Wetland and Grassland Retention and Restoration as an Effective Carbon Management Strategy in Alberta

The Business Case

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Disclaimer

The following report is intended to present ideas for consideration and discussion and is not intended to be prescriptive. This report documents the carbon management and climate adaptation services of Alberta's wetland and grassland ecosystems. The report is a compilation of ideas and does not reflect the opinions of AB NAWMP, DUC or Viresco Solutions.

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Glossary

AWEP	- Agricultural Watershed Enhancement Program
AWP	- Alberta Wetland Policy
BFWMSWs	- Freshwater mineral soil wetlands found in the boreal region of Alberta as defined by the Alberta Wetland Classification System (Alberta Environment and Sustainable Resource Development (ESRD) 2015)
BMF	- Biodiversity Management Frameworks
BMP	- Best Management Practices
DUC	- Ducks Unlimited Canada
FWMSWs	- Freshwater mineral soil wetlands in Alberta (including parkland, prairie and boreal regions), including marsh, shallow open water and swamp wetland types as defined by the Alberta Wetland Classification System (Alberta Environment and Sustainable Resource Development (ESRD) 2015)
GOA	- Government of Alberta
GHG	- Greenhouse Gas
INDC	- Internationally Determined Contributions
IPCC	- Intergovernmental Panel on Climate Change
LUF	- Land Use Framework
MOSA	- Mineable Oil Sands Area
NAWMP	- North American Waterfowl Management Plan
NGO	- Non-Governmental Organisation
PPFWMSWs	- Freshwater mineral soil wetlands found in the parkland and prairie regions of Alberta as defined by the Alberta Wetland Classification System (Alberta Environment and Sustainable Resource Development (ESRD) 2015)
REMF	- Regional Environmental Management Framework
SARA	- Species at Risk Act
SOC	- Soil Organic Carbon
SSR	- South Saskatchewan Region
Wetlands	- All wetland types described in the Alberta Wetland Classification System at the “Class” level: bogs, fens, marshes, shallow open water, and swamps (Alberta Environment and Sustainable Resource Development (ESRD) 2015)
WRRP	- Watershed Resiliency and Restoration Program

Executive Summary

Alberta is host to significant carbon management and climate adaptation tools in the form of wetlands (including freshwater mineral soil wetlands in the parkland, prairie and boreal regions, and boreal peatlands) and perennial grasslands. The retention and minimisation of functional impacts to these ecosystems is essential to maintaining a biological carbon store of 39-43 billion tCO_2e, and sequestration of 33,535,000 tCO_2e (equivalent to 7 million passenger vehicles) per year, with an estimated average value of $2.5 billion per year (Sawyer and Bataille 2017). Table 1 shows that the carbon management services provided by retained ecosystems are very cost-effective on a cost per tCO_2e basis, compared to current ($20/$tCO_2e$), and expected future prices ($30-100/$tCO_2e$ to 2030) of carbon (Sawyer and Bataille 2017).

Table 1: Cost of Carbon Management Through Ecosystem Retention

	Cost of net GHG sequestration **due to retained ecosystems at $18.50/ha/yr. (land costs are averaged over 100-year period) ($/$tCO_2e$)**	**Cost of retention including** retention of SOC stores (100-year average), GHG emissions from Land Use Change, and Carbon Sequestration **at $18.50/ha/yr. (land costs are averaged over 100-year period) ($/$tCO_2e$)**
FWMSW – Dry Prairie	5.61	2.62
FWMSW – Parkland	5.61	2.38
Grassland – Dry Prairie	26.43	14.08
Grassland – Parkland	26.43	9.12
Boreal Fens*	16.82	0.44
Boreal Bogs*	16.82	0.44
Boreal FWMSW*	8.41	3.39

NOTE: Dry Prairie and Parkland figures are given separately due to variations in cropping emissions; annual ecosystem losses in each ecoregion are unavailable. The data above **should not be interpreted as total ecosystem losses, but rather as a range** of the potential GHG emissions due to ecosystem losses.

* Figures for boreal wetlands do not include avoided GHG emissions from land use change. Vast SOC stores in these ecosystems drive down the cost of retention, showing the value of these ecosystems as carbon stores.

However, if ecosystem losses continue at the current rate, the associated loss of biologically stored carbon and carbon sequestration services alone could cost Alberta an estimated average of $2.4 billion per year between 2018-2030 (see *7.2.0 Value of Carbon Lost due to Conversion - Cost:Benefit Analysis*) (Sawyer and Bataille 2017). These losses could negate the advances being made in other sectors. For example, it is estimated that an additional 21,500 MW of renewable electricity generation capacity would be required to offset the greenhouse gas emissions and loss of carbon sequestration services associated with the current annual rate of ecosystem losses in Alberta (see *7.2.1 Impact of Ongoing Ecosystem Losses on Current Efforts to Reduce GHG Emissions in the Energy Sector*).

