in the LSRS.

Suitability Definitions	
Class	**Limitation**
1	None to slight
2	Slight
3	Moderate
4	Severe
5	Very severe
6	Extremely severe
7	Unsuitable
NR	Not rated

Subclasses are split by three general restriction categories which are climate, soil, and landscape. Climate restrictions include temperature and moisture limiting factors where there is inadequate heat units or moisture for optimal growth. Inadequate heat units are the limiting factor in Alberta, resulting in no Class 1 suitability. Soil restrictions include water holding capacity or texture limitations, limitations to soil structure and organic matter, inadequate topsoil depth, reactive soils (i.e., high or low pH), salinity, sodicity, high peat content, poor or excess drainage, poor temperatures, high rock content, decompaction issues, or poor depth and substrate characteristics. Landscape limitations may include slope, landscape pattern, stoniness/coarse fragments, wood content, and inundation. Subclasses are described in more detail in Table 2-4. The map shown in Figure 2-3 below outlines an example output of the LSRS as it is provided within the AGRISID.

Table 2-4: Subclasses, or the kind of limitation in LSRS.

Land Suitability Rating System Restrictions and Limitations			
General Restriction	**Subclass**	**Code**	**Limitation**
C-Climate	Temperature	H	Inadequate heat units for the optimal growth.
	Moisture	A	Inadequate moisture for the optimal growth.
S-Soil	Water holding capacity/texture	M	Crops are adversely affected by lack of water due to inherent soil characteristics.
	Soil structure	D	Crops are adversely affected either by soil structure that limits the depth of rooting, or by surface crusting that limits the emergence of shoots.
	Organic matter	F	Mineral soil with a low organic matter content in the Ap or Ah horizon.
	Depth of topsoil	E	Mineral soil with a thin Ap or Ah horizon.
	Soil reaction	V	Soils with a pH value either too high or too low for optimal growth.
	Salinity	N	Soils with amounts of soluble salts sufficient to have an adverse effect on growth.
	Sodicity	Y	Soils having amounts of exchangeable sodium sufficient to have an adverse effect on soil structure and/or growth.
	Organic surface	O	Mineral soils having a peaty surface layer up to 40 cm thick.
	Drainage	W	Soils in which excess water (not due to inundation) limits the production.
	Organic soil Temperature	Z	Additional temperature limitation associated with organic soils.
	Rock	R	Soils having bedrock sufficiently close to the surface to have an adverse effect on production.
	Degree of decomposition or fibre content	B	Organic soils in which the degree of decomposition of the organic material is not optimum for production.
	Depth and substrate	G	Shallow organic soils with underlying material that is not optimum for production.
L-Landscape	Slope	T	Landscapes with slopes steep enough to incur a risk of water erosion or to limit production.
	Landscape pattern	K	Land areas with strongly contrasting soils and/or non-arable obstacles that limit production or substantially impact management practices.
	Stoniness and coarse fragments	P	Land that is sufficiently stony or gravelly so as to hinder tillage or limit production.
	Wood content	J	Organic soils with a content of wood or of *Eriophorum* sp. sufficient to limit production.
	Inundation	I	Land areas subject to inundation or flooding that limits production.

* Information in this table was sourced from the Alberta Soil information Viewer (Government of Alberta, 2023d)

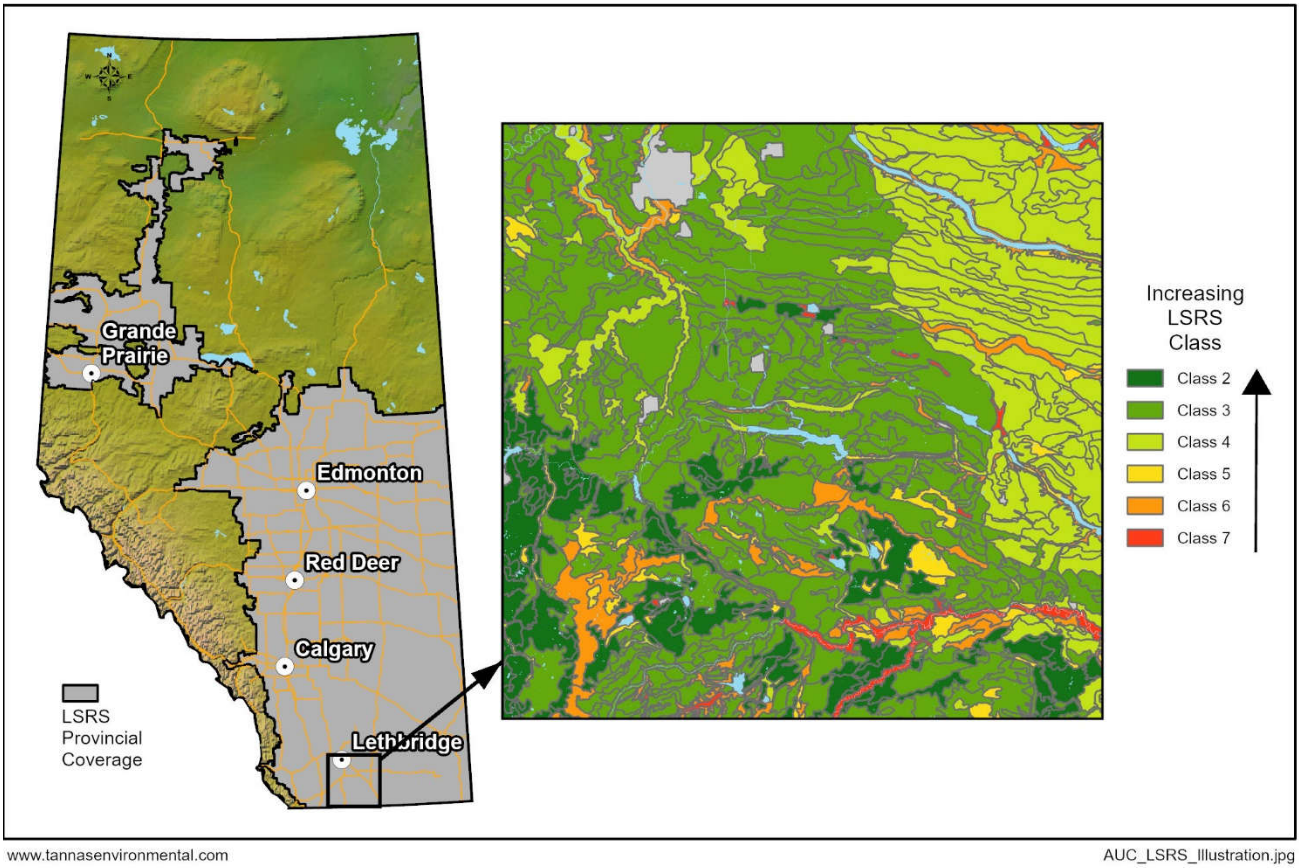

Figure 2-3: Alberta Land Suitability Rating System (LSRS).

2.3.1.2 Agricultural Region of Alberta Soil Inventory Database

In 1920, the University of Alberta endeavored to survey the soils within the province, and today their works are the basis for the comprehensive contemporary soil mapping that exists in various databases (Government of Alberta, 2001). AGRASID was developed to compile historical soils inventories to provide information on soils and landscapes while applying a uniform approach in a digital application (Government of Alberta, 2001). AGRASID is based on the Soil Landscape Model which is an amalgamation of the soil model and the landscape model, these models are outlined below (Government of Alberta, 2001). A sample of the AGRASID viewer is provided in Figure 2-4.

- Soil model
    - Composite of dominant or co-dominant and significant soils found within the soil polygon.
- Landscape model
    - Composite of the morphology, genesis, relief, slope class, and surface form modifier attributes.

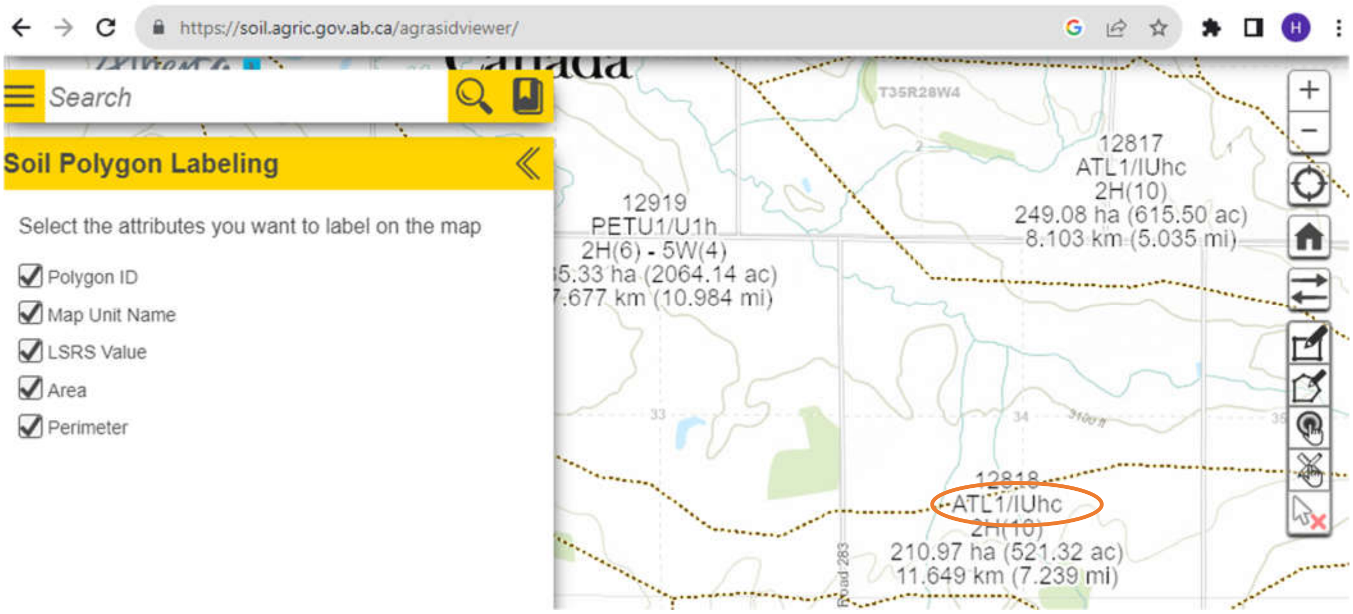

Figure 2-4: AGRASID viewer with all map labels turned on.

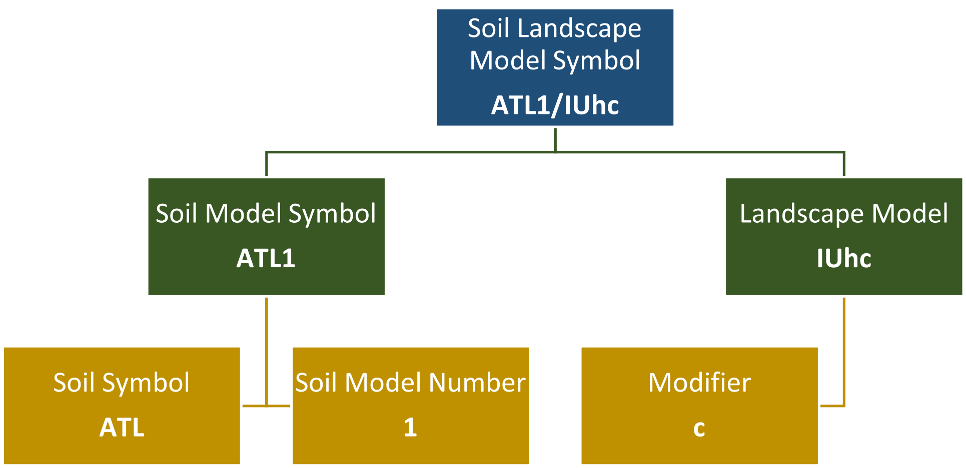

Figure 2-5: Schematic showing the breakdown of the AGRASID map unit.

The map codes point to the major soils and landscape modifiers as shown in Figure 2-5. ATL1 is our dominant soil in this polygon. The code for "ATL" stands for soil name "Antler". The soil can then be looked up in CanSIS Soils of Alberta index (Government of Canada, 2019b), which shows the soil is an Orthic Black Chernozem, in native condition, and undisturbed by agriculture. Landscape model codes and landscape modifiers are listed in the Soil Inventory Procedures Manual (CAESA, 1998). The query of the AGRASID polygon within the data viewer as seen in Figure 2-4, shows the landscape model code 1Uh which, is stated as "inclined and undulating – high relief". The c modifier shows the description to be "channeled (<50 cm, rill, re-occur at the same position year after year)".

AGRASID compiles several databases and provides a rough-cut soil polygon delineation that can be used in desktop applications which is ideal for planning and decision making. This data is relatively accurate and can provide the viewer with site and soil characteristics for agricultural and settled areas of the province (Adams et al., 2013). As shown above, simple polygons and map labels give a significant amount of information for a desktop analysis and a snapshot of what is occurring below ground.

Soils are good indicator of land productivity. The classification of soils is the basis of the vegetation-based classifications in the next section linking to the LSRS. Typically, soil classification can provide significant additional information on the potential productivity of a parcel of land. It also tells us more about the potential uses of land such as irrigation potential, grazing productivity, and annual crop production potential.

2.3.1.3 Using AGRASID to determine the LSRS

AGRASID map layers provide a LSRS value in the online tool which can be understand relatively easily. From the Map Unit Name for the polygon, assessed in Figure 2-6, there is the code “CYG2/Uh1”. The CYG code refers to a Cygnet soil and is an Eluviated Black Chernozem that is disturbed by agriculture (Government of Canada, 2019b). The landscape model code 1Uh means “inclined and undulating – high relief” (CAESA, 1998).

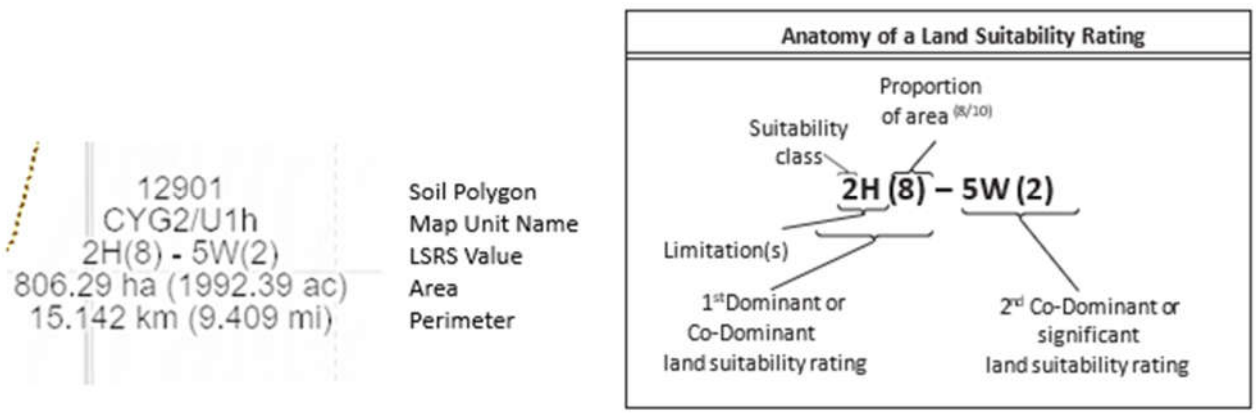

Figure 2-6: Breakdown of a LSRS value as it appears in the AGRASID viewer.

In addition to the soil’s information, the AGRASID viewer tells us about the LSRS value. The map label for the AGRASID polygon displayed in Figure 2-6, shows the soil map label is a CYG2/U1h and the LSRS value is 2H(8) – 5W(2). Using the guide in Figure 2-6 and the definitions in Table 2-3 and Table 2-4 it is possible to see that 80.0% of the area is Class 2 (slight limitation) with an H subclass limitation (climate; temperature), and 20.0% of the area is a Class 5 (very severe limitation) with a W subclass limitation (soils; drainage is poor).

2.3.1.4 Yields and Economic Value Related to LSRS

The LSRS is a powerful predictor for the economic value of land across Alberta. It is a predictor of yields, thereby being able to predict the agricultural value of land. Soils in Alberta are classified as a Class 2 or poorer due to climatic limitations, primarily due to a lack of sufficient heat units, which are the maximum and minimum daily temperatures needed for specific crops (Bock et al., 2018). The best agricultural soils in Alberta are located along the Calgary-Edmonton corridor. In this area, roughly 50.0% of the land is considered moderate, good, or very good for crop production. To the west of this corridor, soils are considered poorer, while the soils are considered good to east of the corridor (Martellozzo et al., 2015).

The LSRS value is one of the major determinants of land value. Soil quality is positively related to farmland value, with higher value soils (i.e., Class 2 or 3) associated with higher yields, and therefore higher farmland values

(Bentley et al., 2015). Soil quality is a function of climate, parent material, and landscape, which affect the productivity, flexibility, and sustainability of agriculture (Bock et al., 2018), and in turn the yields and economic value of the land.

The LSRS can be used to predict the yield of various crops. Under the similar CLI system, Class 1 soils can yield 80.0-100.0% of the crop maximum, while Class 3 soils are only capable of yielding 50.0% of the crop maximum (Bock et al., 2018). Because of varying soil and climatic conditions across Alberta, yields can vary significantly over the province. Yield values from Chapagain & Good (2015) show variation in several crops, including wheat. The minimum yield reported was from Greenview, Alberta, in the north-western portion of the white zone, with a yield of 2.26 ton/acre (t/ac). The soils in this area are poorer in quality, suitability Class 3 (Government of Alberta, 2023). Chapagain & Good (2015) reported the highest wheat yields in Central Alberta, near Lacombe, with a yield of 4.28 t/ac. The suitability class in this area was 2 indicating better quality soils (Government of Alberta, 2023).

The LSRS can impact land use choices as well. Differences in land quality and productivity effect the use of land. Beef farms have lower land values per acre than crop farms, but can be productive on worse-ranked soils, while annual crop farms achieve higher values, but require better LSRS suitability classes (Bentley et al., 2015).

2.3.2 Vegetation Based Classification Systems

Vegetation based classification systems provide insight into the productivity of agricultural land and its current uses. Many of these classification systems integrate soils and landscape to provide the basis of the vegetation that will thrive on a specific location. These systems also provide information on historical disturbance such as tillage that may affect the potential productivity of the soils in an area. The scale of mapped vegetation polygons makes vegetation layers more sensitive for planning than AGRASID and LSRS as they capture landscape level data more precisely through finer-scaled vegetative cover.

2.3.3 Grassland Vegetation Inventory

The GVI is a comprehensive inventory of biophysical, anthropogenic, and land use available in the southern portion of the white area. The GVI is a Government of Alberta spatial data source, that was compiled using a combination of imagery analysis (i.e., digital colour-infrared stereo photography), ecological range sites based on soils data for native vegetated areas, and land use data for non-native or unvegetated areas. The GVI is a robust classification system that encompasses the range of native vegetation and land use classes within the southern portion of Alberta's grassland natural subregion.

The hierarchy of the landscape features described through the GVI classification starts with primary class as the broadest division and is subdivided to the finest class of site-type. Within GVI, there are three primary classes (i.e., water, native/natural, and anthropogenic), five land classes (i.e., wetland, upland, agricultural, industrial, settled), four sub-classes, and 32 site-types as shown in Table 2-5 (Government of Alberta, 2011). An example output from GVI is shown in Figure 2-7, showing the primary land classes.

The GVI provides high quality spatial information (0.4m resolution) that incorporates native vegetation and land-use to determine the 32 site-types (Government of Alberta, 2011). The site-type classifications have been used widely to inform land management, including species-at-risk conservation (Prairie Conservation Forum 2012), sustainable grazing (Government of Alberta 2021), and industry siting (Alberta Environment and Parks 2018). Within native vegetated areas, the 14 site-types describing native/natural uplands which are based on soils characteristics provide insight into the productive capacity of the land. For the agricultural land class, there are two main site-types which are crop, and tame pasture, with two variants being irrigated and non-irrigated for a total of four site-types. A sample of the output of GVI is displayed in Figure 2-7 In this output, the native vegetation vs non-native vegetation is shown within a portion of the province.

Table 2-5: Hierarchy of grassland vegetation inventory site types.

Primary Class	Land Class	Land Sub-Class	Site Type
Anthropogenic	Agricultural	Crop	Irrigated, non-irrigated
		Tame Pasture	
	Industrial	N/A	Pits, developed, urban, rural
	Settled	N/A	
Native/Natural	Upland	N/A	Sub-irrigated, overflow, clayey, loamy, sandy, limy, sand, blowouts/solonetzic, choppy sandhills, thin breaks, shallow to gravel, saline lowland, gravel, bad/bedrock
	Wetland	Lentic (Non-Flowing)	Temporary, seasonal, alkali, semi-permanent to permanent
		Lotic (Flowing)	Coniferous, deciduous, shrub, herbaceous
Water	Wetland	Lentic (Non-Flowing)	Open water, river
		Lotic (Flowing)	

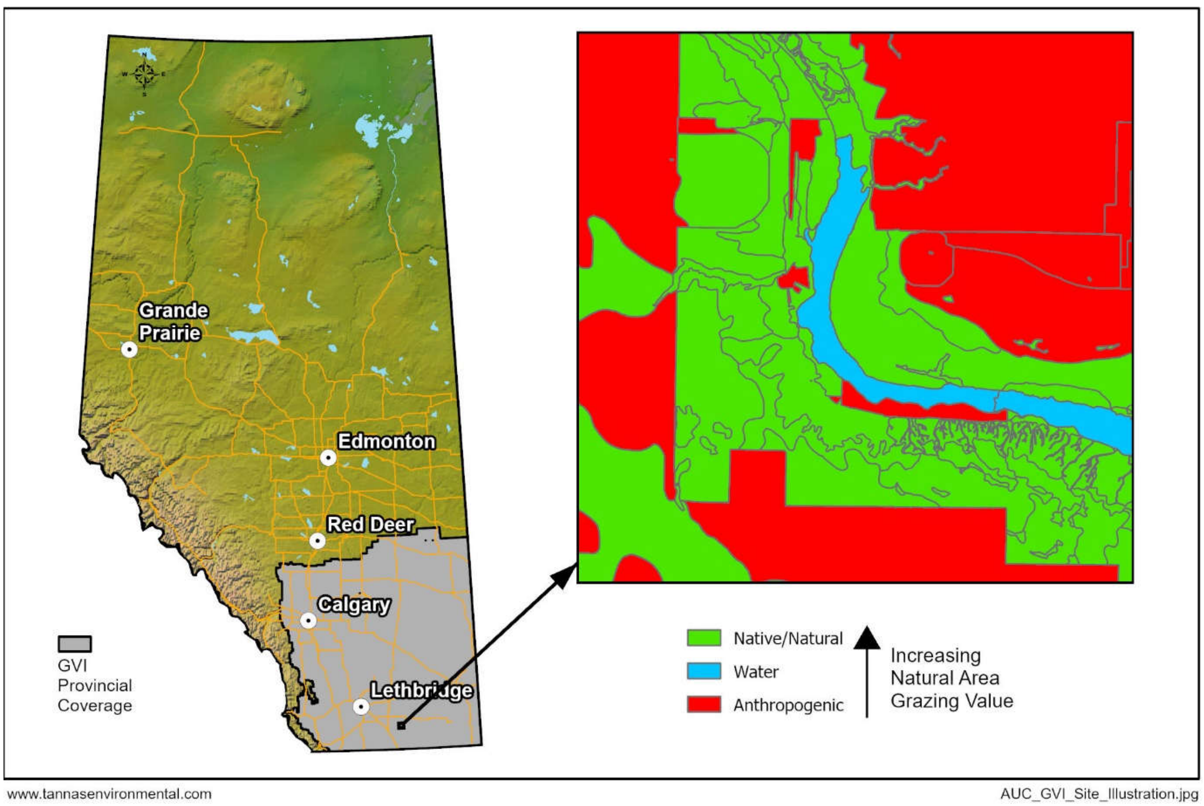

Figure 2-7: Alberta Grassland Vegetation Inventory (GVI) showing native grasslands and forests.