Wetland restoration activities provide climate adaptation (flood and drought alleviation, local climate cooling and humidification, wildfire suppression) and a legacy carbon management tool for future generations, while restoring other historically lost ecosystem services (water quality improvements, biodiversity, cultural and recreational services). Grassland restoration and management provides further carbon sequestration and storage, in addition to previously lost ecosystem services (reduced erosion, water quality improvements, biodiversity, cultural and recreational services).

The carbon management, climate adaptation and ecosystem services provided through functional wetland and grassland ecosystems, align with national priorities outlined in the Pan Canadian Framework on Clean Growth and Climate Change, green infrastructure investments and international commitments (such as Aichi biodiversity targets); and provincial priorities outlined in the Alberta Climate Leadership Plan, Land Use Framework and Regional Plans, flood and drought management policies, and biodiversity plans (such as the Caribou Recovery Strategy).

This report describes the business case for the retention and minimisation of functional impacts to remaining wetland and grassland ecosystems in Alberta as cost-effective carbon management tools, that also provide many additional ecosystem services that align with federal and provincial priorities. The case is also made for the restoration of historically lost ecosystems to restore lost carbon management and climate adaptation services. Existing conservation and stewardship tools are explored to provide insight into regulatory approaches, and government and NGO incentive-based options to realise wetland and grassland retention and restoration aims.

1.0 Introduction

Following the 2015 21st Conference of the Parties (COP) in Paris, it is clear that although significant steps are being taken to limit global warming to 2°C above pre-industrial levels, greenhouse gas (GHG) emissions will need to be reduced further than the Intended Nationally Determined Contributions (INDCs). Canada's ratification of the Paris Agreement in October 2016, has given Canada a global responsibility to meet or exceed an ambitious GHG emission reduction target of 30% below 2005 levels by 2030. Subsequently, there is increased focus on additional and as yet unidentified approaches to further reduce and offset GHG emissions.

Building on the momentum of the Paris Agreement, Canada's First Environment Ministers have developed the *Pan Canadian Framework on Clean Growth and Climate Change* (Government of Canada 2017). The *Framework* details how Canada aims to reach a 2030 projected GHG emission reduction target of 219 Mt, through the implementation of recently announced federal and provincial regulations and policies, and from measures targeting electricity, building energy efficiency, transportation and industry. The *Framework* also details substantial actions to build resilience and adaptation to climate change through infrastructure, protecting and improving human health, and reducing climate-related hazards and disaster risks.

However, implementing the measures set out in the *Pan Canadian Framework* will not be enough to achieve the emission reduction targets under the Paris Agreement, a further 44 Mt of GHG emission reductions will be required. The *Framework* has identified that protecting and enhancing carbon stored in wetlands and grasslands will be integral, in part, to meeting the 44 Mt gap, and outlines how Federal, provincial and territorial governments will work in partnership to, "*invest in traditional and natural infrastructure that reduces disaster risks and protects Canadian communities from climate-related hazards such as flooding and wildfires"* (Government of Canada 2017).

This report describes the business case for including the retention and restoration of Alberta's perennial grasslands, freshwater mineral soil wetlands in the parkland and prairie regions[1] (PPFWMSWs), and boreal wetlands[2] (including bogs and fens (boreal peatlands), and boreal freshwater mineral soil wetlands (BFWMSWs)), as cost-effective carbon management and climate adaptation tools integral to Alberta's carbon management strategy and the Alberta *Climate Leadership Plan*. The report also outlines the numerous economic, social, and environmental co-benefits, including valuable climate change mitigation and adaptation attributes, provided by retention and restoration of these ecosystems and how they align with federal and provincial priorities.

[1] In this report Prairie Parkland Freshwater Mineral Soil Wetlands (PPFWMSWs) include all marsh, shallow open water and swamp wetlands found in the parkland and grassland regions, as classified in the Alberta Wetland Classification System (Alberta Environment and Sustainable Resource Development (ESRD) 2015).

[2] In this report boreal wetlands include all wetlands found in the boreal region: bogs, fens, marshes, shallow open water, and swamps. Boreal peatlands include bogs and fens, as described in the Alberta Wetland Classification System (Alberta Environment and Sustainable Resource Development (ESRD) 2015).

1.1 The Importance of Biological Offsets

It is widely recognized that biologically-based GHG emission reduction, removal and replacement activities can far exceed biological sector (agriculture and forestry) emission contributions (Metz, et al. 2007). While traditional approaches to addressing climate change such as cleaner energy and improved energy efficiency are important, transitioning our energy resources will take time. To achieve the global goal of a deeply decarbonized future, and limit global warming to 2^{O}C, biological offsets and reductions must be utilised as a 'Biological Bridge' to cleaner energy sources.