2.3.4 Primary Land and Vegetation Inventory

The PLVI is a photo-based digital inventory that uses ecological site phase (i.e., ecosite) as one level of the classification. The PLVI identifies the type, extent, and conditions of vegetation in the forested and parkland areas of Alberta (Government of Alberta, 2020). This includes portions of both the green and white areas of the province. The PLVI is a similar vegetation and landscape level assessment as GVI, and addresses areas of the province not covered by GVI, although, coverage across the province is limited. The output of PLVI is shown in Figure 2-8 below.

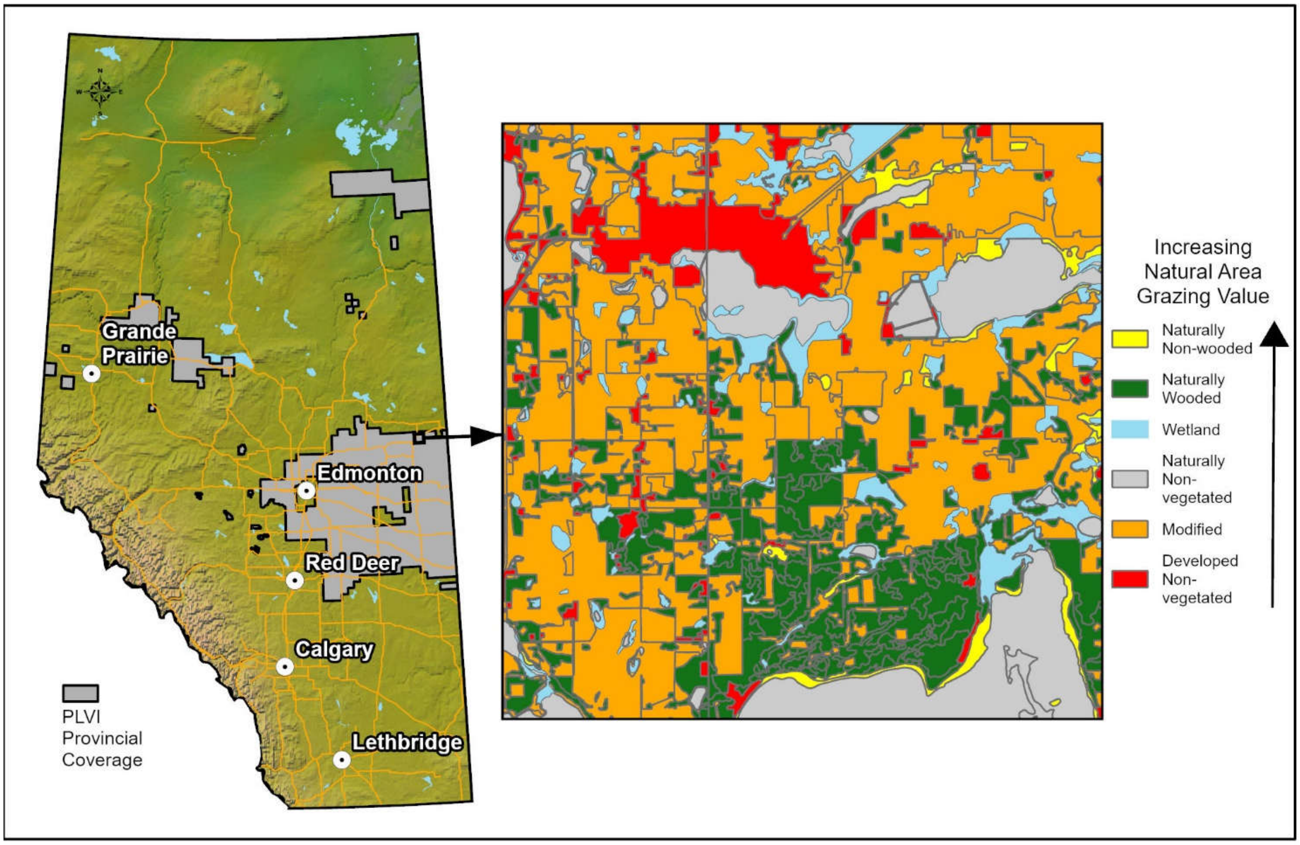

Figure 2-8: Alberta Primary Land and Vegetation Inventory (PLVI).

2.3.4.1 Alberta Vegetation Inventory

AVI data is a photo-based digital inventory that was developed to identify the type, extent, and conditions of forest vegetation (Government of Alberta, 2022). This spatial inventory was developed to support forestry management in the province, describing the forest canopy and site characteristics. The land classes also include non-vegetated, anthropogenic landscape features (Government of Alberta, 2022). This inventory provides information on what vegetation exists on the landscape and what changes are occurring. The dataset is used primarily within the green area for distinguishing forest cover and can provide insight into land use and identify areas that are potentially disturbed within these areas (Government of Alberta, 2022).

2.3.5 Irrigation Land Assessment

The ILR is a land classification for irrigation used to determine the degree of suitability of land for irrigation. Alberta is the only province in Canada with a mandatory requirement for an irrigable classification of lands within its irrigation districts (Government of Alberta, 2016). This requirement is laid out in the *Irrigation Districts Act* (Irrigation Districts Act, 2000) that originally came into effect in 1968 (Government of Alberta, 2016). These standards have been updated and the *Irrigation Districts Act* replaced the *Irrigation Act* in May 2000 (Government of Alberta, 2016). The *Irrigation Act* outlines the minimum requirements for land to be classified as irrigable and supplied with water (Irrigation Districts Act, 2000). Currently, within Alberta there are thirteen active irrigation districts as shown in Figure 2-9. While this figure captures most of the land that is irrigated in the province, land that is irrigated exists outside of the irrigation districts, which may not be included in existing digital map layers.

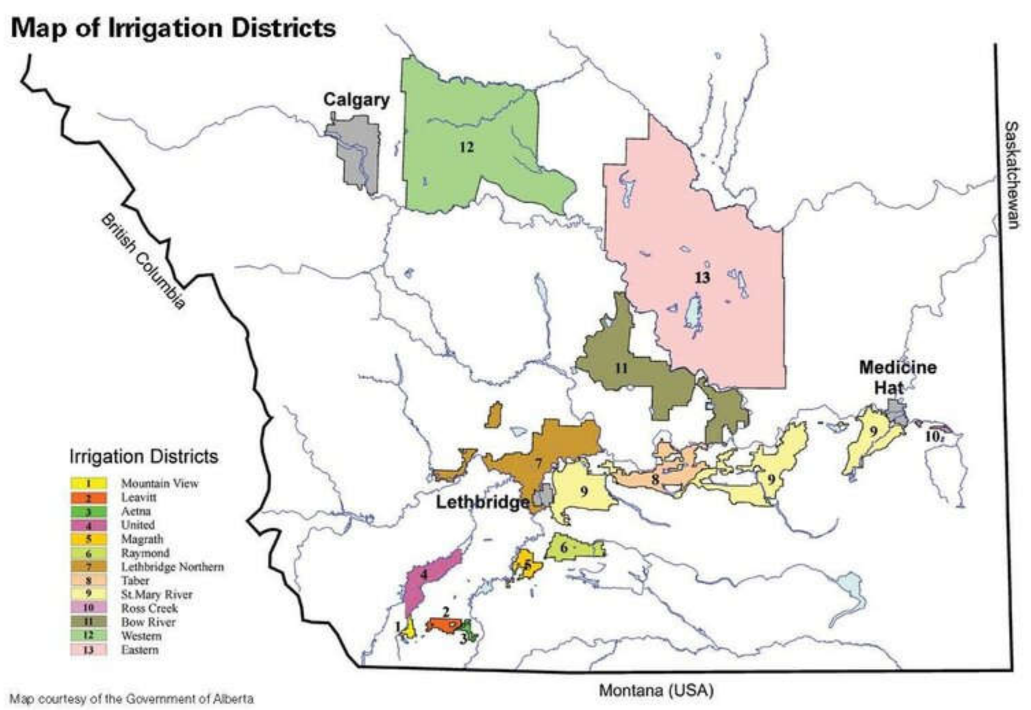

Figure 2-9: Map of irrigation districts in Alberta (Nicol, 2023).

The assessment of land for irrigation considers permanent factors (i.e., soil depth, parent material, texture, and adverse topography) and changeable factors (i.e., fertility, drainage, groundwater, salt content, soil pH, and erodibility). The predicted response to irrigation includes soil structure (i.e., physical and chemical), micro-relief, relocation and chemical changes of soluble salts, stone and brush removal, drainage, subsidence, and increased erosion (Government of Alberta, 2004, 2016). The purpose of the land for irrigation assessment is to ensure that land that is irrigated is permanently productive under the changes that are anticipated with irrigation (Government of Alberta, 2016).

The soil rating is created based on the physical properties of the soil. Soils for irrigation should have adequate moisture holding capacity, adequate internal soil drainage (i.e., allowing proper aeration of the root zone), adequate infiltration rates to facilitate replenishment of moisture lost through evapotranspiration, suitable texture/structure, absence of injurious levels of salinity/sodicity/toxic elements, and sufficient depth of suitable material to allow root development (Government of Alberta, 2004, 2016). The physical soil rating based on geology and physical characteristics of the soil is modified by the changeable factors to create 6 district categories as shown in Table 2-6. Within these categories, Class 1 through 4, and Class 6 are finalized classifications and Class 5 is land under investigation (Government of Alberta, 2004, 2016).

Table 2-6: Classification of irrigation land in Alberta.

Suitability Definitions		
Class	**Quality**	**Limitation**
1	**Excellent**	No significant limitations
2	**Good**	Moderate limitations
3	**Fair**	Moderately severe limitations
4	**Poor**	Severe limitations (requires special management)
5R	**Temporary irrigable**	Undergoing reclamation to become irrigable land
5	**Non-irrigable pending**	Requires investigation to determine status
6	**non-irrigable**	Non-irrigable

3.0 Agricultural Land Quality Model

3.1 Need for an Alberta Wide Agricultural Land Quality Model

Current land quality rankings can be mapped using several unique digital mapping products available throughout Alberta. However, there is no integrated database that combines all these data sources into a single siting tool for agricultural lands. Tools such as AGRASID, irrigation land maps, and vegetation inventory layers (i.e., GVI, AVI and PLVI) all provide information individually, but a single layer does not exist that incorporates all land quality characteristics together. A model that integrates available land quality data sources into a single visual layer could provide a consistent and straight forward approach to planning renewable energy projects. An agricultural land quality model will guide the avoidance of high value agriculture land or help guide project design to ensure agricultural impacts are minimized.

The following sections describe our approach to the development of an Agriculture Land Quality Model (ALQM). This model is designed using available digital data and is proposed as an important component in characterizing agricultural land quality for land use planning for energy projects to reduce conflict with agriculture. This model has not yet been tested in the field and it is recommended that field testing and public engagement be part of the process to finalize the model and roll out a province wide ALQM map. Creation of the final model with a shapefile layer for the white zone of Alberta would take around 3 months. This includes getting access to non-public data, merging all the data layers together and the quality control process. In the interim period until the model is active there are a number of options available. Either prohibiting development on high value lands or use of the existing layers to estimate the model's output. These options are discussed in the recommendation section in detail.

3.2 Existing Approaches within Alberta

In 2018, the Miistakis Institute developed an evaluation tool that assessed agricultural land in consideration of renewable energy development (Lee et al., 2018). The pilot project combined a public survey of land value with existing provincial databases for Wheatland and Newell County (Lee et al., 2018). The project demonstrated that current databases and information sources can provide a map of agricultural land value for siting of renewable energy projects. The projects also provided guidance for mitigation measures to limit the loss of agricultural land quality and quantity from land use competition. The long-term goal of this evaluation tool is to maintain a strong agricultural industry while developing profitable energy projects (Lee et al., 2018). The Miistakis Institute showed that it is possible to integrate the evaluation of agricultural land value with other important values such as historical resources, viewscapes, and native ecosystems to create a comprehensive and uniform approach to siting energy projects within Alberta. Complementing the work done in the pilot project, the following sections describe a proposed tool intended to apply to the entire province of Alberta.

3.3 Methodology

The following ALQM is based on the model developed by the Miistakis Institute, with more focused approach to evaluate the agricultural quality only. Within this report the approach has been modified to ensure it is applicable on a province wide scale instead of a local scale.

3.4 Data Selection

Several steps are required to create a spatial layer and database that unifies all agricultural land values into a single metric that is easily understood. The first step is the selection of the relevant databases. The databases and associated rationale for inclusion are described in Figure 3-1. Four agricultural land values areas were selected as metrics for the model including: Alberta land suitability rating (LSRS) which assess value for dry land crop production, native plant communities (NPC) for grazing in the livestock industry, irrigation land (IL), and irrigation infrastructure (II) assessing the value of irrigation.

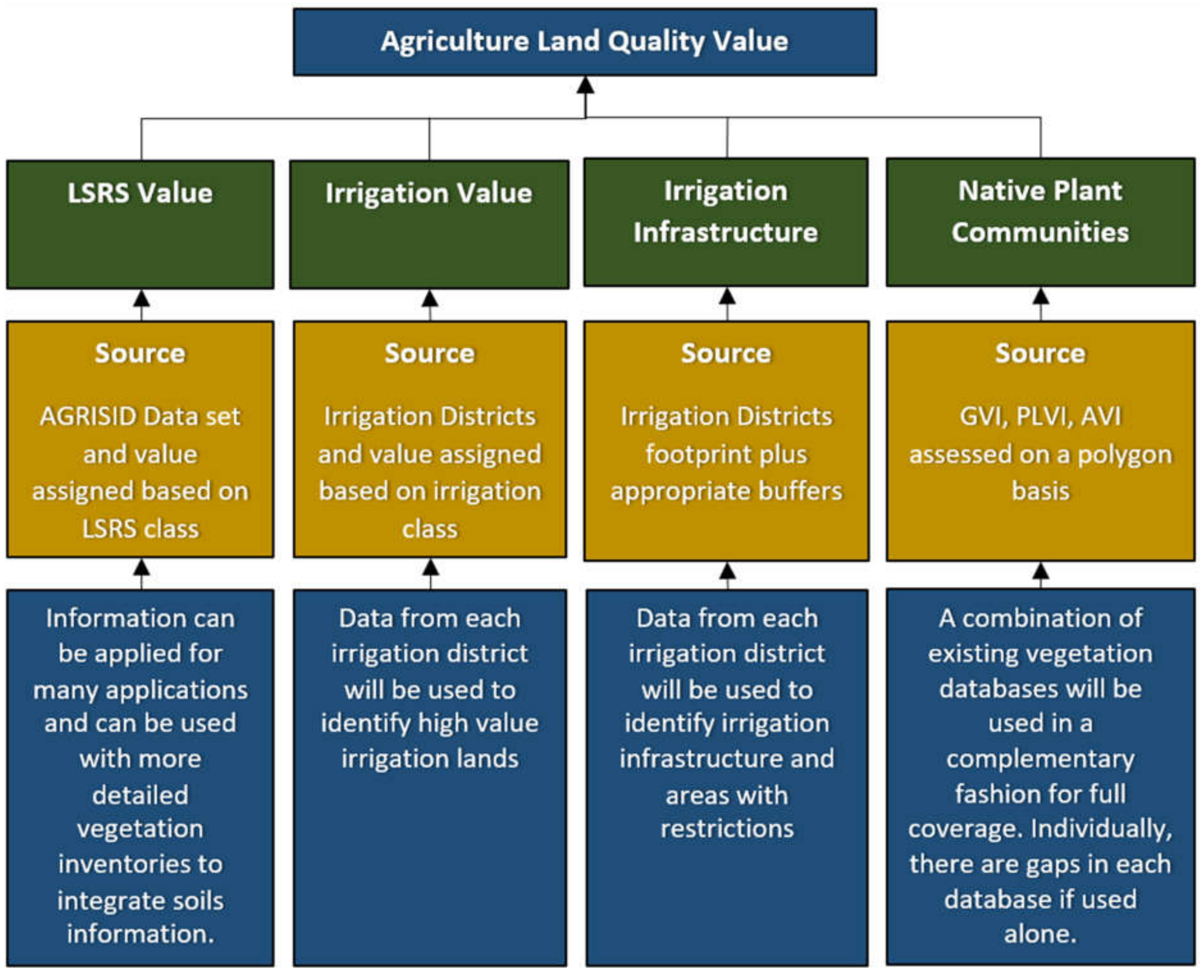

Figure 3-1: Data selected for development of the ALQM and the parent data source.

3.5 Assigning Values to the Data

Within Table 3-1, is a summary of the scoring system for each of the four agricultural land value metrics proposed to be incorporated into the ALQM. A detailed description of the scoring is included below in Sections 3.5.1 to 3.5.4. The value of agricultural land is ranked using an ordinal variable with five categories from very high to very low, which corresponds with the numeric score from 100 to 0 that is derived from the scoring system.

Table 3-1: ALQM scoring system for each of the four agricultural land value metrics.

Agricultural Land Quality	Value	Score
Land Suitability based on the Alberta classification (LSRS)		
Class 1 - (no limitations to slight limitation (not present))	Very High	100
Class 2 - (slight limitations to growth)	Very High	100
Class 3 - (moderate limitations to growth)	Very High	100
Class 4 - (severe limitations to growth)	High	75
Class 5 - (very severe limitations to growth)	Medium	50
Class 6 - (extremely severe limitations to growth)	Low	25
Class 7 - (unsuitable for crop production)	Low	25
NR - (not rated)	Very Low	0
Irrigation Infrastructure (II)	**Very High**	**100**
Right of ways and setbacks	Very High	100
Irrigation Land (IL)		
Class 1 - (excellent for irrigated agriculture with no significant limitations)	Very High	100
Class 2 - (good irrigation land with moderate limitations)	Very High	100
Class 3 - (fair for irrigation)	Medium	50
Class 4 - (severe limitations for irrigation, requires special management	Low	25
Class 5R - (temporary irrigation, pending reclamation)	High	75
Class 5 and 6 - (non-irrigable lands)	Very Low	0
Native Plant Communities (NPC)		
Native Grassland (NG)*	**Very High**	**100**
Fescue grasslands (including those with protective notation)	Very High	100
Native Grasslands that are healthy (Healthy)	Very High	100
Native Grasslands that are healthy with problems (HWP)	High	75
Native Grasslands that are unhealthy (UH)	Medium	50
Modified Native Grasslands that are healthy (Healthy)	Medium	50
Modified Native Grasslands that are healthy with problems (HWP)	Low	25
Modified Native Grasslands that are unhealthy (UH)	Very Low	0
Native Forests (NF)*	**Medium**	**50**
Native Forests that are Healthy (Healthy)	Medium	50
Native Forests that are Healthy with Problems (HWP)	Medium	50
Native Forests that are unhealthy (UH)	Low	25

*Note that all native ecosystems default to very high value (Grasslands) and medium value (Forests) in the model unless a full range inventory (Government of Alberta, 2021) is completed to determine their actual value and has been completed in the past 3 years by a rangeland management specialist.

**Note that if the GVI, AVI or PLVI identify an area as native grassland it will always default to the highest value unless a complete range inventory is completed to identify that it is not native grassland and is in fact tame pasture. This assessment should be completed by a qualified professional with experience native plant communities.

3.5.1 Land Quality Based on LSRS

Land with an LSRS of Class 1, 2 or 3 received the highest score, as outlined in Table 3-1, which are lands that are considered prime agricultural land (Begam & Adilu, 2017) and are suitable for annual crop production. The score is based on the fact that economic output of prime farmland is generally higher than lower class land making it more valuable from an agricultural perspective. Alberta does not have sufficient heat units for Class 1 agricultural land, and so the best agricultural lands are Class 2 or 3 lands (Glen, 2013). However, not all Class 2 and 3 lands are available for farming. 18.0% of the prime agricultural land is either under non-agricultural use including parks, urban areas, crown ownership, or undeveloped (Begam & Adilu, 2017).

Class 4 and 5 lands are still productive agricultural lands that support similar cash crops as higher quality land, but have more limitations that can reduce the yields, or the types of crops produced. Class 4 lands are considered to be high value. With appropriate mitigations some Class 4 lands may be as productive as Class 3 lands. Within Alberta, many Class 4 lands are in annual crop production, although the species, varieties, or equipment used may have limitations due to the soil, climate, or landscape characteristics. Class 5 lands are generally less productive, with more severe limitations and are valued at medium value within this assessment. These lands may not be suitable for annual crop production but are valuable for other commodities like hay production. If annual crops are produced on these lands there will be more limitations on varieties, productivity, and equipment used on these lands.

Class 6 and 7 lands have severe limitations that are largely considered unsuitable for crop production (Begam & Adilu, 2017). These lands are typically more suitable for grazing and hay production in most cases. For this reason, these lands are ranked as low value within this assessment. The type of target agriculture that occurs on these lands may be shifted to grazing models much more easily. Some limitations may have solutions such as providing irrigation where soil moisture is low. On the other hand, some limitations cannot be offset like sites with high salinity. The types of agricultural production found on these lands are typically related to grazing and forage production and as such they typically have a lower economic value.

The final scoring for land within the ALQM is outlined below:

- Prime farmland (LSRS Class 1, 2, 3) are scored 100.
- The LSRS class 4 land is scored at 50.
- The LSRS class 5 land is scored at 25.
- The LSRS class 6 land is scored at 75.
- The LSRS class 7 land is scored at 0.

In the AGRISID map layers, up to 3 LSRS scores may be provided for a single soil polygon. To provide a single score within the model, the following formula is used:

Field Verification Option

The single score provided in the ALQM model, which is displayed in Figure 3-2, can be modified with ground truthing. Specifically, the LSRS shows the primary, secondary and tertiary class within a polygon. However, the project footprint may only be in one of these areas within one of these classes of land. Field assessment is required to determine the appropriate LSRS (Agronomic Interpretations Working Group, 1995).

Additional Considerations and Limitations

Final ALQM Score for LSRS = Primary Class Score x % of polygon + Secondary Class Score x % of polygon + Tertiary Class Score x % of polygon

While LSRS is relatively accurate, it is important to remember the scale of mapping. The polygon sizes for the LSRS are relatively large and as such many projects will only be a small portion of a single polygon. Further study may change the LSRS score of a project area based on the specific characteristics within the larger LSRS polygon.

Final Output

The output of the LSRS scoring will create a data layer as shown in Figure 3-2 below. It is possible to see the prime farmland in dark green and the poor value farmland in red and orange.

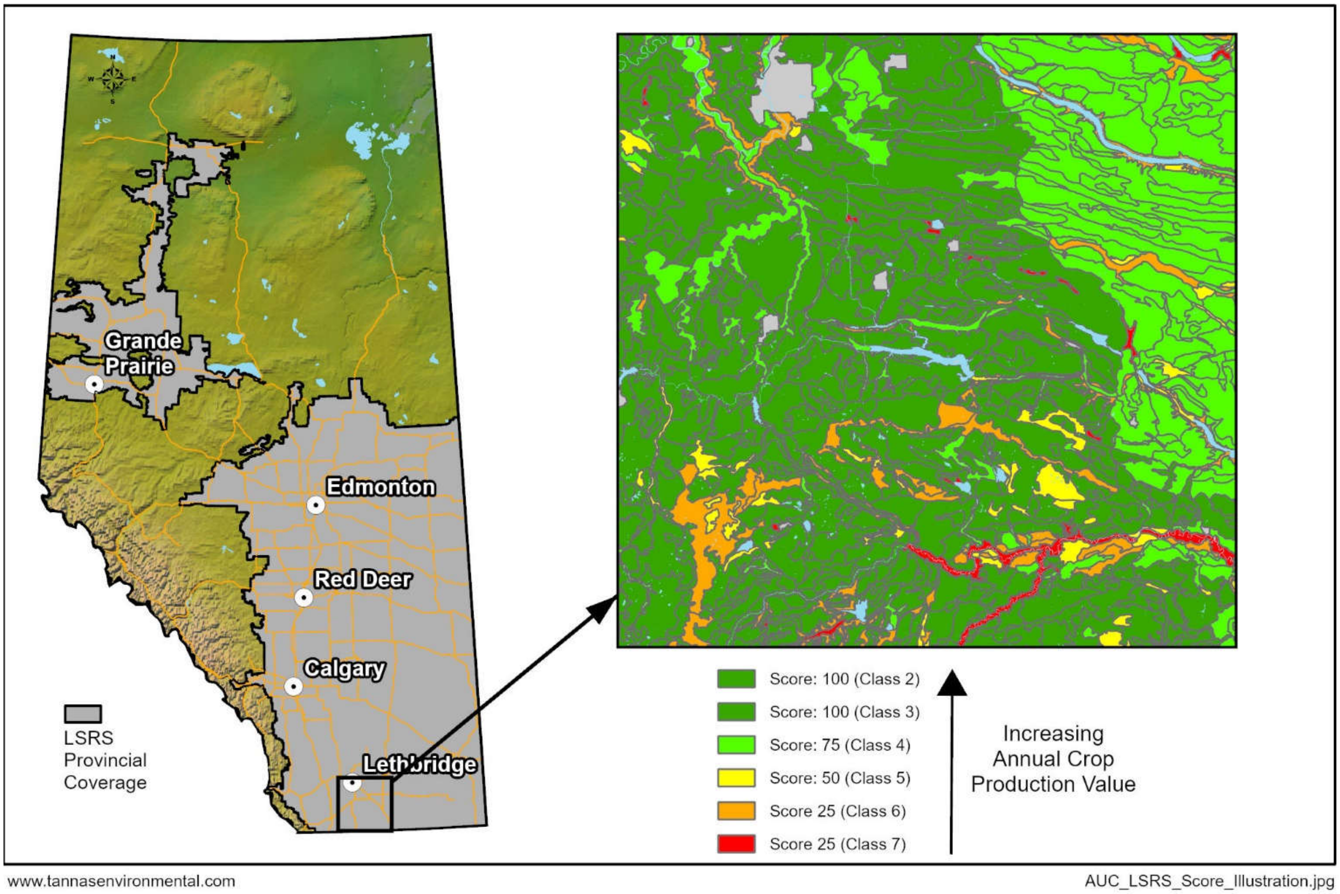

Figure 3-2: Sample visual showing scoring categories of the LSRS within the ALQM.

3.5.2 Land Quality Based on Irrigation Land Value

Scoring and Rational

Irrigation has the capability of improving the value of agricultural land through overcoming the limitation of low soil moisture, an important limiting factor of productivity. The supply of irrigation water and the suitability of the land for sustainable production under irrigation limits what land can be irrigated. Irrigation lands can be challenging to find due to the specific soils and geology requirements that limit its irrigation suitability. The productivity of irrigated land is also typically improved as water is delivered when and where the plants need it ensuring optimization of plant growth regardless of climatic conditions. Land that is classified as excellent or good for irrigation is of a very high value to agriculture in Alberta. Irrigated land Classes 1 and 2 are therefore ranked as very high value within the model (Table 3-1).

Class 3 irrigated land has been ranked as medium value as it still provides some potential to overcome soil moisture limitation, but its suitability has limitations that may impact productivity and sustainability of the land. Class 4 irrigation land has been ranked as low value as its potential for irrigation is very limited.

There are some additional classes of irrigatable land that should be considered. Class 5R land represents land that is being improved and assessed for irrigation and may become Class 1, 2, 3, or 4 land. As there is potential for Class 5R to be assessed as Class 1 irrigation land, the ALQM model considers it as high value until its final classification is made. Class 5 and 6 land is ranked as very low value due to its poor irrigation potential or unknown irrigation potential as shown in Table 3-1.

The final scoring system for irrigation land is as follows:

Additional Considerations and Limitations

- Irrigation land Class 1 and 2 land is scored 100 in the ALQM.
- Irrigation land Class 3 is scored at 50 in the ALQM.
- Irrigation land Class 4 is scored at 25 in the ALQM.
- Irrigation land Class 5R is scored at 75 in the ALQM.
- Irrigation land Class 5 and 6 is scored at 25 in the ALQM.

3.5.3 Land Quality Based on Irrigation Infrastructure

The irrigation infrastructure is set to a default of very high value (score 100) within the ALQM model as shown in Table 3-1. The irrigation infrastructure will include the footprint of the infrastructure and an appropriate setback from it. Irrigation infrastructure includes all the main water supply infrastructure that supports irrigation land in Alberta. This infrastructure includes reservoirs, pipelines, canals, and other associated infrastructure required to move water to irrigation land. Setbacks from irrigation infrastructure is important to allow for changes to infrastructure in the future along with maintenance of this infrastructure.

3.5.4 Land Quality Based on Native Vegetation Communities

Areas that are under agricultural production but remain as native ecosystems such as native grasslands are of high value for livestock production. Much of the cattle herd in Alberta spends a portion of the year on native grassland and forest ecosystems where feeding them is possible in a sustainable and cost-effective manner.

3.5.4.1 Native Grasslands

Scoring and Rational

Native grasslands will always score a default value of 100 or high value in the ALQM. A widely accepted definition of native grasslands is a grassland with more than 30.0% of the cover being made up of native species and a modified native grassland is a grassland with less than 30.0% of the cover made up of native species (Adams et al., 2016). Desktop analysis tools like GVI, PLVI, and AVI cannot provide a fine enough classification to split native grasslands into high or low value so they will be assessed as one score until they are field verified. Globally, native grasslands are declining, and in Alberta, it is estimated that only 17.0% of the original native fescue grasslands are remaining (Adams et al., 2003). Within the central parkland only around 5.0% of the plains rough fescue grasslands remain (Kupsch et al., 2013). Aside from providing high quality habitat for many species of flora and fauna, native grasslands are extremely important to livestock production in Alberta as both summer and winter pasture. Nationally, Alberta produces 44.0% of all beef cattle (St. Pierre & McComb, 2023).

Field Verification Option

Due to the difficulty in identifying native grasslands from imagery analysis, field verification of spatial resources that classify vegetation is required to confirm presence of native grasslands. Standard assessment procedures should be followed and completed by a qualified professional. Range health assessments (RHA) are to be completed using the standard methods described in the Range Health Assessment For Grassland, Forest & Tame Pasture Field Workbook (Adams et al., 2016). The following scoring is based on the RHA score and is intended to help avoid and minimize impacts to native grasslands and an example output is found in Figure 3-3 and Figure 3-4.

- Healthy grasslands are grasslands that score above 75.0% in the health assessment, meaning they are in good condition and do not have any modifications that limit their function. Healthy grasslands and fescue grasslands score 100 in the ALQM.
- Healthy with problems grasslands score between 75.0% and 50.0% health assessment, meaning they have been impacted by disturbance (or grazing) which has caused a limitation to their function. Healthy with problems grasslands score 75 in the ALQM.
- Unhealthy grasslands score below 50.0% in the health assessment. Typically, this means they have seen long term heavy disturbance (or grazing) and may have significant limitations to their function. Unhealthy grasslands score 50 in the ALQM.
- Modified grasslands are plant communities with less than 30.0% cover of native species, which have impaired ecological function. Modified grasslands that are healthy or healthy with problems score 25 in the ALQM.
- Modified grasslands with plant communities with less than 30.0% cover of native species that are unhealthy will score 0 in the ALQM.

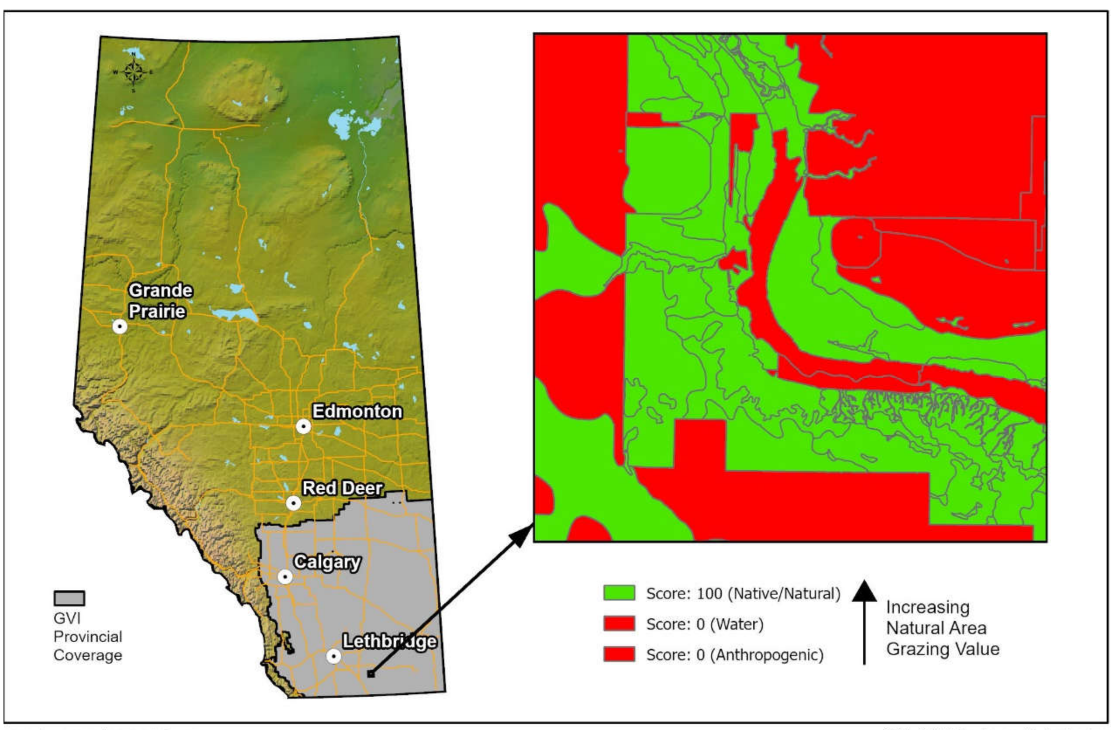

Figure 3-3: Natural vegetation scoring output for ALQM from GVI.

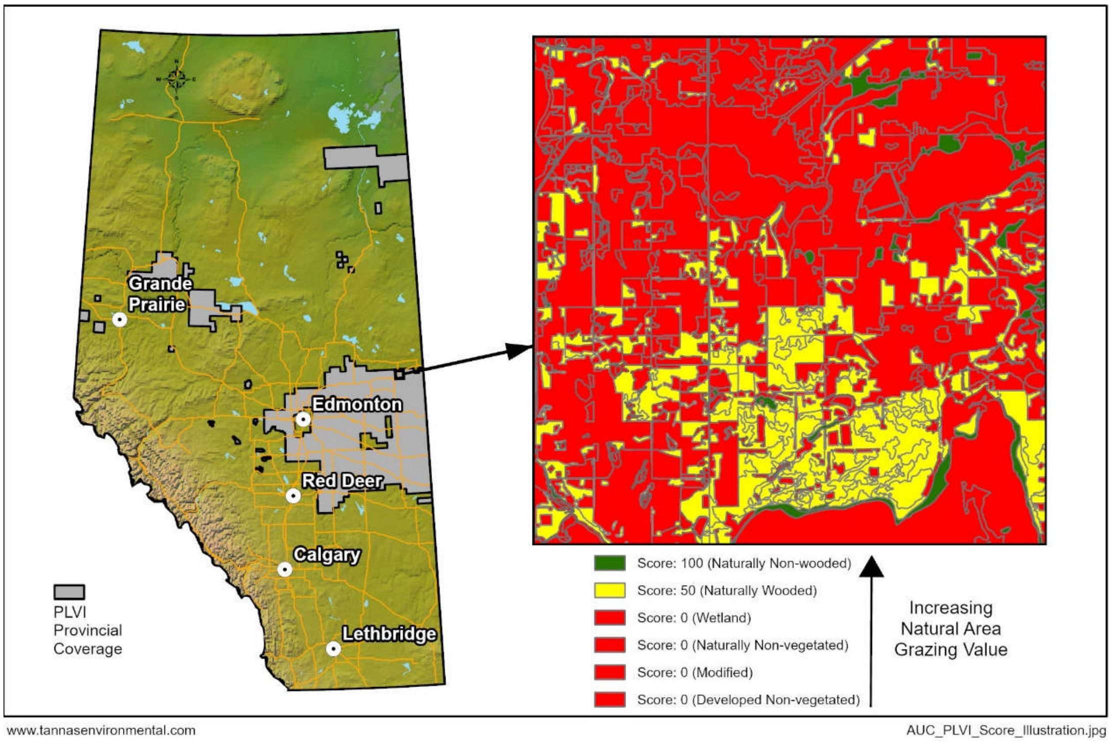

Figure 3-4: Natural vegetation scoring output for the ALQM model from PLVI.

Additional Considerations and Limitations

In Alberta, it is recognized that native grasslands are difficult to reclaim, and fescue grasslands have a protective notation to ensure additional processes are followed for siting, development, and reclamation (Alberta Sustainable Resource Development, 2010). These challenges require projects to put extra consideration into construction to ensure that reclamation is possible.

Field verification is a valuable way to ensure that the digital data layers are accurate, and representative of on the ground conditions. While the existing data layers are comprehensive resources, most are based on imagery interpretation and errors are anticipated. Field verification should be completed in a repeatable and standardized way so that it is accurate for decision makers. Utilizing the proposed range health assessment protocol provides robust information to confirm plant community classifications and are tied to the plant community guides for each natural subregion that provide further detail on plant communities and the recommended carrying capacity associated with them (Kupsch et al., 2013)

Native landscapes are in general much harder to reclaim than non-native landscapes (i.e., annual crop land, forage production land). Native grasslands can be some of the hardest to reclaim successfully. This is because not only do the soils have to be reclaimed but complex native plant communities must be established. While reclamation of all native grasslands is complex, some specific grasslands, such as fescue grasslands are extremely challenging to reclaim (Tannas, 2011). In addition to the reclamation challenges energy development can act as a vector to introduce non-native species that can affect the ecological integrity and productivity of these ecosystems.

3.5.4.2 Forested Landscapes

Scoring and Rational

Forested lands will always receive a default medium value with a score of 50 in the ALQM (Table 3-1). In forested landscapes the value for agricultural production is reduced as compared to grasslands that typically have a higher carrying capacity for livestock. However, there is a significant amount of grazing that occurs in forested ecosystems across Alberta and even with a lower per acre value, these areas are still valued for grazing. Forested ecosystems can provide quality summer forage that can allow grazing of native grasslands to be deferred to winter in some regions allowing ranchers to significantly reduce cost.

Field Verification Option

The default score for forests is a medium value. For this value to be reduced field verification is required. Standard assessment procedures should be followed and completed by a qualified professional. Range health assessments will be completed using the standard methods described in the Government of Alberta Range Health Assessment methods (Adams et al., 2016). The following scoring is based on the Range Health Assessment and is intended to help avoid and minimize impacts to forests.

- Healthy forests are forests that score above 75.0% in the health assessment, meaning they are in good condition and do not have any modifications that limit their function. Healthy forests score 50 in the ALQM.
- Healthy with problems forests score between 75.0% and 50.0% health assessment, meaning they have been impacted by disturbance (or grazing) which has caused a limitation to their function. Healthy with problems forests score 50 in the ALQM.
- Unhealthy forests score below 50.0% in the health assessment. Typically, this means they have seen long term heavy disturbance (or grazing) and may have significant limitations to their function. Unhealthy forests score 25 in the ALQM.

With field assessments the health of the ecosystem can be used to detect and characterize forests in poorer health that are easier to reclaim. Forests with a status of healthy with problems receive a score of medium value and forests that are unhealth receive a low value for agricultural production.

Additional Considerations and Limitations

Native forests tend to be easier to reclaim than grasslands as the tree canopy establishment is the primary driver of succession within the ecosystem. However, proper soil handling and placement is critical in the establishment of an ecosystem. Many of the same challenges that limit productivity of grasslands for grazing may also impact forested areas. The implementation of processes such as agrivoltaics within forested renewable energy projects may also provide an opportunity to increase the agricultural production per acre when project planning thoroughly considers agricultural productivity and innovative synchronous uses. This could yield a net benefit to both agriculture and energy production.

Field verification requirements for forested areas mirror those of grassland areas as discussed above. Further refinement of the model is possible once the assessment on the ground is completed.

3.6 Final ALQM Model

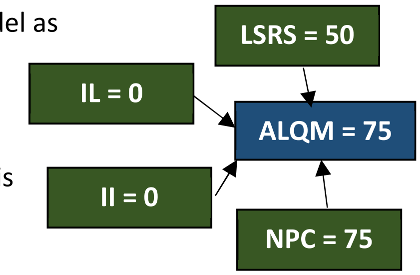

Figure 3-5: Calculating ALQM.

The scores from each agricultural land value category are placed in the model as shown in Figure 3-5. The scores come from Table 3-1 and Figure 3-6. For example, LSRS value (LSRS), irrigation land value (IL), irrigation infrastructure value (II) and native plant community value (NPC) as illustrated in green boxes shown in Figure 3-6. In the sections above, there is a detailed account of the reasoning for the scores assigned to each of the four agricultural value areas, and the final ALQM scoring, as represented by the blue box in Figure 3-5. The highest score from each agricultural land quality group (e.g., LSRS, II) is provided, as depicted by the green boxes in Figure 3-5. The greatest score from the four agricultural land values areas is assigned to the polygon being assessed and represents the ALQM score for that polygon as seen in Figure 3-5.

Scores are set out of a maximum of 100 for each agricultural value area allowing the highest value for each agricultural land value to have equal standing within the model. This information will be accumulated into an ALQM map that shows the highest agricultural value of each parcel of land. It will also identify the score for each land use to allow better land use planning. An example of the output is shown in Figure 3-7 where the GVI overlay is in a cross hatch so it is possible to see the overlapping values. The final layer will show only the highest value for a given area.