There is increasing emphasis on developing guidelines and reporting on GHG emissions associated with land use change. At the national scale in Canada, stock changes associated with "Land Use, Land Use Change and Forestry" activities are accounted for in Canada's national inventory reporting of GHG sinks and sources (Environment and Climate Change Canada 2016). Stock changes associated with all FWMSWs (marsh, shallow open water and swamp) and grasslands will be reported from 2015, including those resulting from the conversion/management of grasslands and FWMSWs, and the conversion of cropland to grassland (IPCC 2014). To date, stock changes and emissions associated with only three wetland categories have been reported on, in line with the land categories as defined in IPCC (2006): 1) peatland drained for peat extraction, 2) flooded land (large hydroelectric reservoirs), and 3) drainage of some organic soils such as for cultivation. There is no corresponding area estimate of wetlands within the other major land use categories in Canada (Cropland, Forest Land, Grassland, and Settlements). Therefore, we currently know very little regarding how wetland carbon stocks and GHG emissions have been altered in response to land use changes and how these have in turn influenced GHG emissions at the national scale. This will likely change in the near future given the updated guidance provided by the 2013 Wetlands Supplement developed by the IPCC.

The retention and restoration of Alberta's wetlands and grasslands can result in real, and verifiable net sequestration of carbon. Avoided conversion of these ecosystems not only maintains the carbon sequestration capacity, but also avoids significant GHG emissions associated with functional and physical loss. In addition to carbon sequestration, Canada's wetlands and grasslands perform a variety of environmental functions that aid adaptation and mitigation in a changing climate, with many social and economic benefits. Flood and drought alleviation, the humidifying and cooling effects on local climate, and critical habitats for listed species such as woodland caribou, are important functions afforded by wetlands and grasslands consistent with the conservation goals in Alberta's land management and climate change policies. Other economic and social benefits of wetlands and grasslands include improved water quality, biodiversity, and educational and recreational opportunities, including important cultural and traditional land use areas for indigenous peoples. When compared with other means of carbon sequestration and GHG emission reductions, the co-benefits and economic value provided by biological infrastructure such as wetlands and grasslands are significant advantages.

2.0 The Regional Context

Alberta's *Climate Leadership Plan* sets out a provincial approach to achieving GHG emission reductions in Alberta, focusing primarily on energy efficiency, carbon pricing and the oil and gas industry (Leach, et al. 2016). However, the significant potential for GHG emission reductions and sequestration from biological processes and land use change is not explicitly detailed in preliminary discussions, and the lead author of the Panel's report underlying the Climate Leadership Plan, Andrew Leach, acknowledges the gap in the report. Effective management and conservation of Alberta's wetlands, perennial grasslands and surrounding uplands is not only essential to addressing Alberta's GHG emissions and building climate resiliency, as well as achieving Canada's international commitments, but also has strong alignment with other provincial, federal, and international priorities.

2.1.0 Current State

Historic settlement and development has led to altered function of many of Alberta's landscapes, many benefits of which are realised in the necessary production of food, fibre, timber and paper products. However, the physical loss of many wetlands and perennial grasslands in the prairie, parkland and boreal ecoregions has not only been a significant source of GHG emissions over time, but has also led to lost potential for sequestration of atmospheric carbon, as well as the loss of socio-economic and environmental co-benefits provided by functional ecosystems. Retention of remaining landscapes is important for many reasons, while restoration activities can assist with restoring functional capacity lost to development. Table 2 shows the estimated impact of historical losses of each ecosystem on GHG emissions, excluding impacts on lost sequestration potential and land use change.

Losses of these systems are ongoing within Alberta. Although definitive figures for ecosystem losses in Alberta are not easily obtained, Table 3: Estimated Ongoing Ecosystem Losses in AlbertaTable 3 shows conservative estimates for annual losses from best available data sources. These figures do not include functional losses that are likely much more significant. Ongoing losses of boreal wetlands are difficult to estimate partly due to lack of historic monitoring, and to the heavy influence of industrial development; losses occur largely as a result of market forces and as a result are dynamic in nature.

Table 2: GHG emissions due to Historical Ecosystem Losses in Alberta

	PPFWMSW (Creed, et al. 2017)[3]	Boreal FWMSWs [4] (DUC 2017)	Boreal Peatlands[4] (DUC 2017)	Perennial Grasslands (Alberta Parks 2015) (Bremer 2008)
Historical area lost (ha)	294,000	332,000	346,400	8,631,000
Total GHG emissions due to historical losses* (tCO_2e)	96M	96M	388M	[25.6 – 86.3M] [5]
Equivalent barrels of oil (millions)**	222	222	898	[59 – 200]

* GHG emissions include loss of carbon from soil organic carbon (SOC) stores only; lost sequestration capacity and emissions from land use change are excluded and these figures are therefore very conservative. See *7.1.0 Costs and Benefits* and *Appendix 1: GHG emissions and Cost Benefit Calculations* sections for further details.