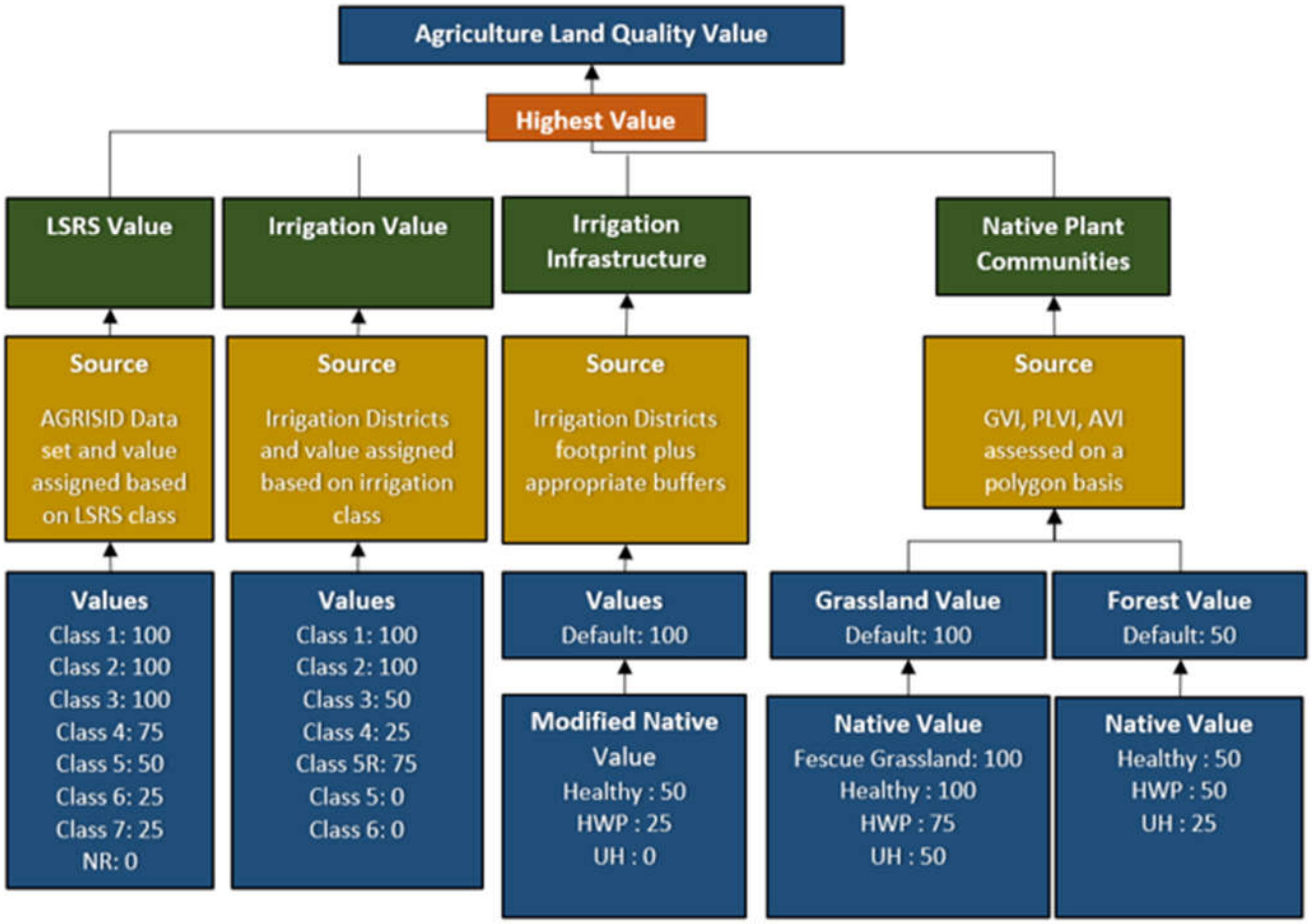

Figure 3-6: Model for the Land Quality Value dataset.

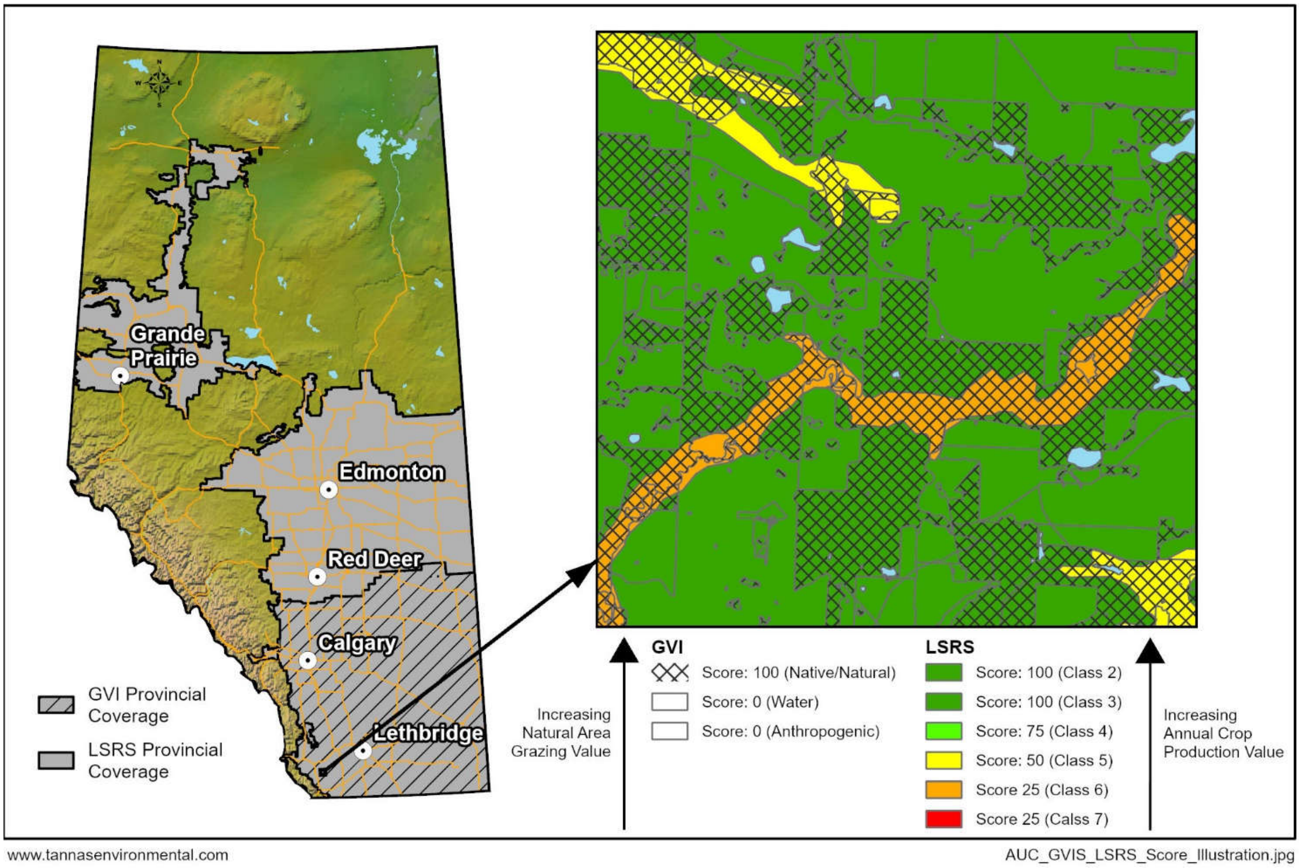

Figure 3-7: Final ALQM output showing overlapping values of native grassland and LSRS.

4.0 Realized Impact of Power Plant Development on Agricultural Land in Alberta

Power plant development on agricultural land can cause impacts that can generally be divided into impacts with short and/or long-term effects. Short term impacts of power plants, renewable energy projects in particular, have immediate and gradual physical consequences for the land and its use, which may lead to economic consequences. Long term impacts of power plants are often avoidable; however, they are considered a potential impact unless they are appropriately mitigated. Exploring what the impacts are is an important part of the mitigation process and is what this section of the report focuses on. Short term impacts include factors like dust, traffic, and temporary land access. Long term impacts include soil management and conservation (e.g., compaction, erosion, admixing), and land use impacts.

Based on a survey of complaints received by relevant authorities in Alberta, most complaints regarding renewable energy projects occurred during their construction phase and involved soil concerns, particularly dust and erosion (Thibault et al., 2013). The agencies receiving these complaints include the AUC, the respective municipality, and the REO (Renewable Energy Operator) owner. A study conducted by the Pembina Institute concluded that wind energy project operation is the least concerning for residents except for some noise and siting issues, while the construction phase of an REO has led to the greatest issues for rural communities (Thibault et al., 2013).

4.1 Short Term Physical Impacts

Short term agricultural impacts are generally related to the construction phase of renewable energy projects. The process of constructing a renewable facility can have additional short-term effects that indirectly impact the farming process. These include the creation of dust and land access constraints.

4.1.1 Dust, Noise and Traffic

Impacts such as dust, noise, and traffic can impact residents and cause land access issues during the construction process. These issues are common with construction projects and impact the residents of rural communities, which in most cases include the local farming communities. Therefore, they are not specific to agricultural production on farmland and will not be assessed fully in this report. Noise from construction equipment can disrupt the lives of residents. Increased traffic can cause risks of collisions with livestock. Unpaved roads are often the biggest source of soil erosion and dust during construction activities for energy projects (Ott et al., 2021). The erosion can be mitigated by road surface hardening (i.e., spraying calcium carbonate), but if any road maintenance is done during operation the erosion risk rises (Ott et al., 2021).

4.1.2 Short Term Land Access

Many projects require a larger construction footprint than the final or realized footprint that the project requires. For example, extra area might be needed for laydown areas that will be temporary in nature and not part of the permanent infrastructure. Short-term access can impact agriculture negatively through damage to crops, disruption of breeding seasons for livestock, and challenges for farmers to access their land through construction areas. Short term land access issues are common in many resource extraction projects and are like that seen within the oil and gas industry. For some projects such as solar projects, short term access issues may include access to land around the facility during construction, while wind projects will have unique impacts such as temporary right of ways (RoW) that should be constructed between wind turbines that will cut through agricultural lands. Seeding and spraying activities may not be feasible as RoW cannot be crossed leaving large areas of land impacted. An REOs impact to agricultural production extends beyond the project's operational footprint and into the construction footprint and wider project area. Breeding seasons for livestock can be disrupted if construction is occurring near livestock, especially when they become isolated.

4.2 Long Term Impacts

There are several long-term impacts that energy projects can have which will vary by the type of energy production and the design of the project itself. The following sections explore in detail the long-term impacts to agricultural land resulting from energy development. Long term impacts can be linked to the degradation of land productivity and loss of productive land. Land degradation has been well documented to include soil horizon mixing (i.e., admixing), contamination, topsoil loss (i.e., erosion), compaction (Mitchem et al., 2009), loss of native vegetation (Lancaster et al., 2018), and introduction of clubroot (Government of Alberta, 2014). Long term impacts to agricultural land area occurs through conversion of agricultural land into other land uses or through the reduction in agricultural land value.

4.2.1 Compaction

Soil compaction is well documented to negatively impact plant growth metrics. Soil compaction increases the bulk density of soil, while reducing soil porosity and the hydraulic properties of the soil (Horton et al., 1994). The net effect of these changes on plant growth (i.e., agricultural production) is decreased with reduced germination (Chamen et al., 2015), above ground growth, root growth, and root depth (Shaheb et al., 2021). Reduction in the overall size of roots of plants results in the reduced availability of key soil nutrients (Miransari et al., 2009; Shaheb et al., 2021) in many crops (Chamen et al., 2015). In addition to loss of access through limited rooting, the soil physical characteristics can change which is linked to loss of nitrogen through denitrification (Wolkowski, 1990). Compaction can decrease drought tolerance (Shaheb et al., 2021), reduced yields (Chamen et al., 2015; Shaheb et al., 2021), and decrease water storage compacity (Da Silva & Kay, 1996). These negative impacts of compaction increase the cost of production and reduce the overall revenue of farming (Chamen et al., 2015). For cereal grains decreases in yield of up to 30.0% was noted in multiple studies of wheat, barley, oats, and oilseeds. Typical reductions appear to be between 15.0% and 25.0% for many studies (Chamen et al., 2015).

Large agricultural equipment is the primary driver of compaction (Chamen et al., 2015). This occurs even though agricultural equipment generally employes low impact techniques in design and travel across the land is limited (Mitchem et al., 2009). Construction equipment completing typical construction activities common to energy production projects can cause significant soil compaction as documented in the oil and gas sector (Mitchem et al., 2009). In the reclamation of many oil and gas facilities, compaction has caused severe limitations to crop growth, and unique techniques to change construction methods have been devised to reduce these effects (Mitchem et al., 2009).

Compaction impacts can result in impacts to the topsoil, subsoil, or parent material. Depending on the depth of compaction, the effects may change. In addition, the soil type can greatly impact the effects of compaction with clay content being linked to significant impacts (Chamen et al., 2015).

4.2.2 Admixing

Partial admixing of soils is an unavoidable consequence of construction due to the size of shovel blades and the thin soil horizons being lifted. Often there is no discernible colour change in soil horizon for an operator to see which results in admixing of soil horizons. This process can be physically disruptive, potentially damaging soil structure and causing compaction, which may hinder root growth and crop development. Admixing can lead to nutrient imbalances, overfertilization, or the leaching of nutrients, which negatively affects crop health and the environment (Lavado & Cairns, 1980). If subsoils that contain salts, a type found throughout central and southeastern Alberta, are admixed with surface layers, salinity problems can occur (Government of Alberta, 2023a). Admixing of soil horizons can also disrupt microbial communities, altering soil biology and nutrient cycling (Government of Alberta, 2023a).

4.2.3 Erosion

Soil erosion occurs during the construction process when topsoil is left unvegetated for too long and precipitation and wind events remove unbound topsoil. The dispersed soil eventually results in sedimentation loading of downstream waterbodies, or through wind erosion which can cover adjacent vegetation and neighboring residences. Erosion primarily removes the fertile topsoil layer, which contains essential nutrients, organic matter, and microorganisms necessary for healthy plant growth. As topsoil is lost, the soil's fertility and nutrient content declines (Novara et al., 2018). Eroded soils may have reduced nutrient levels, leading to nutrient deficiencies in crops (Frye et al., 1982). Nutrient deficiencies can result in stunted growth, poor development, and lower yields (Novara et al., 2018). Erosion disrupts the soil structure, leading to compaction, crusting, and the formation of hardpans (Frye et al., 1982). Eroded soils have reduced water-holding capacity (Frye et al., 1982) which causes increased water runoff and decreased water retention, leading to water stress for crops during dry periods (Frye et al., 1982). Once erosion begins, it tends to be a self-reinforcing process.

As topsoil is lost, the underlying, less fertile soil becomes exposed and more susceptible to further erosion, creating a vicious cycle. Cumulatively, the above factors contribute to decreased crop yields. Lower fertility, poor soil structure, and water stress can result in smaller harvests and lower-quality produce (Frye et al., 1982). Over time, erosion can lead to the degradation of soil resources, making it more challenging to restore soil health and productivity. The long-term impacts can be especially detrimental (Lal & Moldenhauer, 1987). Removal of the vegetative cover in addition to topsoil loss can contribute to loss of soil organic carbon (SOC). The removal of SOC causes a short-term increase in atmospheric carbon; however, the long-term impacts are directly related to soil water holding capacity and nutrient availability (Novara et al., 2018).

4.2.4 Club Root

Clubroot is a growing concern in rural areas of Alberta, as it causes significant economic damage to canola crops. Over 42 municipalities report its presence (Government of Alberta 2021b). Clubroot, or *Plasmodiophora brassicae*, is a long-lived resting spore that can survive in the soil for up to 20 years (Government of Alberta, 2014). It is primarily spread through soil and can be carried from field to field and farm to farm by machinery, especially tillage equipment. Clubroot can also be moved by wind or water erosion (Government of Alberta, 2014). Various crop seeds, hay, and straw can also become contaminated with resting spores via dust or earth tag; therefore, due diligence is required in areas with known occurrences. Clean vehicle policies to remove potentially contaminated soil from vehicles, machinery, and equipment prior to arriving or leaving a site it critical in minimizing impact (Government of Alberta 2014).

4.2.5 Soil Moisture

Renewable energy projects can cause unintended impacts to soil moisture regimes. For example, the operation of wind turbines has been shown to reduce soil moisture through increasing evapotranspiration during normal operation (Wang et al., 2023). The impact is two-fold. Reduced soil moisture will reduce agricultural yields, impacting annual and perennial crops while also increasing fire risk (Wang et al., 2023). Although this impact may be less visual than other impacts on the landscape, it can have a long-term negative impact on areas where soil moisture is already limiting to plant growth. Assessing this potential impact should be part of the considerations of project designs.

Another example can be described in solar facilities that utilize agrivoltaics. The design of solar panels, particularly fixed photovoltaic panels can cause a rain shadow effect that is permanent and can greatly limit plant growth. A fixed tracker system (i.e., photovoltaic panels that pivot) may have a more variable impact on soil moisture. Photovoltaic panels may have the ability to increase concentration of precipitation in specific areas. This increase may benefit plant growth, but if improperly managed could cause increased erosion risks as well.

4.2.6 Vegetation

Physical impacts to vegetation resulting from energy development are largely an outcome of the previously discussed impacts on soils and can be a partial or total loss of productive land for either a short or long period of time. Physical impact to areas of native grassland and forest systems are more complex and revegetation of these areas to healthy functioning plant communities have proven to be much more difficult to complete. The extent and biodiversity of native grassland ecosystem's is decreasing from the cumulative effects of urban sprawl, fragmentation due to subdivision, recreational activities, energy development, and agricultural conversions (Lancaster et al., 2018). Some of these grasslands, such as fescue grasslands, are of specific concern and have received protections which include the fescue protective notation (Alberta Sustainable Resource Development, 2010). Other native grasslands do not have specific protection but retain significant value for agriculture. Native grasslands provide significant forage for the livestock industry within Alberta. Native grasslands are noted for their drought resistance and long-term productivity when managed properly (Tannas, 2011). This provides the livestock industry with cost effective forage. In particular, fescue grasslands are noted for their forage quality in the dormant season that allows ranchers to graze instead of feeding hay through the winter in some areas (Tannas, 2011). The loss of native grasslands has a negative effect on the livestock industry, and particularly the cattle industry which is the largest component of the livestock industry within Alberta.

4.2.7 Land Use Impacts

Land use competition between renewable energy developments and agricultural production can have several consequences. Consequences can vary depending on factors such as the location, type of energy project, and local land management practices. The colocation of agriculture and energy production can result in fragmentation of farmland which makes it more challenging to conduct efficient farming operations and manage large-scale, mechanized agriculture. Land allocated to renewable energy projects is typically no longer available for agriculture, which can have considerable economic consequences if the projects are sited on prime agricultural land (Jeffery et al., 2015; Lovering et al., 2022). Relative to other forms of energy production, such as oil and gas, renewable energy operations require considerable surface disturbance per mega watt (MW) produced.

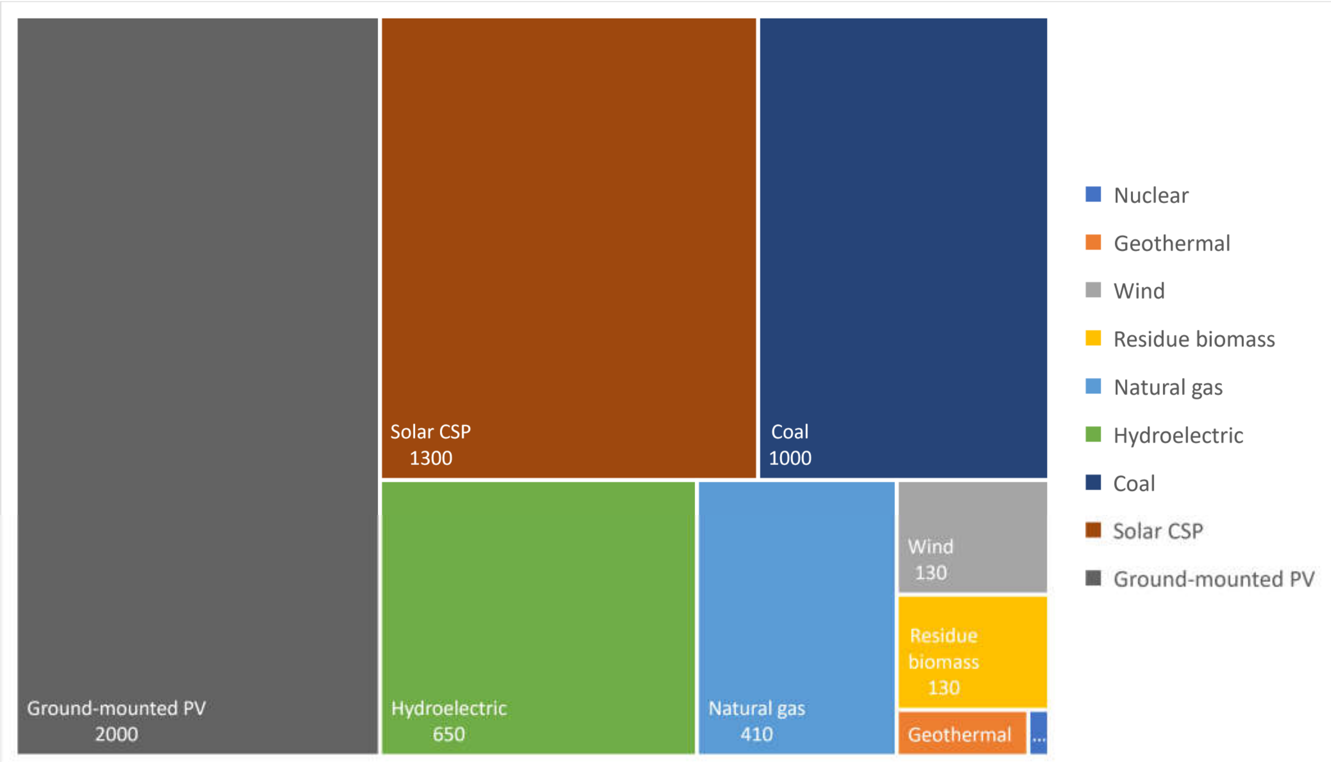

Figure 4-1: Schematic showing the median proportion of land use intensity for different forms of electricity generation. The larger the area the more ha required per TWh/y (Lovering et al., 2022).

Lovering et al. (2022) reviewed several different types of energy production. This study provided a meta-analysis of the area of land (ha) that each form of power generation required to produce one Terawatt hour of electricity per year (TWh/y). When comparing potential power generation types in Alberta on agricultural land, nine power generation techniques were selected from the study to be displayed. Figure 4-1 displays the median Land Use Intensity of Electricity (LUIE) for each selected power generation type. The standard error for most power generation is reasonable except for hydroelectric generation which has a standard error of 4,300 ha/TWh/y (Lovering et al., 2022). Land use efficiency is poorest with ground mounted photovoltaic (PV) with 2000 ha/TWh/y and is the most efficient with nuclear with a median of 7.1 ha/TWh/y (Lovering et al., 2022). Geothermal was the second most efficient with 45 ha/TWh/y (Lovering et al., 2022). The second largest footprint (ha/TWh/y) was by concentrated solar power which is currently not employed in Alberta.

Lovering *et al.,* measured the LUIE for major sources of electricity production and found that a wind projects area requirements are several orders greater than all other common forms of electricity production except for biofuel (Lovering et al., 2022). However, this is only when spacing required between turbines is considered (Dhar et al., 2020). The spacing needed between turbines is not necessarily a direct loss of agricultural land, as the land between wind turbines typically remains productive agricultural land. For this reason, the full footprint of wind is not considered in Figure 4-1. Biomass has been omitted from the figure because its production either uses non-ag lands (i.e., forests) or agricultural products. When considering only the physical infrastructure footprint, wind energy has the third most efficient LUIE rating behind nuclear and geothermal (Lovering et al., 2022). When all land use impacts are considered, the intermittent nature of wind and solar energy requires additional backup generation or storage space that is not accounted for in this study.

The amount of land required to power Alberta's electrical grid will greatly depend on the type of generation considered. The current energy needs within Alberta have roughly doubled in the past 30 years (Alberta Utilities Commission, 2023). The AUC recorded an annual use of 87 TWh in 2022 (Alberta Utilities Commission, 2023) as shown in Table 4-1. The future energy needs within Alberta are likely to grow significantly as the population grows and the province transitions to more sustainable forms of electricity production.

Table 4-1: Power production capacity and supply within Alberta in 2022

Alberta Current Need*					
Energy Source	Supply (%)	Production (%)	MW	GWh/y	TWh/y
Solar	1%	7%	1,292	1,159	1.2
Wind	9%	17%	3,139	7,345	7.3
Hydro-electric	2%	5%	923	1,960	2.0
Coal	12%	7%	1,292	10,155	10.2
Natural Gas	73%	61%	11,262	60,821	60.8
Biomass	2%	2%	369	2,089	2.1
Other	0.3%	1%	185	239	0.2
Total	100%	100%	18,463	83,768	83.8
Net Import				3,904	3.9
Total Used				87,672	87.7

*Information in this table is supplied by the Alberta Utilities Commission (Alberta Utilities Commission, 2023)

4.2.7.1 Impact of Photovoltaic (PV) Panels

Currently, solar in Alberta makes up 7.0% of the total 18,463 MW of capacity but produces only 1.0% of the total power supply (Alberta Utility Commission 2023). Lovering et al. (2022) suggested that PV panels require 2000 ha/TWh/yr. Industry suggests that a 1 MW solar farm requires between 5 and 10 ac (2 - 4 ha) of land. Coldwell solar suggests 6 - 8 ac or 2.4 - 3.2 ha (Coldwell Solar, 2023), while the Solar Energy Industries Association suggests 5 - 10 ac or 2 – 4 ha (SEIA, 2023). When converted to annual production this would be between 1385-2771 ha/TWh/y. The mean provided by Lovering et al. (2022) of 2000 ha appears reasonable for estimating land area requirements as it lines up with these numbers. However, considering that solar energy and wind are not consistent throughout the year, the MW production from solar, wind, and hydro-electric power generation is under preforming compared to other forms of energy production. Based on the information provided (Table 4-1) solar is supplying 1/7th of its total production capacity, while fossil fuels are supplying a larger proportion than their total production capacity. This suggests that the land area required for solar energy production capacity may be even greater than predicted.

4.2.7.2 The Impact of Wind Turbines

Compared to PV panels, wind turbines require less land per MW based on their operational footprints (Lovering et al., 2022). Currently, wind energy makes up 17.0% of Alberta's 18,463 MW of installed generation but only 9.0% of the generation (Alberta Utilities Commission, 2023) as shown in Table 4-1. However, the impacts of wind energy projects are not limited to agricultural land loss.

Wind energy requires a complex road network, as each turbine needs permanent access for construction and maintenance. Access is quite different than conventional oil and gas and specifically different compared to shallow gas projects. Road construction for wind projects requires the construction of a high-grade gravel road into each tower, with a widened access approach off any main road due to the size of the turbine blade. Commonly, the high-grade gravel road remains in place for the life of the project while the widened approach is removed and reclaimed. The permanency of these roads is due to the relatively short lifespan of modern turbines, which averages 20 years and requires maintenance every six months (United States Environmental Protection Agency, 2003). As discussed earlier, this road network causes fragmentation that can impact livestock and crop production. So, while the total area of wind power generation is relatively small, poorly planned installations can have an impact on agriculture that is larger than their operational footprint.

4.2.7.3 Hydro-electric Production

Hydro-electric production in Alberta occurs on many rivers and accounts for 5.0% of the 18,463 MW total capacity (Alberta Utilities Commission, 2023), however, it only accounts for 2.0% of our energy consumption and providing 2.0% of the total energy production (Table 4-1) within Alberta (Alberta Utilities Commission, 2023). In Alberta, there are many micro-dams and small reservoirs generating electricity (Government of Alberta, 2023e) that typically do not remove large tracts of farmland from production. An additional 11,500 MW of economic hydro potential has been identified on existing reservoirs and run of the river projects, which are hydroelectric plants where there is little or no water storage provided (Government of Alberta, 2023d).

Some hydroelectric production can benefit agriculture while producing electricity, such as the Old Man Dam which supplies a large irrigation district. This allows power generation without impacting farmland. The integration of hydro-electric generation with lift storage and irrigation infrastructure would be a unique approach to storing excess solar or wind energy if there was a suitable location for it. Lift storage is a technique of pumping water to a high elevation when electricity prices are low and then generating hydroelectricity from this water when power prices are high. If combined with solar energy, this could effectively supply power at night or when the sun intensity is low.

In contrast, there is potential for hydro-electric projects to remove significant tracts farmland and cause controversy in rural communities as has been documented with the site C project in British Columbia (Jeffery et al., 2015). In many locations, the addition of hydro-electric projects requires the installation of large-scale reservoirs on relatively level landscapes. This results in large tracts of land being flooded.

4.2.7.4 Coal, Natural Gas, Biogas/Biomass and Other Energy Generation

Of the 18,463 MW of generation capacity in Alberta, 7.0% is from coal, 61.0% is from natural gas, 2.0% is from biogas/biomass, and 1.0% is from other sources (Alberta Utilities Commission, 2023). The actual power generated is 12.0% from coal, 73.0% from natural gas, 2% from biogas/biomass, and less than 1.0% from other sources (Alberta Utilities Commission, 2023) as shown in Table 4-1.

5.0 Literature Review of Mitigating Impact of Power Plants on Agricultural Land in Alberta

Section 4.0 of this report examines how agricultural lands can be impacted by renewable energy developments. This section will offer potential considerations to these impacts, including standards for co-land use with agriculture. Mitigation of the physical impacts can be addressed by evaluating direct impacts to land productivity, siting projects to reduce impacts, and requiring projects to maintain the economic viability of the current land use.

5.1 Mitigating Impacts to Land Productivity

The productivity of land can be decreased through impacts to soils and vegetation that occur during a project's construction and reclamation phase.

5.1.1 Environmental Assessments and Management Plans

Proper environmental assessment is the best means of developing management plans which protect environmental and agricultural features on the landscape. At the application stage, providing relevant data will aid in having agricultural land quality assessed and appropriate mitigation measures created. This process begins with a pre-disturbance site assessment (PDSA) and Environmental Protection Plan (EPP).

5.1.1.1 Pre-Disturbance Site Assessment

The pre-disturbance assessment for REOs is a relatively robust process but could use refinement within an agricultural context. Information from the pre-disturbance assessment should be collected to guide development of mitigations to meet the goal of preventing construction from impacting the productive capacity of the land. The level of detail required for these plans should be sufficient to plan technically feasible mitigations into the final construction and reclamation plans. There is a benefit to providing pre-disturbance data to the AUC prior to project approval. This provides the opportunity to evaluate the plan against current site conditions and enables a more informed decision on behalf of the AUC.

Soil conservation begins with accurate soil data collected during the PDSA stage of the project. For renewable energy projects, the PDSA is submitted following project approval. Prior to approval, the Desktop Review Assessment (DRA) provides the initial data for the Conservation and Reclamation Plan for the project (Alberta Environment and Parks, 2018a). The purpose of pre-disturbance data collection is to gain an understanding of the site prior to the project's construction so that appropriate steps can be taken to preserve the integrity of the soil for future reclamation use (Alberta Environment and Parks, 2018a). The PDSA conducted for an REO determines the depths of soil horizons throughout the construction footprint. This pre-construction assessment is critical to develop a soil handling plan that effectively guides operators. Horizon characteristics that are identified during the PDSA, including texture and colour change, trigger a change in soil management to be implemented by the operator.

The requirements for a PDSA are outlined in the Conservation and Reclamation Directive for Renewable Energy Operations (Alberta Environment and Parks, 2018a). As per Table 2 of the C&R Directive, there are no requirements for a PDSA for REOs commissioned prior September 14, 2018. A PDSA using shallow soils data is required if the REO was commissioned between September 14, 2018, and June 30, 2021. A PDSA using shallow and deep soils data is required if the REO was commissioned after July 1, 2021, (Alberta Environment and Parks, 2018a).

To collect pre-disturbance soil data, intrusive sampling techniques are required to distinguish between soil types. Appendix B of the C&R Directive should be used for specific methods to follow when conducting a PSDA for an REO. Additional resources on standard methods for conducting soil surveys and soil mapping include:

- A Soil Mapping System for Canada: Revised (Agriculture Canada Research Branch, 1981)
- Soil Quality Criteria Relative to Disturbance and Reclamation (Soil Quality Criteria Working Group, 1987)
- Canadian System of Soil Classification (Soil Classification Working Group, 1998)

In addition to soil surveys and soil mapping, soil characterization via laboratory analysis is also recommended. As per the Soil Quality Criteria (Soil Quality Criteria Working Group, 1987), pH, electrical conductivity (EC), sodium adsorption ratio (SAR), and coarse fragments are potential limiting factors; therefore, should be assessed to determine if the soil is good, fair, poor, or unsuitable for reclamation purposes. There are some known factors that affect the quality of reclamation material such as geological formations and materials that have been influenced by soil weathering processes that have a pH outside of the accepted range (e.g., calcareous material), elevated salinity, sodicity of certain geological materials, and the presence of coarse fragments (MacKenzie et al. 2012). Consideration for these soil parameters should be included in the reclamation planning process. The PDSA process works well when the appropriate data is collected by qualified professionals. The weakness historically has been that most of more the soils data is collected post approval, and not available to inform the approval process. Apart from the collection of some additional key information pre-approval, the PDSA process is sufficient to inform the construction and reclamation plans.

5.1.1.2 Environmental Protection Plans

Environmental protection measures, particularly those for soil resources, are outlined through a standalone document required under AUC Rule 007 called the Environmental Protection Plan (EPP; Alberta Utilities Commission, 2022).This document itemizes and summarizes all of the mitigation measures and monitoring activities that the applicant is committed to implementing during construction and operation to minimize any adverse effects of the project on the environment (Alberta Utilities Commission, 2022).

The EPP requires that all ecosystem components be identified that may be impacted by construction or operating activity. Appropriate siting of projects may reduce the components that need to be examined in detail at a field level. These are not limited to but include terrain and soils, surface water bodies and hydrology, groundwater, wetlands, vegetation species and communities, wildlife species and habitat, aquatic species and habitat, and air quality (Alberta Utilities Commission, 2022). The primary component of an EPP are the activity specific protection measures, which outline construction steps and associated measures. These measures are typically presented in categories of successive development activities like access and site preparation, foundation construction, and so forth. Where soil resources are concerned, a contractor may be required to develop a soil handling plan which places more emphasis on the step-by-step process of soil stripping, stockpiling, and storage (Bradley & Neville, 2011).

Adherence to the soil handling measures outlined above is facilitated by regular third-party compliance monitoring and audits for projects in the oil sands and oil and gas industry. Providing independent environmental monitors will facilitate proper monitoring. Soil conservation within the grassland region, particularly for renewable energy construction, stands the most to gain by adopting the policies and processes which have led to greater reclamation success seen in the oil industry. Modifications to the EPP should consider specific requirements related to mitigating impacts to land productivity and a focus on how to reclaim equivalent land capability post construction in both the operations and post decommissioning periods of a project.

5.1.2 Soil Conservation for Agriculture

Although legislation requires soil conservation a landowners recourse may be limited if poor soil management occurs on their land

Practicing good soil conservation during the construction phase of a power plant is vital for the long-term productive capacity of that land. Through the *Environmental Protection and Enhancement Act* (EPEA; Environmental Protection and Enhancement Act, 2000) and the *Conservation and Reclamation Regulation* (Conservation and Reclamation Regulation, 1993) requires the prevention of soil degradation during all stages of an REO. The *Soil Conservation Act* (Soil Conservation Act, 2000), also has requirements for prevention of soil degradation. The protection of soil resources through provincial legislation is also a protection for landowners during the land development process. A landowner recourse may be limited if poor soil management occurs on their land during the installation and operation of an energy project.

Through these statutes, numerous directives, and Best Management Practices (BMP) for construction in sensitive natural areas have been developed which support the long-term productive capacity of agricultural lands and natural regions. These reports, outlined in the Conservation and Reclamation Directive for Renewable Energy Projects (Government of Alberta, 2018), include but are not limited to the following:

- Alberta Clubroot Management Plan (Government of Alberta, 2014)
- Beneficial Management Practices for Renewable Energy Projects – Reducing the Footprint in Alberta's Native Grassland, Parkland and Wetland Ecosystems (Neville, 2017)
- Soil Series Information for Reclamation Planning in Alberta - Volume 1 (Pedocan Land Evaluation Ltd, 1993)

Having an independent Qualified Environmental Professional onsite during construction and reclamation is the best way to ensure BMPs are implement correctly and soil conservation practices are applied (e.g., salvaging and placement of reclamation materials). These professionals, who act as Environmental Monitors during the construction process, are trained in soil sciences, construction standards, and reclamation criteria. Their oversight during the soil salvage process is critical to prevent occurrences such as erosion and compaction from deteriorating the long-term productive capacity of the soil.

5.1.2.1 Soil Salvage and Storage

Soil salvage activities for an REO are guided by information in the EPP and C&R plan with the principal objective to minimize the disturbance area for the project and prevent soil loss and degradation. Identification of soil horizons within the construction footprint is the first step to prevent admixing from occurring during the stripping and stockpiling process. This occurs during the PDSA for the project. Prior to soil stripping the areas to be stripped should be clearly delineated in the field to prevent trespass by machinery outside of the construction footprint. Areas for soil stockpiling, determined during the EPP and in consultation with the respective landowner, should also be delineated. Soil stockpile volumes need to be calculated as accurately as possible to ensure sufficient storage is accounted for in the initial REO approval.

5.1.2.2 Salvage Process

Soil salvage should only be conducted in dry or frozen conditions to prevent compaction and excess contamination of the soil horizons. The topsoil should be stripped and stockpiled separately from the subsoil. In certain soil types (solonetzic being the exception), the topsoil layer may not comprise the upper 15 cm of the soil profile. In these scenarios it is often accepted that the subsoil layer will be added to the topsoil layer to a depth of 15 cm. The following lift (below 15cm) will be comprised of just the subsoil layer. Changes in soil horizon can be difficult to discern where the colour change in not evident. An environmental monitor acting as a spotter should be used to guide operators when this occurs.

As stated in the Guidelines for Alternative Soil Handling Procedures During Pipeline Construction, there needs to balance between minimizing the area of disturbance and minimizing the intensity of the disturbance (Pettapiece & Dell, 1996). The goal of soil salvage is to preserve the organic rich surface layer. On cultivated lands, this can be achieved in two ways, by two-lift or three-lift salvage techniques. In cases where topsoil is shallow, the top 15 cm may include the topsoil and subsoil and only require a single lift to be salvaged, but this is to be done at the direction of a qualified reclamation or soil scientist.

Two-lift soil salvage means that two separate layers of soil are stripped. As per the soil handling guidelines, the depth of the first layer can be modified for site-specific conditions (Pettapiece & Dell, 1996). However, it is recommended for the first lift to salvage at a minimum 10 centimeters (cm) and up to a maximum of 35 cm. Although if site conditions permit, the first lift may be increased to 50 cm on rare occasions. The first lift is usually stripped based on colour change; however, if there is no clear indication then a default depth of 15 cm to be stripped is recommended. It is important to not over strip as it will decrease the soils functionality as the subsoil and topsoil are admixed. Admixing can result in a decrease in organic carbon content, infiltration, and seedling emergence post-reclamation, while increasing clay content, bulk density, salinity, sodicity, and pH (Landsburg & Cannon, 1995). Two-lift soil salvage is the standard practice for cultivated lands; however, under certain circumstances such as gravelly or saline soils three-life soil salvage may be necessary (Pettapiece & Dell, 1996).

Salvaged soils being stored over the long term (>30 days) should have a soil management plan (Parks Canada, 2021) and is usually included in the closure and reclamation plan. It is important to handle salvaged soils as little as possible because every move can cause a loss of 10 to 25% of the volume (Parks Canada, 2021); therefore, soils should only be moved twice – once during storage and second during reclamation. BMPs suggest that salvaged soils, especially topsoil, should be stored on the uphill side of the disturbance, if occurring on a sloped terrain, and away from any grades, subsoils, spoil material, construction activity, and day to day operations (Parks Canada, 2021). Different soils should not be stored together, rather they should be in separate piles greater than 3 meters (m) from each other to prevent inadvertently mixing them (Parks Canada, 2021). Additionally, topsoil piles should not exceed 2 m in height with a slope no greater than 15% or 3:1 to maintain the integrity of the soil for reclamation purposes (Parks Canada, 2021). To prevent soil loss, salvaged soils should be stored in sheltered areas, be surrounded by berms or silt fencing, and have a cover crop established on them or a tackifier in place (Parks Canada, 2021). Soils to be stockpiled for long periods should be seeded with a seed mix approved by landowner and the relevant regulatory authority to prevent erosion and colonization of weed species.

5.1.2.3 Practices to Prevent Erosion

Mitigating erosion during the construction phase of a project begins with thorough site assessment to identify areas prone to erosion and evaluate the potential risks. This should be followed by a site-specific erosion control plan that complies with local regulations and environmental permits. Erosion caused by natural sources (i.e., wind, water) and construction machinery should be controlled by contractors during the REO construction process. Erosion control measures should be considered when specifying construction methods, soil conservation during construction, interim stabilization of conserved soils during operations and final reclamation (Government of Alberta, 2011). There are generally five recognized practices and techniques in the construction industry to prevent, reduce, or mitigate erosion after it has occurred. Combinations of these techniques may be required for the scale and complexity associated with an REO. The techniques include surface protection textiles, ground cover armouring, diversion or deceleration of flow, water filtration, and vegetation establishment (Government of Alberta, 2011).

Surface protection textiles are laid directly on the exposed soil surface and provide a barrier between it and the elements. These come in a variety of products, are biodegradable, and are easy to install. Given the challenges involved with laying them during high wind events, they should be in place before storms are anticipated. Examples of surface protection includes coco matting, bento matting, erosion blankets, or even a tarp in last minute situations (Government of Alberta, 2011).

Ground cover armouring is used when regularly flowing systems need to be protected for the long-term. In high flow situations this type of erosion control is about the only method sufficient to prevent flood waters from removing the vegetated surface. These systems can be difficult to install in remote areas due to the material transport constraints. Examples of ground cover armouring includes large rocks, concrete, hard plastic, or steel. These types of systems are often seen in cross-drainage structures or ditches (Government of Alberta, 2011).

Where the installation of erosion control systems is not feasible, a contractor may consider diverting or decelerating the flow of water to prevent erosion. Slowing the flow of surface water allows sediment and other material to settle out before it is transported to downstream waterbodies (Government of Alberta, 2011). The flow of water can be slowed by converting straight flow paths into S or C shapes (or other orientation). This erosion solution can be combined with installed erosion control protection to make the whole system more effective. Examples of surface flow diversion include check dams, silt fencing, and berm construction (Government of Alberta, 2011).

If installation of hard erosion protection or diversion measures is not feasible due to short time frames, soil can be contained onsite through filtration devices. These products allow water to pass through at varying rates while collecting soils and other ground cover. They can be used over a large area, such as straw wattles, or can be attached to a point source, such as a filter cloth bags (Government of Alberta, 2011). Products used to trap sediment over a large area become less effective when the flow of water increases. Filter bags can be attached to downspouts or water diversion hoses (Government of Alberta, 2011). While these products are affordable and can be implemented all over a site, their effectiveness is reduced in variable conditions, and they often require monitoring.

For intermittent, light to moderately flowing waters, establishing vegetation on the soil surface is the best way to prevent erosion. When a native or desirable species is used, this technique also prevents weed species from establishing. Seeding can be done rapidly using hydroseeding or by planting larger shrubs and trees. An initial cover of a landowner preferred seed mix or a mix approved by the regulator should be planted immediately for maximum erosion protection (Alberta Sustainable Resource Development, 2010). While establishing vegetation can be a long-term solution, heavy flood conditions may uproot planted material. However, if construction requires erosion control in the later stages of the growing season, plants may not establish in time. Additionally, in the event surface waters do not flow, the planted vegetation will still require watering.

5.1.2.4 Practices to Prevent Compaction

Compaction can be mitigated and alleviated through proper construction management practices. It is always easier to prevent compaction than repair compacted soils. Where possible, avoidance and mitigation measures should always be employed first, and alleviation measures should be employed when avoidance is not possible. Mitigation of the impacts of compaction can be effectively achieved through use of low ground pressure tires (Lamandé & Schjønning, 2011), construction during dry and frozen soil conditions (Alberta Environment and Parks, 2018b), and use of matting to protect soil (Alberta Sustainable Resource Development, 2010). Alleviation of compaction may be effectively completed through paratilling, tillage, and ripping.

5.1.2.5 Avoiding Compaction

Soils at REO construction sites are generally compacted because of excavation, mixing, stockpiling, equipment storage, and traffic. In addition, exposed subsoil is susceptible to compaction. Clay soils and wet soils are more susceptible to compaction. Even at sites where selective grading is employed, compaction occurs because of construction equipment, stockpiling, and vehicle traffic. Avoiding construction in early spring and after rain events to prevent compaction from occurring. In cases where it is necessary to construct or access a site and the ground is still wet or soft, rig matting can be used to prevent further degradation of topsoil and vegetation cover (Lancaster et al., 2018).

Low ground pressure tires and tracked equipment can be used to reduce the stresses applied to soil (Chamen et al., 2015; Pagliai et al., 2003). However, soil compaction can still occur while using tracked and low ground pressure tires. Low ground pressure tires and tracks effectively restrict compaction to surface soil layers in agricultural tractors (Pagliai et al., 2003). Compaction at surface is related to mean ground pressure, while at 0.9 m depth compaction is more closely correlated with the wheel load (Lamandé & Schjønning, 2011). This means that while using low pressure tires can reduce compaction at the surface the load will still cause compaction at depth (Lamandé & Schjønning, 2011). Low impact tires may be useful for reducing surface compaction, they may not prevent deeper compaction from occurring.

5.1.2.6 Alleviation of Compaction

The negative effects of compaction can be alleviated through several techniques if they are applied correctly. These include subsoiling/paratilling, tillage, and ripping.

Paratilling

Subsoiling (also known as deep ripping) is a process that fractures compacted soil without adversely disturbing plant life, topsoil, and surface residue. Fracturing compacted soil promotes root penetration by reducing soil density and strength, improving moisture infiltration and retention, and increasing air spaces in the soil (Chamen et al., 2015). This technique can alleviate completely the impacts of compaction but has a higher upfront cost (Chamen et al., 2015). Paratilling is a type of deep non-inversion tillage utilized to loosen soil structure without compromising the soil conversation practices that are already employed on farms (Ewen et al., 2012). Paratilling is normally completed at a depth between 30 cm and 45 cm in depth and spaced between 45 cm and 90 cm (Ewen et al., 2012).

Tillage

Plowing of surface soils can alleviate compaction through surface treatment (Chamen et al., 2015). Plowing causes significant soil modification and can lead to admixing in shallow soils and increased erosion. Other surface treatments such as cultivation and discing can be effective in alleviating surface compaction.

Ripping

When stripping of topsoil and subsoil has been completed it is possible to rip soil to alleviate compaction. Ripping without specialized equipment should only be done within a single surface layer of the soil. As such it is best completed in parent material prior to placement of subsoil and topsoil to avoid admixing.

5.1.3 Clubroot

As per the Alberta Clubroot Management Plan (Government of Alberta, 2014) and the Canadian Association of Petroleum Producer's (CAPP), Best Management Practices: Clubroot Disease Management (Canadian Association of Petroleum Producers, 2008) there are three levels of cleaning:

- Level 1 – rough cleaning by scraping off any soil or crop debris from equipment.
- Level 2 – fine cleaning by pressure washing vehicles with hot water or an industrial detergent while paying extra attention to areas where soil can accumulate.
- Level 3 – Disinfection by misting equipment with a 1 to 2% bleach solution after a level 2 clean. If possible, it is recommended to let the solution sit on the equipment for 15 to 20 minutes, ensuring to keep the equipment wet by resoaking or respraying it.

Other ways to minimize the spread of clubroot is to avoid working or moving equipment during wet conditions (Canadian Association of Petroleum Producers, 2008; Government of Alberta, 2014).

5.1.4 Mitigating Vegetation Impacts

Native grasslands have a high value for livestock as well as other ecosystem services they provide. Loss of native grasslands through direct removal or secondary impacts such as invasive species establishment has caused significant concern within the province. There have been a number of protections placed upon native grasslands along with best management practices and guidelines to restore them once they have been disturbed. As mentioned in the soils section there are several regulations and best management practices developed to help protect and restore native grassland ecosystems. In regard to vegetation, the following resources support the protection of native grasslands through minimal disturbance process and reclamation practices:

Recovery Strategies for Industrial Development in Native Grassland/Prairie:

- Dry Mixedgrass Natural Subregion (Gramineae Services Ltd., 2013)
- Mixedgrass Natural Subregion (Neville et al., 2014)
- Northern Fescue Natural Subregion (Lancaster et al., 2017)
- Foothills Fescue, Foothills Parkland and Montane (Lancaster et al., 2018)
- Recommended Principles and Guidelines for Minimizing Disturbance of Native Prairie from Wind Energy Development (Bradley & Neville, 2011)

- Plant Material Selection and Seed Mix Design for Native Grassland Restoration Projects (Tannas et al., 2016)

5.2 Recommended Mitigation Measures for Wind and Geothermal

The impacts of wind turbines and geothermal facilities on agriculture are generally related to loss of productive land. This includes but is not limited to the footprint of the turbine, crane pads, well pad, generator stations, and road infrastructure associated with the wind and geothermal infrastructure. These impacts are like oil and gas, and as such mitigations should follow those developed for other industrial activity. There are differences such as piping of hot water (i.e., geothermal) or buried power lines (i.e., wind) compared to oil and gas infrastructure, but the impact to agricultural lands is very similar. Proper siting, design, and monitoring are all required to ensure minimal impacts to agricultural lands.

5.2.1 Temporary Mitigations

Temporary mitigations may be as simple as compensation for lost crops in forage and annual crop production areas (i.e., during construction). Temporary mitigations could be complex as well, for example, if breeding seasons for livestock are disrupted. Construction season timing can be used as a tool to avoid these types of conflicts effectively. Construction in the winter avoids most agricultural activities, and late summer or fall construction can avoid breeding seasons for most livestock.

5.2.2 Siting Based Mitigations

Locating wind turbines and geothermal wells in areas with lower agricultural value will reduce impacts. Selection of sites can be in the corner of fields, along fence lines, and along roads to reduce the potential for conflict. Selection of locations without severe topography can reduce the amount of soil disturbance and subsequent risks to loss of production on the land.

5.2.3 Design Based Mitigations

Requirements for all energy production should include ensuring road and infrastructure is laid out in a way that is compatible with agricultural production. Roads should allow for large farming equipment to effectively access all of the agricultural land without cutting off portions and making them unusable. Land that is no longer accessible will count as part of the minimum loss on productive yield. Wind turbines and geothermal well locations should consider existing farm trails and road networks before building new ones. All techniques that reduce the physical footprint of impact should be considered.

5.3 Recommended Mitigation Measures for Solar and Agrivoltaics

PV power generation comes in several forms but is typically found either on a small scale on structures or on a large scale in dedicated solar farms. The footprint that solar facilities require is a lot larger than some other energy generation techniques, and as such, the mitigation techniques require a more complex approach to mitigate impacts to agriculture. Without appropriate design, many photovoltaic projects will significantly reduce the value of agricultural land, if not eliminate it completely. In order ensure agricultural productivity is not harmed, a solution called agrivoltaics has been proposed in many jurisdictions, and it is gaining traction as a solution that is flexible and economically viable.

5.3.1 Agrivoltaic Systems Overview

5.3.1.1 Definition

Agrivoltaics is a dual use system that simultaneously uses an area of land for both PV power generation and agriculture (Coşgun, 2021). Agrivoltaics can be adapted to many forms of agriculture, including horticulture (i.e., outdoor, or indoor greenhouse production), annual crop production, livestock production, and forage production (e.g., hay). Agrivoltaic systems offer several advantages including diversified income sources for farmers, reduced land use conflicts, improved land productivity, and the generation of clean energy without significant land conversion (Jamil & Pearce, 2023).

5.3.1.2 Strengths and Weaknesses of Agrivoltaics

The use of agrivoltaic systems solves one of the largest problems with traditional photovoltaic power production, which is the removal of agricultural land from production (Klenske, 2022). Instead of converting land from one use to another, agrivoltaic systems can produce a total output per land area that is greater than either system alone. Land Equivalent Ratios (LER) are often used to measure total output per land area. For agrivoltaic operations, LERs are typically greater than one indicating an efficient use of land area (Amaducci et al., 2018; Campana et al., 2021; Dupraz et al., 2011). Dupraz et al. (2011) predicted an overall increase of 35-73% in land productivity from synergies in agrivoltaic systems. Within Table 5-1 some of the key strengths and weaknesses of agrivoltaic systems is highlighted.

Table 5-1: Key strengths and weaknesses of agrivoltaics in Alberta.

Strengths	Weaknesses
Potential to increase overall output per unit of land	Sacrifice some crop or energy production
Project close to large population with easy access to markets for fresh local agriculture products	Systems not tested in local environment
Panels can be more efficient with crops underneath to help cool panels	Extra expenses and design may be required to accommodate farming activities and adequate growing environment
Shading can improve water efficiency during hot dry conditions	During cooler times of the year shading is likely to have negative impacts on crop growth
Panels can lengthen the growing season	Equipment sizes are large in Alberta limiting panel configurations that work for agriculture

5.3.2 Agrivoltaic Design

Agrivoltaic systems can be classified primarily on the agriculture system they support (i.e., crop or livestock), and based on if the production system is closed or open (Willockx et al., 2020). Photovoltaic greenhouses produce crops in a closed system, while field crops are produced in an open system as shown in Figure 5-1. There are two main structural options for agrivoltaic systems, which are lower panels between the crop, and higher panels above the crop (Willockx et al., 2020). Solar panels are mounted on structures above the ground, such as fixed racks, tracking systems, or specially designed structures (Willockx et al., 2020). These structures elevate the solar panels to provide ample space underneath for agricultural activities. Solar panels can also be mounted vertically to increase operating room and reduce shading. The spacing between solar panels, the height of the panel structures, and the arrangement of crops are carefully planned to ensure that both the solar panels and the crops receive the necessary sunlight (Willockx et al., 2020).

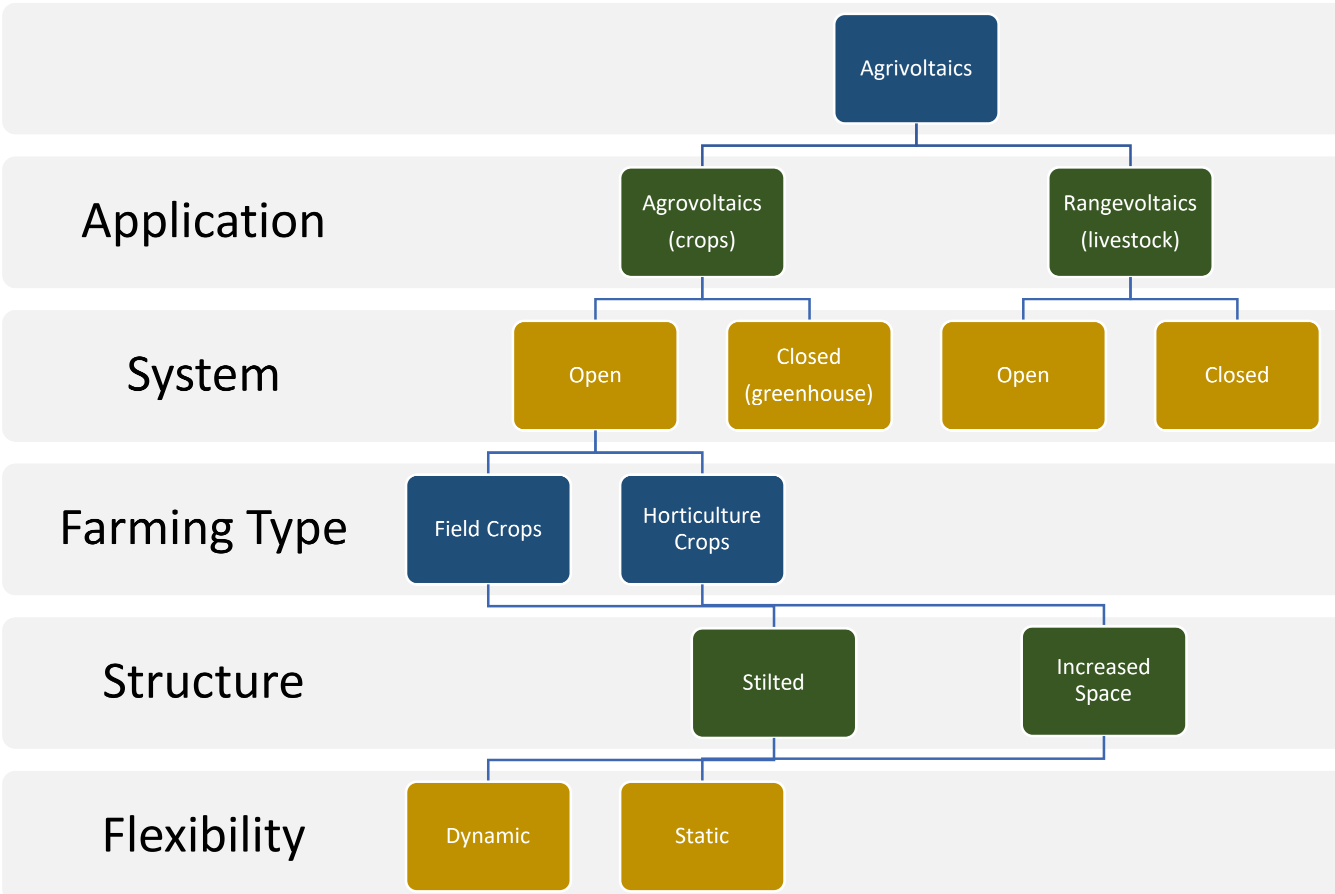

Figure 5-1: Classification of agrivoltaic systems adapted from (Willockx, Uytterhaegen, et al., 2020).

5.3.2.1 Photovoltaic Greenhouses

A common challenge with greenhouses is that more sunlight is required than in needed open fields. As a result, solar panels on greenhouses can have a negative effect on production when they cause significant shading (Klenske, 2022). Brite Solar has constructed a 1,000m^2 test greenhouse in Greece covered in nanostructure-coated solar cells able to produce 50 kW of power (Klenske, 2022). Most research on agrivoltaics has been on photovoltaics greenhouses (Toledo & Scognamiglio, 2021).

5.3.2.2 Open Field Systems

Field crops are produced between or underneath panels in open field systems. Many arrangements can be configured to meet energy and crop production goals. Less than 30% of research completed on agrivoltaics has evaluated open field systems (Toledo & Scognamiglio, 2021). Implementation of large scale agrivoltaic systems should consider the economic and social constraints that exist. In agriculture systems, farmers and producers are more likely to live at their places of work in contrast to most business models where employees compute to their place of work. As a result, in agriculture considerations there is a much higher linkage to the personal lives of the business owners. Technology and design solutions exist to mitigate challenges in implementing agrivoltaic systems as shown in Table 5-2. However, these solutions require upfront planning and design, and there is little that can be done to fix poorly designed systems once they are installed.

Table 5-2: Barriers and solutions to implementation of agrivoltaics in open-field systems summarized from (Toledo & Scognamiglio, 2021).

Topic	Design Related Solution	Technology Related Solution
Minimizing shadows on crops (biomass yield)	Optimal design: • Distance between the arrays of modules. • Distance of the modules from the ground.	• Sun-tracking systems. • Semi-transparent PV modules (by spacing PV cells). • Light-selective PV devices.
Maximizing electric energy generation	Optimal planning: • Avoiding sharing losses from surrounding elements (structures, buildings, trees, inter-row shading of the PV modules should be minimized). Optimal design: • Azimuth facing equator and tilt close to latitude.	• Highly efficient systems (e.g., sun-tracking systems). • Highly efficiency modules or technologies (e.g., bifacial module technology).
Social acceptance (landscape dimension)	Optimal landscape design: • Pattern of PV arrays aligned to the parcel. • Natural fences and low height structures to minimize visual disturbance. • Use of marginal areas. • Removable systems. Optimal design: • Different tilt, azimuth and height to reproduce the topography of the land.	• New materials for structure.
Social acceptance	New business models: • Higher economic efficiency per land unit (farmer perspective). • Benefits for local economy and employment (tourism, local recreation, etc.).	

Panels Above Crop

With this PV structure, panels are typically on stilts two to five meters high (Willockx et al., 2020). Crops can be grown underneath of the panels. The main disadvantages of higher structures are increased visual impacts and greater construction costs for foundations, stilts, and reinforcement (Willockx et al., 2020). SolAgra is an example of a panel system that is designed for equipment to fit underneath. This system also has shifting technology to adjust shading based on the environment and crop needs.

Panels Between Crops

Lower panels between the crop are more typical for field crops where large equipment is used (Willockx et al., 2020). Less structural design is required to ensure the PV infrastructure can withstand the wind and elements when it is shorter.

5.3.2.3 Livestock and Agrivoltaics

Taller panel arrangement is more appropriate for applications for livestock grazing and can provide shading and keeps the panels above the livestock to prevent damage (Willockx et al., 2020). For small livestock, such as sheep, panels do not need to be taller for compatibility with grazing. Some grazing systems have used panel lines to act as fences. However, if the main agricultural output is larger livestock, unique agrivoltaic systems should be proposed that allow for cattle to graze while not having a negative impact on photovoltaic infrastructure.

5.3.3 Effect of Photovoltaic Infrastructure on Plants

Managing an agrivoltaic system requires careful attention to crop selection, planting and harvesting practices, and ongoing maintenance of the solar panels (Laub et al., 2022). The effect of placement of PV infrastructure on agriculture is driven by the effects of PV panels on the environment around them. PV panels can alter temperatures (Barron-Gafford et al., 2019; Coşgun, 2021), thereby increasing soil moisture (Barron-Gafford et al., 2019), decreasing wind speed (Adeh et al., 2018), and reducing water use of crops (Barron-Gafford et al., 2019; Coşgun, 2021). Changes to the microclimatic conditions result in a net benefit to plant growth in reduced drought stress (Barron-Gafford et al., 2019), greater food production (Barron-Gafford et al., 2019) and a positive effect on PV panels in reduced heat stress (Barron-Gafford et al., 2019). The net result of these effects is that crops can have increased productivity in arid environments (Barron-Gafford et al., 2019), although impacts may vary by crop. Shading from PV infrastructure also has varying impacts on crop growth.

5.3.3.1 Photovoltaic Effect: Temperature

PV infrastructure can alter temperatures around them. Some research has noted that PV infrastructure has a minor impact on air temperature (significantly different on only 12 days of season), mostly on calm, sunny days (Marrou et al., 2013). However, other research has noted maximum daily temperatures as 3°C cooler in hot dry periods and up to 2°C warmer when weather was cooler (Hudelson & Lieth, 2021). Soil temperature was reduced in shaded areas by about 2°C in French agrivoltaic systems (Marrou et al., 2013). Another effect of PV installations is that they can create a heated island effect like urban areas that raise the temperature within the installation (Barron-Gafford et al., 2019). The effects on plant growth depends on each specific species, with some species having higher productivity due to shade, while others are supressed by shade (Barron-Gafford et al., 2019).

Decreased air temperatures in agrivoltaic systems are the most beneficial in dry and hot years, resulting in enhanced leaf photosynthesis which will consequently increase yield (Schweiger & Pataczek, 2023). These conditions are common throughout the agricultural regions of Alberta and are becoming more prevalent as climate change continues. Based on climate modeling from the Alberta Climate and Information Service, average daily mean temperatures were well above normal conditions (e.g., 3-to-50-year heat events) throughout the province during the growing season of this year, expect for the month of July being an exception (Government of Alberta, 2023).

In addition to temperature relief provided by solar panels, UV protection is another service offered by PV systems which supports the growth of plants. UV exposure is considerably higher in the foothill's region relative to lower elevation areas of the province such as the prairies. UV radiation is known to damage the physiological and reproductive processes of plants (Hollósy, 2002). In higher elevation areas, plants are often overexposed to sunlight and where light reaches their surface beyond what is needed for photosynthesis, the plant undergoes stress which results in decreased yields (Uchanski et al., 2023). Many crop growers in high elevation environments use shade cloths in their operation to reduce plant stress caused by excess sun exposure (Uchanski et al., 2023). This suggests that partial shading from a properly designed PV system or from semi-transparent panels may benefit crop yield and forage production of shade tolerant species in higher elevation areas of the province. However, this may be overshadowed by other factors such as cooler temperatures and rain shadows. Further testing is required in Alberta to understand how each crop will respond to PV panels within our unique climate.

5.3.3.2 Photovoltaic Effect: Soil Moisture

Soil moisture is improved under PV infrastructure. Changes in the microclimate around solar panels mean less evaporation from the soil which improves water balance. On a similar note, the presence of PV infrastructure can result in improved water use efficiency. Water use efficiency can be much better for some plants and this yields higher over all productivity and lower water input needs (Barron-Gafford et al., 2019). One study found that pasture grasses under solar panels were 328% more water efficient (Adeh et al., 2018).

5.3.3.3 Photovoltaic Effect: Wind

Wind speed and direction is altered by PV infrastructure. The overall changes to wind speed depend on surrounding infrastructure. In one study, no significant impacts were noted on wind speed (Marrou et al., 2013). This suggests that wind speed is not necessarily a large contributor to micro-climatic condition shifts under PV infrastructure.

5.3.3.4 Photovoltaic Effect: Light

Shading from PV panels and infrastructure can have negative impacts on crops. PV infrastructure creates environmental gradients within the farmed area. Even if the impacts on crops are minor, these gradients need to be considered in agronomic plans for the specific crop. PV panels decrease solar radiation available for crop growth (Adeh et al., 2018). The pattern of shading depends on panel arrangement. Arrangements such as checkerboard patterns or north-south orientations can improve the uniformity of light distribution (Cossu et al., 2018; Riaz et al., 2021). Panel density has more impact on radiation available for crop growth than panel tracking technologies (Amaducci et al., 2018). Distance between panel rows significantly affects radiation available for crop growth. For example, one study found that changing row distance from 20 m to 5 m decreased crop yield by half (Campana et al., 2021). Photosynthetically active radiation was on average reduced by about 30% under tensile style panels with a row distance of 6.3 m and a height of 5 m (Weselek et al., 2021). In the absence of other stressors, decreased light is generally expected to decrease biomass accumulation and yields.

The effect of shading on crops is dependent on the species and extent of shading. Under shade, plants generally allocate resources to aboveground photosynthetically active tissue. This natural condition is especially pertinent to species where the aboveground leaf material is of economic value. Species such as crisphead, cutting lettuce, pepper, celeriac, winter wheat, and a grass-clover mixture have shown increased biomass product (Schweiger & Pataczek, 2023). Based on a study contrasting yield responses at varying levels of shade, berries, fruits, and fruity vegetables benefitted from reduced solar radiation up to 30% (Laub et al., 2022). These species are considered shade benefitting agricultural crops. Shade tolerant species, which include leafy vegetables, root crops, and some C3 cereals (e.g., wheat and barley) have variable responses to shading depending on the climatic regions in which they are grown. A study conducted in Germany which examined the yield responses of various crops at different shading intensities demonstrated that shade tolerant species may suffer proportionally to the level of solar reduction. For numerous C3 species, many cultivated here in Alberta, minor shading (up to 15%) was positively associated with growth. Colorado State University found that while under 38% shading, grassland species only reduced above ground plant material by 6% and evapotranspiration was reduced by 1.3% (Kannenberg et al., 2023). The study undertaken utilized smooth brome, a species widely seeded across Alberta, as a candidate due its agronomic potential. This study demonstrates the enhanced land use potential of PV systems in semi-arid conditions when C3 species are incorporated. Maize and grain legumes are considered shade susceptible agricultural species that showed considerably lower crop yields in the German study under minor reductions in solar radiation (Laub et al., 2022). While this study did not consider alternations in microclimate that affect plant growth in different regions and climatic conditions, it indicates where limitations of agrivoltaic technology may exist. Shade tolerant and susceptible species may still be incorporated into an agrivoltaic system if their shade tolerances are considered during panel selection. Semi-transparent panels allow more light intensity to reach crops while not increasing soil and air temperatures (Uchanski et al., 2023).

5.3.3.5 Photovoltaic Effect: Yields

A common misconception is that shaded crops will lead to lower yields, however, many studies have demonstrated that through beneficial adjustments to the micro-climate, agrivoltaics increases crop yield for a wide variety of crops (Jamil & Pearce, 2023). The effect of microclimate modifications from PV panels can vary depending on the climate, topography, and soils of a site. Furthermore, impacts of various microclimate modifications can have different impacts on different crops. Impacts can even vary with different varieties and stages of growth for the same crop. For example, shading in early stages of development can have substantial negative impacts, while shading in the heat of summer can reduce stress and improve plant growth (Jamil & Pearce, 2023). The microclimates that PV panels create can increase soil moisture due to decrease wind speed and evapotranspiration, thereby reducing the water use of crops (Barron-Gafford et al., 2019b). These changes to microclimatic conditions result in a net benefit to plant growth through reduced drought and heat stress. The net result of these effects is that crops can have increased productivity in arid environments (Barron-Gafford et al., 2019).

5.3.4 Agrivoltaic Design and Implementation Considerations

As the agrivoltaic industry is in its infancy here in Alberta there are numerous factors to consider before implementing a PV system. With available light being the greatest limitation on plant growth under PV panels, designing an agrivoltaic system should begin with crop selection and a panel arrangement that optimizes yields.

Current literature on agrivoltaics generally divides crops under agrivoltaic systems as being shade benefitting, tolerant, and susceptible (Schweiger & Pataczek, 2023). Presently, there is little data for crop yields under shaded systems in the province. Research on agronomic parameters such as crop performance and yield would support the development of agrivoltaic standards for the province. Within Alberta the primary agricultural crops and approximate acreage under production include:

- Wheat varieties: Approximately 7 million ac.
- Canola: Approximately 6 million ac.
- Barley: Approximately 3 million ac.
- Oats: Approximately 0.8 million ac.
- Mixed grain: Approximately 0.2 million ac.
- Hay and other field crops (Jamil & Pearce, 2023).

Before Alberta specific agrivoltaic PV systems can be developed, research on crop specific response to shading, altered water availability, altered air and soil temperature, should be considered (Schweiger & Pataczek, 2023). When combined with the latest available agrivoltaic technology, this research could define specific methods for PV design and installation. Criteria for expected land loss per MWh produced, land suitability, expected post deployment plant yield, harvest requirements under a given PV system, and projected LER would provide land managers the tools they need to make informed decisions about agrivoltaic adoption. Agrivoltaic standards optimized through collaborative research and education would facilitate the widespread social acceptance of the renewable energy. Industry standards would also support regulators and certification bodies in ensuring that agrivoltaic systems are meeting minimum installation, operation, and maintenance standards (Jamil & Pearce, 2023).

Where biological constraints may limit a given crop under panels, PV system design (e.g., panel selection, height, and spacing) can be altered to maintain sufficient solar radiance. The primary research that should be completed for Alberta's crops is to determine optimal geometries of agrivoltaic racking systems and designs. Considerations include whether to use a vertical or tilt system, fixed or tracking mounts, close packed or spaced, mono or bifacial, partially transparent, or opaque panels. Where a land manager is growing shade benefitting species, a full density array would be best to conserve land, while a half or three-quarter density array would be suitable for shade tolerant species (Jamil & Pearce, 2023). For shade susceptible species, vertically mounted east-west facing bifacial panels may be the best option. The implications agrivoltaic systems have on optimal plant growth warrants considerable thought and collaboration between land managers and power plant owners during the design stage. Computer models and simulation tools can help determine the optimal spacing (Jamil & Pearce, 2023).

5.3.5 Agrivoltaic Current Use and Opportunities

Despite having the second most favourable solar conditions in the country behind Saskatchewan, Alberta has very few designated agrivoltaic projects in operation (Joshua Pearce, 2023). Current usage of agrivoltaics in Alberta includes projects where PVs have been combined with grazing sheep. Capital Powers Strathmore Solar project sits on a 32800 ac site that will be grazed by sheep (Ferguson, 2022). While these systems are of benefit, they vastly underutilize the potential of agrivoltaics and do not represent the greatest LERs achievable. The LERs for an agrivoltaic operation in Germany were between 1.56-1.70 in 2017 and 1.67-1.87 in 2018 which suggests that a 56% to 87% increase in land use efficiency is possible (Jamil & Pearce, 2023). Moreover, with a solar potential of 1276 kilowatt-hours, per kilowatt, per year (kWh/kW/yr), Albertas solar potential exceeds that of Germany and numerous other countries where agrivoltaics systems are common (Jamil & Pearce, 2023). As of 2022, Alberta had 3,797 MW of renewable energy supplied to its grid or 10.75% of total generation (Government of Alberta, 2023g). To reach the legislated target of 30% renewable energy by 2030, dual use of land involving electricity and agriculture may be required to prevent conflict between the agricultural and energy industries.

To reduce pressures on prime agricultural lands (i.e., those identified in the ALQM) there has been an argument to deployment of agrivoltaic projects on Albertas southern Crown Lands (Jamil & Pearce, 2023). These lands, which cover 6.3 million ac and are predominantly utilized by grazing leases holders, are natural/native grassland, native forests, and partially cleared and seeded to tame forage (O'Malley et al., 2016). In addition to summer pasture, these lands are used recreationally, and by industry for activities, including gravel development, pipelining, seismic testing, and oil and gas well operation (Government of Alberta, 2023f). With careful siting that avoids native grassland areas and novel installation methods such as the Spinnanker foundation system, PV panel arrays can be installed with minimal surface disturbance (Trommsdorff et al., 2021). This approach may have some merit in some areas, but installations would have to be installed to maintain the current grazing lease function, generally cattle grazing, maintain compliance with the *Public Lands Act* and *Public Land Administrative Regulation,* and to not cause injury to the livestock industry. Some existing disturbances like oil and gas have been able to co-exist with grazing while maintaining native ecosystems, but this should be implemented carefully.

5.3.6 Planning for Agrivoltaics

The renewable energy sector has the most to gain with respect to agrivoltaic deployment in Alberta if they include primary producers (farmers, grazing lease holders, land managers) and municipalities in the approval decision-making process. Agrivoltaic systems are distinctly sited to benefit primary producers by diversifying their income portfolio. While renewable energy, particularly solar energy, is a priority for the province's green initiatives, these projects have the greatest impact on the livelihoods of the landowners who choose to house them (Jamil & Pearce, 2023). The individuals most impacted by REOs (predominantly farmers) should be included in the agrivoltaic design and approval process for the fair and sustainable deployment of this technology.

6.0 Reclamation Work Required to Achieve Equivalent Land Capability

In general, reclamation is the process that returns a site to equivalent land capability (ELC) and is defined by the *Environmental Protection and Enhancement Act* as:

- *The removal of equipment or buildings or other structures or appurtenances.*
- *The decontamination of buildings or other structures or other appurtenances, or land or water.*
- *The stabilization, contouring, maintenance, conditioning or reconstruction of the surface of land.*
- *Any other procedure, operation or requirement specified in the regulations.*

There are various definitions of equivalent land capability; however, as per (Alberta Environment and Parks, 2018a) Conservation and Reclamation Directive for Renewable Energy Operations, ELC is:

> *"the ability of the land to support various land uses after conservation and reclamation is similar to the ability that existed that existed prior to an activity being conducted on the land, but that the individual land uses will not necessarily be identical".*

It is further defined by the (Public Lands Administration Regulation, 2011) Public Lands Administration Regulation as:

> *"land that is the subject of a disposition, a condition in which the ecosystem processes on the on the land are capable of producing goods and services of a quality and in a quantity that is at least equivalent to that which existed before the disposition was issued to the holder".*

Achieving ELC requires both extensive pre- and post-disturbance activities such as data collection, soil salvage, decommissioning, reclamation, monitoring, assessment, and certification.

The reclamation approach for REOs would benefit from using the existing reclamation processes and criteria. This will ensure there is consistency between regulators, primary produces, industry, stakeholders, and professionals when assessing reclaimed lands for ELC. Additionally, this approach provides a process that is grounded in decades of practical application across Alberta.

6.1 Conservation and Reclamation Plan

All REOs regardless of commissioning date require a C&R plan, however, their content may vary. C&R plans according to the Conservation and Reclamation Guidelines for Alberta (Government of Alberta, 1997) outlines the following:

- project planning
- site preparation, construction, and operation
- reclamation
- land management

As per Alberta Energy and Parks' Conservation and Reclamation Directive for Renewable Energy Operations a C&R plan is site specific and should be used to help achieve successful reclamation outcomes (Alberta Environment and Parks, 2018a). The C&R plan should encompass all disturbance areas, document which reclamation criteria is applicable, and outline reconstructed landforms, soils conditions, vegetation communities and revegetation techniques. The C&R plan can be adjusted throughout the project's life cycle if necessary or updated following interim monitoring of the project. Overall, the C&R plan ensures that there is a clear and uniform approach to managing projects such as those proposed by REOs.

6.2 Interim Reclamation

One key aspect of REO reclamation planning that is often not discussed is that agricultural production is to occur during the operation of the project. Proper interim reclamation is required to bring land back to equivalent land capability immediately post construction. To achieve this, it is recommended that interim reclamation certificates be required for all projects post construction. This could mirror the final reclamation process described below. It could also require an interim certificate that mirrors the requirements of the final reclamation certificate. By utilizing this approach, the work required at final reclamation will be minimized as all areas that can be reclaimed successfully post construction would already have an interim reclamation certificate that shows they have been reclaimed to the standards required for the final reclamation certificate. Interim reclamation certificates would only be granted for areas that would not be re-disturbed during final reclamation. This interim certificate should require a 25-year warranty similar to that seen in the oil and gas industry. This allows REOs to complete a single successful assessment to get their interim reclamation certificate, but if there are problems that occur within the next 25 years, they are required to fix them to maintain their certificates validity.

6.3 Final Reclamation

6.3.1 Decommissioning

Decommissioning involves the permanent dismantling of the site, carrying out any measures required to ensure that the site is left in a permanently safe and secure condition (Houlihan and Hale 2011). Prior to decommissioning, the operator of the REO must submit a new or updated C&R plan that outlines the decommissioning, reclamation, and monitoring activity outcomes (Alberta Environment and Parks, 2018a). If any infrastructure is to remain in place it must be justified in the C&R plan and approved by the relevant stakeholders. It must also be demonstrated that the remaining infrastructure is stable, non-hazardous, non-erosive, and will not result in an adverse effect (Government of Alberta, 2019). This requirement should consider the potential impact of any remaining infrastructure on the agricultural sector. Any infrastructure that causes loss to land productivity must be removed to ensure that equivalent land capability is returned post reclamation. Some key issues that may exist within the renewable sector include bases of wind turbines, road networks, pipelines, support posts for solar facilities, and buried power lines. There is a potential that some or all of this infrastructure may be left behind and all could have negative impacts on future land use and productivity of the land. From an agricultural perspective any piece of infrastructure remaining that reduces productivity or poses a risk to equipment should be decommissioned in such a way that future agricultural use will not be impeded. Removal of any underground infrastructure to an appropriate depth is required. This depth needs to consider current agricultural uses as well as future agricultural use. Paratilling occurs to a depth of up to 50cm and soil can shift over time down slope on hills. These factors should be considered in the decommissioning process.

6.3.2 Reclamation

If a REO is not being re-powered than all lands containing the project infrastructure must be reclaimed at the end of its life as per the Conservation and Reclamation Directive for Renewable Energy Operations (Alberta

Environment and Parks, 2018a). Reclamation activities are site specific and will be guided by the C&R plan; however, in general they include re-contouring the landscape, replacing subsoil and topsoil, and revegetation (where applicable). While conducting reclamation activities it is important to reference the applicable reclamation criteria to ensure the landscape, soils, and vegetation meet the criteria when reclamation is complete. Reclamation activities can be conducted all at once or in a more progressive manner. The AER's Specialized Enhancement Directive 002 defines progressive reclamation as:

> *Site with areas that have been previously reclaimed following construction (i.e., areas outside of the teardrop). These areas must not have been re-disturbed during the final reclamation in order to qualify for a different reclamation date, as per the criteria.*

Progressive reclamation helps shorten the timeframe for achieving reclamation objectives while keeping the total area under disturbance at a minimum (Alberta Environment and Parks, 2018a).

6.3.3 Monitoring

Monitoring is intended to inform on the status of the REO footprint following construction, during operations, at key milestones, and when any progressive reclamation occurs. Interim monitoring focuses primarily on providing updates on the project's footprint and the status of vegetation following a disturbance and can help prevent undesirable alternative trajectories or costly remedial work (Alberta Environment and Parks, 2018a). Monitoring objectives should be aligned with the metrics defined in the applicable reclamation criteria, such as the 2010 Reclamation Criteria, and must be completed by a qualified environmental practitioner or other competent practitioner (Alberta Environment and Parks, 2018a). Interim monitoring should be conducted the next full growing season after an area has been reclaimed and must be repeated for at least three subsequent growing seasons (Alberta Environment and Parks, 2018a):

- Year one – landscape, soils and vegetation are assessed in the field.
- Year two – vegetation at a minimum are assessed in the field.
- Year three and four – vegetation at a minimum are assessed either in the field or via alternative approaches such as satellite imagery or combine yield data.

These assessments should also be conducted during the prime assessment stage for the crop being grown. If species listed under the Alberta *Weed Act* and any species elevated at a municipal level are identified during a monitoring event it is important to create a weed management plan. This plan should be tailored to the species present, taking into consideration the land use, and various receptors that may be present. The weed management plan should be followed until it can be demonstrated that the undesirable species have been removed, eradicated, or controlled as per the Alberta *Weed Act*. Once monitoring indicates that the site is on the appropriate trajectory a reclamation assessment can be conducted. Consideration should be given to the idea of allowing a 25-year warranty of interim reclamation work after reclamation assessment that passes the reclamation criteria. This would eliminate the detailed monitoring for multiple years while requiring any problems that show up to be fixed.

6.3.4 Reclamation Assessment

An operator must conduct a reclamation certificate site assessment prior to applying for a reclamation certificate for any areas that were used to construct, operate, and reclaim and REO (Alberta Environment and Parks, 2018a).

As per the Conservation and Reclamation Directive for Renewable Energy Operations (Alberta Environment and Parks, 2018a).

It is recommended that the 2010 Reclamation Criteria for Wellsites and Associated Facilities be used. The criteria provide the framework for how final reclamation success will be determined at the time of the reclamation certificate. The criteria are also considered a starting point for transparency and consistency of reclamation expectations and have been specifically designed to evaluate for ELC for the approved end land use. The selected criteria must account for and align with the end land use while also considering the scale and severity of the footprint.

The 2010 Reclamation Criteria for Wellsites and Associated Facilities on Cultivated Lands (Environment and Sustainable Resource Development, ESRD; Alberta Environment 2013) measures the appropriate parameters and evaluates whether land function and operability are comparable to the surrounding area of an appropriate reference area. The criteria also describe the allowable changes in site conditions. The cultivated criteria include lands managed under conventional, minimum or zero till practices for agricultural purposes. It also applies to tame forages, tame pastures, hay lands, or areas seeded to perennial agronomic species.

The 2010 Reclamation Criteria utilizes a point assessment system that accommodates the variability of the soils and vegetation. If a site has a greater degree of variability, then additional assessment points may be required. During the assessment, soil, vegetation, and landscape are assessed. For the landscape assessment, the site is assessed as a whole and compared to the adjacent land. Any differences in the landscape cannot interfere with normal land use and cannot have a negative impact on or offsite. The vegetation and soil assessments are a combination of measurable inputs and ratings. Should the site meet all the requirements of the criteria a reclamation certificate can be applied for.

The purpose of a reclamation certificate application is to provide final reclamation data and any other supporting documentation (Alberta Environment and Parks, 2018a). The data collected during the reclamation certificate site assessment will be compared to pre-disturbance information as well as information from the interim monitoring events to determine if ELC has been achieved. Once it has been determined that ELC has been achieved a reclamation certificate will be issued.

7.0 Recommendations for Mitigating Impacts to Agricultural Land

This section explores the potential options and innovative solutions to protect agricultural land productivity within the province of Alberta. These mitigation measures are aimed at the physical and economic impacts identified throughout the above sections. Protection of agricultural land from impacts of power plant development can be grouped into avoidance and minimization measures. Avoidance measures are strategies to prevent the placement of energy projects in locations which should not interact with high value agricultural lands, while minimization measures are those that reduce impacts as much as possible. These measures are derived from peer reviewed literature and professional experience in the construction and environmental sectors. The recommendations in this section, have been mentioned in the previous sections of this report, but are being expanded upon below in the greater context of cumulative effects and long-term land use policy development within Alberta. A summary of the recommendations are outlined in Table 7-1 below for review.

Table 7-1: Report recommendations

Recommendation Identifier	Recommendation	Report Section
A	**Policy Changes**	
A-1	Agricultural Land Quality Model that provides a consistent and straight forward approach to planning renewable energy projects through identifying and prioritizing high agricultural land values	3.0-3.6, 7.1.2
A-2	Implement interim land quality review tools	7.1.1
A-3	Requirement to refine land quality assessments through ground truthing for application submissions	7.1.3
A-4	An agricultural directive for wind and solar projects	7.2.2, 7.3
A-5	Refining ROE application documents such as the PDSA and EPP in an agricultural context with best management practices	5.1.1, 7.2.4
A-6	Siting REOs based on a tiered approach where minimum standard targets of production are required for each tier	7.2.1.1
B	**Technologies**	
B-1	Implementing agrivoltaics as a standard for projects sited on agricultural lands	5.3.1-5.3.6, 7.2.1.2
B-2	Siting and design-based mitigations for REOs	5.2, 7.1.2
C	**Construction Practices**	
C-1	Integrating construction best management practices from oil and gas criteria into renewable construction	5.1.2, 7.2.4
D	**Reclamation Standards**	
D-1	Interim reclamation certificates and standards should be required for all projects post-construction and focus on including agricultural production during operation	6.2, 7.2.2
D-2	Adoption of 2010 Reclamation Criteria for Wellsites and Associated Facilities on Cultivated Lands	6.3.4, 7.2.5

Recommendation Identifier	Recommendation	Report Section
D-3	Creation of monitoring standards for pre-construction and post interim/ final reclamation.	7.2.3

7.1 Recommendations for Evaluating and Avoiding High Quality Agricultural Land

One of the key methods of mitigating impacts is to avoid high value agricultural land. Avoidance can be completed through siting projects properly so that the lowest value agricultural land is selected for development. The ALQM is one proposed tool to do this, but a similar assessment can be completed through each individual layer (i.e., GVI, Irrigation Land, LSRS, Irrigation infrastructure). Once high value and low value agricultural lands are identified it is possible to site projects on the lowest value agricultural land or mitigate impacts appropriately.

7.1.1 Interim Land Quality Review Tools

There is currently no single information source that gathers all the sources informing agricultural land capacity into one database to evaluate agricultural land value within Alberta. This deficiency means that any interim assessment using a single data layer or source does no provide a comprehensive evaluation of the multiple variables that inform land capacity evaluations. Currently, the review process has applicants interpret agricultural land value using soils including LSRS, and natural vegetation layers (GVI/PLVI) to evaluate site conditions. There data sources are readily available to applicants and can be easily evaluated. Without the ALQM, assessment of agricultural land value will remain fragmented and, conducted on an application-by-application basis without the ability to provide higher-level view of land quality for siting and project approvals.

7.1.1.1 Approach 1: Use the ALQM Scoring Table on Existing Data Sets

As an interim approach, the scoring approach outlined in Table 3-1 can be used in conjunction with each individual data layer to assess the agricultural quality of land for each application. This would allow for the assessment to be completed on an individual project basis. For a project the following would be completed:

1) Score LSRS value of the property in question based on the ALQM scoring (Table 3-1)
2) Score the Irrigation Land value and Irrigation infrastructure of the property in question based on the ALQM score (Table 3-1)
3) Score the natural vegetation cover value of the property in question based on the ALQM score on GVI, PLVI or AVI (Table 3-1)
4) Take the highest value of the land from steps 1 to 3 as the agricultural value of the land

This interim approach to assessing agricultural land quality would allow for scoring of all agricultural land values within a project footprint. This process would be more cumbersome and as such would have to be completed on a project specific basis, but is possible. It would also allow proponents to look at land value and design according to the agricultural capacity of the land. All the functions of the ALQM would exist and ground truthing to verify land quality would be possible.

7.1.1.2 Approach 2: Use Existing Data Sets Only

An alternative interim approach would be to not allow projects on high value agricultural land. This approach would exclude projects from land that is deemed high value without any scoring system, but based on explicit criteria. Land with the following designations are recommended to be used to exclude power project siting:

1) LSRS of Class 2 and 3 land
2) Native vegetation areas
3) Irrigation Lands

However, this approach is relatively heavy handed and does not create a process to mitigate impacts and allow energy projects to be designed to balance agricultural use and energy production on the land.

7.1.2 Creation of the Agriculture Land Quality Model

The ALQM that has been proposed within this report should be relatively easily to develop and implement over a two-to-three-month period depending on negotiating access to some of the data layers. The process will involve gaining access to the appropriate database layers that are not publicly available and merging the layers together into a useful tool. Significant effort will be needed for desktop verification and refinement of the application.

Using the ALQM planners can site projects where agricultural land values are lowest.

7.1.2.1 Use of the Agricultural Land Quality Model to Mitigate Impacts on Agriculture

The agricultural land quality model is a powerful tool that can be used to site energy projects. The goal of the model is to outline all potentially high value agricultural land types (i.e., dryland annual crop production, irrigation, forage production, and grazing) in a single map layer for the entire province. Planners can then utilize the model to estimate the agricultural land value of proposed project locations and site projects where agricultural land values are lowest. The model can also be refined through field assessments that can confirm the agriculture land value and refine the model to a given land footprint.

It is recommended that prime value agricultural land retain the ability to produce high value annual crops.

Moderate value agricultural land should maintain a minimum level of pre-development production of crop to remain classified as agricultural land.

7.1.2.2 Avoiding Impacts to Agricultural Lands

Selecting land that is of no agricultural value, or of very low agricultural value will protect against loss of agricultural land. There are numerous locations across Alberta where land is of low agricultural value (e.g., old industrial sites, abandoned cultivation in low class land). Land selection has the potential to reduce conflict between agriculture and energy production if done correctly. In some locations, there may be synergies where the placement of energy production in strategic location may work with agriculture to benefit both industries. These types of projects may include placement of solar facilities on irrigation canals to provide shade to water while at the same time producing power. Other synergies exist such as solar production on greenhouses.

7.1.3 Integration of Ground Truthing to Refine Land Quality Assessments for Applications

Ground truthing is a critical process that must be utilized to verify the results within the ALQM. Ground truthing must be completed in a scientific and repeatable manner. The AUC may benefit from receiving accurate information about agricultural land impacts is available for the decision-making process. Agricultural land quality metrics should guide the design of energy projects to mitigate impacts to agricultural land. Applicants should supply evidence supporting the classification of all digital layers discussed in Section 3.5. Currently available digital layers which are used in ALQM (e.g., AGRASID) have minimal ground truthing and are sometimes at scales much too large for individual projects. Appropriate ground truthing is necessary to facilitate accurate assessment on any given parcel of land. The ALQM requires ground truthing to confirm several parameters (i.e., quality of native grasslands and native forests). In the absence of ground truthing the model defaults to the highest value possible for these areas and applicants will have to design on this basis. Through ground truthing, it is possible for applications to supply information that confirms the agricultural value of the land to support an energy project is lower than the model estimates. In this way it makes ground truthing beneficial not just for the regulator which receives accurate information to base an approval on, but also for applicants who may be able to reduce the ALQM score through properly collected scientific data from surveys of the property.

The parameters that may require ground truthing are outlined in Table 7-2, and are based on the factors assessed to confirm LSRS, irrigation value, native plant community status, as well as crop yields which provide evidence of productivity of the land. Not all factors require ground-truthing and not all factors will require assessment for each project. This is a comprehensive list of the potential assessments that may be required. A qualified professional will determine which factors must be assessed depending on the project needs. Assessment density will vary depending on the project. For grassland and forested assessments, a minimum of one assessment per GVI or PLVI polygon (or equivalent) will be completed where perennial forage exists. Plant communities will be classified as native, modified native or tame based on the range health assessment protocols for the province of Alberta (Adams et al., 2016).

Table 7-2: Information to be ground-truthed and expertise required by agriculture value category from the ALQM.

Agricultural Value Category	Potential Assessments Required	Assessor Requirements
LSRS	Climate (temperature, moisture), soils (water holding capacity, soil structure, organic matter, depth of topsoil, soil reaction, salinity, sodicity, organic surface, drainage, organic soil temperature, rock, degree of decomposition depth of substrate), and landscape (slope, landscape pattern, stoniness, wood content, inundation).	Professional Agrologist or Biologist specialized in agronomy, reclamation and/or soils science.
Irrigation Value	Soil depth, parent material, texture, adverse topography, fertility, drainage, groundwater, salt content soil pH, erodibility, soil structure, micro-relief, relocation of chemical changes of soluble salts, and stoniness.	Professional Agrologist qualified to assess irrigation land.
Native Plant Community	Plant community classification, range health assessments, species list, dominant species and cover, carrying capacity calculations, and forage production.	Professional Agrologist or Biologist qualified in rangeland management.

7.2 Recommendations to Maintain Agricultural Land Use

Maintaining agricultural land use alongside renewable energy development would be benefitted through adoption of a number of standards involving monitoring, minimum production requirements, regulatory directives, and a reclamation assessment and certification process focused on maintaining the productivity of agricultural land.

7.2.1 Creation of Land Quality Based Requirements

7.2.1.1 Minimizing Impact to High Value Agricultural Land Through Minimum Standards

Preferential siting on lands of low agricultural value, like old industrial sites or abandoned cultivation, can help preserve agricultural land

The development of renewable energy in Alberta could incorporate agricultural needs into their siting process for a more synergistic approach. A food first approach that supports a continued level of production from the agricultural lands in which they are sited would hasten the adoption of agrivoltaic technology across the province. Sustainable siting and design of wind and geothermal projects would minimize conflict between agriculture and energy production. This process could benefit from a clear regulatory framework that prevents the poor design of renewable energy projects and misuse agrivoltaic technologies by bad actors. For this to occur, agrivoltaic technologies and other mitigation measures for renewable project types could be defined and categorized to support a uniform and consistent approach by various regulatory agencies with jurisdiction over the technology. Minimum standards could be put in place for all energy projects to minimize impacts on agricultural land.

To safeguard the agricultural sector involved with deployment of renewable energy projects, a tiered approach based on land utilization could be developed. Within this proposed concept, maintaining standard targets of agricultural production within a given tier would be required. To develop an electrical energy project on tier 1 lands (i.e., Score 75-100 in the ALQM and are prime farmland, irrigation land or native grassland) a developer would have to design a system that facilitates crop production to meet the standard target. In Japan, a minimum yield of 80% pre-energy production is used (Gonocruz et al., 2021). This level of agricultural production allows agricultural land to remain viable and productive. In addition to the yield output, the production must be of similarly high value crops as to what the land is capable of. There is an agricultural sector wide benefit for prime farmland and irrigation land to retain its ability to produce annual cereal crops, horticulture crops, and other crops typically produced on the prime farmland of the local region and suitable to the land type in question. Areas of moderate agricultural value should maintain at least a minimum level of pre-development production of crops appropriate to the land quality to be considered agricultural land. Agricultural land of low value may not require a minimum agricultural production standard depending on the energy intensity and project type. In creating a policy like this, REOs will design projects that take agricultural land value and productivity requirements into account in the planning stages of a project.

In the context of the proposed tiered approach, replacing annual crop production with grazing is not a suitable substitute from a design perspective. Even if a landowner decides to graze or grow forage in very high value annual crop production land, the agricultural sector will benefit if the land remain capable of producing annual crops at this 80% minimum yield. This aligns with the approach in Japan (Gonocruz et al., 2021) and ensures land can be used to is maximum potential in the future. The government could support this process by incentivizing adoption of different minimum agricultural yields for each tier as outlined in Table 7-3. A preliminary plan may involve a four tired system based on the general divisions of land utilization in the province suggested by Jamil & Pearce (2023). To align with the ALQM, a productivity-based target has been adapted and includes the categories outlined in Table 7-3.

Table 7-3: Requirements for agricultural production based on the quality of farmland relating to ALQM scoring.

Tier	Agriculture Value Category	ALQM Score	Typical Crop and Farming Types	Mitigation Requirement
Tier 1	High to Very High Value	75-100	Annual crops, vegetables, irrigation, and limited forage production and native grassland grazing.	Agricultural production must maintain a minimum of 80.0% of pre-installation production of annual crop production.
Tier 2	Moderate to High Value	50-74	Annual crops with some limitations, forage production, and limited grazing.	Agricultural production must maintain a minimum of 60.0% of pre-installation annual crop production and 80.0% of forage production.
Tier 3	Low to Moderate Value	25-49	Forage production, grazing and rare annual crop production.	Agricultural production must maintain a minimum of 60.0% of forage production and 80.0% of grazing capacity.
Tier 4	Very low to Low Value	0-24	Grazing.	Agricultural production must maintain a minimum of 80.0% of grazing capacity.

Some forms of energy production may be able to maintain these minimum production levels relatively easily (i.e., geothermal and wind), while other energy production systems will require careful planning to achieve these objectives (i.e., solar). These objectives are realistic, but will require additional considerations during project design compared to current requirements.

7.2.1.2 Recommendation to Adopt Agrivoltaics Requirements

For solar projects, agrivoltaics may be a solution to allow development to occur on agricultural land. Utilizing a combination of the ALQM and tiered approach above, projects can assess the agricultural land value and the type of agrivoltaic system that would be required while meeting the tier's agricultural production requirements. Agrivoltaic technologies are variable and the design of each project should be adapted to the agricultural land value. With proper planning, integration of annual crop and irrigated crop production may enable siting of solar installations on high quality agricultural land.

7.2.2 Recommended Directive for Agricultural Land and Energy Production

> *An agricultural directive for wind and solar energy projects could provide guidance on the required pre-site assessments, design requirements, and monitoring recommended to facilitate successful mitigation of agricultural impacts.*

Based on a review of other biophysical components that are impacted by energy production, such as wildlife, it is recommended that a specific directive be created for agriculture and energy production. Wildlife resources in the province are protected from oil and gas development on public land through the *Master Schedule of Standards and Conditions* (Alberta Environment and Parks, 2021) and from REOs in the *Wildlife Directive for Alberta Wind/Solar Energy Projects* (Government of Alberta, 2017). The same approach could be taken for agricultural resources in the province, which includes agricultural lands and grazing areas. This directive could utilize the ALQM dataset once it is fully operational as a baseline for planning future projects and mitigating impacts. The directive could set minimum standards for agricultural production (i.e., yield) along with the types of agriculture that must be maintained on a given land class. The suggested tiered approach to land productivity in Table 7-3 may be the basis for the requirements within the directive. This directive can provide guidance on the required pre-site assessments, design requirements, and monitoring recommended to ensure a project successfully mitigates impacts to agricultural production. With comprehensive standards on design, construction and monitoring it will be possible to minimize the impacts on the Alberta agriculture sector by energy projects.

7.2.3 Recommendations for Planning Energy Projects

There is an opportunity for more consideration for the value of agricultural lands during the regulatory process for REO approvals. The AUC may involve the Ministry of Alberta Agriculture and Irrigation and the Ministry of Municipal Affairs before approving a renewable development. This external consultation on behalf of the AUC currently exists for wildlife resources potentially impacted by an REO. Through a Referral Report, proponents of an REO submit all their wildlife studies conducted prior to project approval to Alberta Environment and Protected Area (EPA) biologists as directed by the AUC. The Referral Report is reviewed by EPA biologists and an REO risk ranking is provided. This external review by the provincial regulator for wildlife resources in the province provides that REOs are constructed and operated with the least impact to wildlife resources and in a manner consistent with applicable wildlife legislation.

The mandates of Alberta Agriculture and Irrigation and the Ministry of Municipal Affairs suggest that they are best suited to speak on behalf of the agricultural sector. Alberta Agriculture and Irrigation generally works in an advisory capacity in collaboration with other ministries, municipal governments, and landowners. Through their policies and legislation, they support the safe, responsible, and fair production of Albertas agricultural products (Government of Alberta, 2023f). The Ministry of Municipal Affairs serves as an advisory body to municipalities for planning and development purposes. Through the MGA, municipalities are granted the right to undertake strategies and land-use bylaws that facilitate the best utilization of lands within their region (Government of Alberta 2023h). Their involvement in the approval review process of an REO would incorporate their views into the design process. This would facilitate a more sustainable project and promote acceptance of renewable energy technology in key areas of the province.

An external review process by these ministries, similar to the one mentioned above for wildlife resources, could be created. This could be done through an agricultural directive that outlines specific requirements and concerns that applicants must meet. This system would verify that the proponent has conducted their due diligence with respect to the agricultural lands and the adjacent communities their project will impact. This process is meant to be a simple way of ensuring that minimum requirements are met to minimize impacts to agricultural land rather than act as a line of red tape which might slow the regulatory process.

If created and publicly deployed, the proposed ALQM model would support siting of REOs that has the least impact to agriculture. Conservation based tools such as this exist for wildlife (Fisheries & Wildlife Management Information System) and wetland resources (ABMI Wetland Inventory) in the province enabling project siting that avoids wildlife habitat to the greatest degree. Through directives for solar and wind energy projects, proponents are required to meet numerous conservation-oriented standards and conditions before their project will be approved. A similar directive would serve agricultural lands in the same way.

If the same due diligence is applied to protect agricultural lands in the province as is seen with wildlife and other resources, the renewable industry may support the agricultural sector. This will be benefit renewable energy as long term energy option.

7.2.4 Recommended Construction and Reclamation Techniques

There are numerous construction and reclamation techniques that can be utilized to facilitate an effective return to equivalent land capability. Many of these techniques available are driven by oil and gas construction practices. The EPP and PDSA assessments should be updated to ensure that all appropriate information about the landscape and soils is included in the initial assessments and appropriate construction and reclamation techniques are proposed to mitigate impacts to the land. Following established best management practices during construction will set up reclamation for success.

7.2.4.1 Best Management Practices

Some key areas where BMPs should be followed include:

1) Soil handling and salvage techniques
    a. Two and three lift salvage
    b. Compaction
    c. Admixing
    d. Erosion
2) Minimal disturbance techniques
    a. Construction in none sensitive time periods (winter)
    b. Use of two track trails instead of high-grade roads in pasture
    c. Construction in dry and ideally frozen conditions
    d. Use of rig matting for temporary workspace
3) Clubroot protocols

7.2.5 Creation of Interim Reclamation Standards

Interim reclamation standards would provide confidence to farmers and ranchers that after construction their land that is not covered by infrastructure will be returned to its equivalent land capability during the operation of the energy project. The interim reclamation requirements would require field assessments and monitoring to show that productivity of the land has been returned. The best approach to this is to leverage the existing oil and gas reclamation criteria for monitoring. This will allow easy access to a trained assessment workforce as well as a single standard for numerous types of energy projects to follow on agricultural land. Interim assessments will provide piece of mind for land owners and minimize the chance that poor construction practices will result in long term damage to land. This could be done through requirements for deficiencies to be resolved in a timely manner or compensation being given for lost yields.

7.2.6 Creation of Monitoring Standards

For projects where agricultural production could occur during operation of the energy project, baseline yield data should be required within the project footprint and in control areas that will not be impacted by the project footprint to assess the metrics outlined in Table 7-4. A minimum of two growing seasons of yield data should be required prior to project construction. Crop productivity assessments should look at techniques used in the oil and gas reclamation criteria (Environment and Sustainable Resource Development, 2013) for annual crops, but also may include technology such as data collected directly from combines where applicable. Techniques such as production clips may be recommended for forages (i.e., hay, tame pasture). Standardized assessment techniques should be used.

Crop yields should be monitored for a minimum of 3 years or until minimum production is reached for 2 consecutive years.

Monitoring of yield verification will occur for a minimum of 3 years post construction or until minimum yield requirements are met for at least two consecutive years. It is recommended that every 5 years a summary report on agricultural production be provided to confirm that the land continues to be utilized as designed within the application for projects such as agrivoltaics where less is understood on the impacts to agriculture.

Table 7-4: Information to be ground-truthed and expertise required for crop yield monitoring

Agricultural Value Category	Potential Assessments Required	Assessor Requirements
Crop Yield	Annual crops (crop yield, crop health, height), hay (biomass production, composition, health), tame pasture (biomass production, composition, health).	Professional Agrologist specializing in agronomy, reclamation, rangeland management.

7.2.7 Recommendations to Adopt the Oil and Gas Reclamation Criteria

The goal of reclamation is to return land to an equivalent land capability. There are several ways the existing 2010 Reclamation Criteria for Wellsites and Associated Facilities can be built upon starting with both the vegetation and soil. Implementing these assessments may require some adaptations, but adopting a uniform approach to reclamation assessments is recommended. The 2010 oil and gas reclamation criteria has undergone years of field implementation, public engagement, and research. Adopting these criteria has the benefit of utilizing a well-researched and tested approach that will be efficient and effective, and prevent duplicate efforts. Uniform criteria will also provide the energy industry with an already trained and competent workforce to complete these assessments. Some specific considerations related to soils and vegetation assessments within the reclamation criteria are outlined in the soils and vegetation sub-sections below.

7.2.7.1 Soils

The overall soils assessment should be changed so that it closely resembles a detailed soil survey by adding additional soil physical characteristics to the assessment. Examples of these characteristics include presence of carbonates and their depth if present, degree of admixing, and subsoil color. The addition of these additional physical characteristics can help provide additional insight into the reclaimed soil quality. To capture these additional physical characteristics, it may be necessary to increase the depth of the soil assessment from 50 centimeters (cm) below grade to the depth of overall disturbance.

7.2.7.2 Vegetation

Vegetation assessments are highly subjective depending on the type of vegetation present (i.e., crop), and time of year the assessment takes place. For example, the vegetation assessments should encompass the entire crop rotation that has been implemented by the farmer. This may mean adding additional vegetation assessments above and beyond the four required in the Conservation and Reclamation Directive for Renewable Energy Operations (Alberta Environment and Parks, 2018a). Additionally, head weights for cereal crops were designed to be a metric for crop yield; however, they are subjective. To eliminate this, yield should be limited to seed head length for cereals and corn. For pulse crops the entire above ground part of the plant should be weighed while small seeded crops would not have a yield measure. Small seeded crops such as flax, canola and legumes and grass species would not have a yield measure. For specialty crops such as potatoes and sugar beets the tuber portion of the plant would be weighed to obtain a yield measurement.

As per the 2010 criteria, all cultivated vegetation assessments are to be assessed during the prime assessment stage. However, this does not consider greenfield or silage crops which cannot be assessed during the prime assessment stage; therefore, they should be assessed similarly to a hay crop instead. Additionally, perennial crops intended for grazing often do not reach the prime assessment stage due to grazing activities. To accurately assess these crops, they should be assessed in a similar manner to that of native prairie where species composition, percent cover, litter quantity, and bare ground are assessed.

7.3 Integration of the Recommendations into the Application Process

Applicants could provide a refined ALQM assessment of the property based on ground truthing.

At the application stage, it is critical that all relevant data be provided to ensure the agricultural land quality is adequately assessed and appropriate mitigation measures are included. This will facilitate cumulative effects analysis from all REOs sited on agricultural land. On each parcel of land within the REO project area a detailed evaluation of agricultural land quality could be provided through a PDSA with the initial application.

Within the application the agricultural land quality of the project footprint should be assessed, the proposed ALQM offers a feasible assessment method. The type of agricultural production possible is valuable information (e.g., irrigated production, dry land crop production, grazing). The applicant would verify the land quality aligns with the ALQM and update the metric scoring as applicable based on ground truthing that is robust and comprehensive. It is recommended that an agricultural directive for wind and solar energy projects (Section 7.2.2) be developed that outlines these assessments along with the recommendations within Section 7.1 of this document.

The application would outline the type of agricultural production that would be viable during operation of the facility. This could be done in alignment with the tiered approach for renewable development siting (Section 7.2.1.1) which would also be outlined in the proposed agricultural directive for wind and solar energy projects (Section 7.2.2). Land would be placed in a specific tier based on the current ALQM, ground truthing completed, and the refinements to the ALQM model resulting from the field work conducted. This information on agricultural land value would be presented in the application and would determine the required assessments for the PDSA and the construction and reclamation plan (interim and final).

Field assessments required should provide sufficient detail to determine the appropriate soil characteristics (i.e., texture, salts, coarse fragment, etc.) across the project footprint (Section 7.1.3). A map will be provided of the soils in the project footprint that outlines the results at a more accurate scale than AGRASID. These refined polygons will contain unique limitations that reflect the existing datasets such as the LSRS, GVI, or irrigation evaluation criteria. The exact methods utilized for field truthing may vary by project type and the mitigation plan proposed, but a base level of verification of the land capacity is necessary to be provided.

The applicant would also provide a defense of the agricultural production proposed and an appropriate monitoring program with robust controls to ensure that these requirements are met. The proposed agricultural mitigations must meet the requirements outlined in the specific ALQM productivity tier that the land is assessed to be within (Section 7.2.1.1).

With the completion of a conservation and reclamation plan that incorporates guidelines from the 2010 Reclamation Criteria for Wellsites and Associated Facilities (Section 7.2.7) and Best Management Practices

(Section 7.2.4.1), the application will be ready for review by external ministries specialized in matters of agriculture and municipal affairs (Section 7.2.3). The proponent's assessment of the agricultural land value of their site and the feasibility of the agricultural mitigations will be assessed and returned to the AUC in the form of a risk ranking or other recommendation.

Certification Page

I hereby certify that:

The requested surveys and reporting were completed by qualified professionals who considered all factors and influences that are within the scope of this assessment.

No person at Tannas Conservation Services Ltd. or associated sub-consultant working on this project have any contemplated interest in the projects or properties being assessed.

This report has been completed in conformity with the standards and ethics of the Alberta Institute of Agrologists and the Alberta Society of Professional Biologists.

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