** (US Environmental Protection Agency 2016)

Table 3: Estimated Ongoing Ecosystem Losses in Alberta

	PPFWMSWs - Total	PPFWMSWs - Approved with compensation	Boreal Peatlands	Boreal FWMSWs	Perennial Grasslands
Annual area lost (ha)	1,000[6]	120[7]	8,500[8]	10,300[8]	52,500[9]

2.1.1 Freshwater Mineral Soil Wetlands in the Prairie and Parkland Regions

In North America, FWMSWs account for 18% (40Gt) of the total carbon stored in wetlands (Bridgham, Megonigal, et al. 2006). FWMSWs maintain stores of carbon within the soil carbon store and biomass associated with functional ecosystems, and continue to act as net carbon sinks.

[3] Historic PPFWMSW losses calculated from Creed et al. (2017) proportional wetland losses from RWVAUs in Prairie and Parkland regions.
[4] Calculated using ABMI human footprint data (2014) and DUC's wetland mapping tool – contact Alain Richard at DUC for more information.
[5] Estimated from total area of Grassland Natural Region and Parkland Natural Region (Alberta Parks 2015), and estimated remaining temperate grassland (Bremer 2008)
[6] Source data from (Prairie Habitat Joint Venture 2014)
[7] Source data from (Environment Canada 2017)
[8] Sourced from ABMI Human Footprint Data 2007-2014 - contact Alain Richard at DUC for more information.
[9] Calculated from source data in (Bremer 2008) and (Gage, Olimb and Nelson 2016) – See *Appendix 1: GHG emissions and Cost Benefit Calculations* for details

While FWMSWs account for only 12% of total wetland area in Canada, historical and ongoing losses of these wetlands are substantial. DUC estimates that historically, 70% of Prairie wetlands have been lost or altered, and that since the 1950's, more than 500,000 hectares of Prairie wetlands have been lost. GHG emissions associated with the loss of carbon stores within FWSMW soils and biomass, and lost carbon sequestration capacity provided by FWMSWs, are correspondingly significant.

Historical PPFWMSW losses in Alberta are estimated at 294,000 hectares contributing GHG emissions comparable to 222 million barrels of oil over time. Put in today's terms, this lost sequestration potential could have been offsetting GHG emissions from over 200,000 passenger vehicles every year. Estimated ongoing PPFWMSW losses continue to contribute GHG emissions equivalent to nearly 70,000 passenger vehicles every year, excluding lost sequestration potential and land use change emissions (see *7.1.0 Costs and Benefits* and *Appendix 1: GHG emissions and Cost Benefit Calculations* sections for further details) (US Environmental Protection Agency 2016). It is estimated that 1.3 million hectares of PPFWMSWs remain in the Prairie and Parkland regions of Alberta, which are naturally functioning to offset the GHG emissions of 900,000 passenger vehicles every year (Prairie Habitat Joint Venture 2014) (US Environmental Protection Agency 2016).

2.1.2 Boreal Wetlands

Within Canada, the boreal region is the largest biome, covering an estimated 584 million hectares (ha) or 58.5% of Canada's land base (Anielski and Wilson 2009). Of this area, roughly 20%, or 119 million ha, consists of wetlands [10] (Badiou and Witherly 2015). In Alberta, 70% of Alberta's land base falls within the boreal region, within which wetlands are a prominent feature[11]. Five major classes of wetlands (bogs, fens, swamps, marshes and shallow open water systems) comprise approximately 15.3 million ha, collectively. For the purposes of this report, boreal wetlands are divided further into peatlands (bogs and fens) and boreal FWMSWs (swamps, marshes and shallow open water systems). Despite lower sequestration rates in boreal peatlands compared to temperate FWMSWs, slower decomposition rates and sheer abundance make boreal peatlands a significant carbon store in Alberta, and on a global scale (see Table 4).

Boreal peatlands (bogs and fens) are amongst the most abundant wetlands in Alberta's boreal region, covering an area of approximately 8.6 million hectares. Peatlands have been found to accumulate between 20-200 cm of depth every 1,000 years with rates of 0.29 tC/ha/yr (1.06 tCO_2e/ha/yr) considered a reasonable average rate of accumulation (not considering GHG emissions) (Gorham 1991). It is estimated that boreal peatlands alone store 9.6 billion tonnes of carbon in Alberta, and that 11.5-13 billion tonnes of carbon are stored within all of Alberta's boreal wetlands, approximately equivalent to the GHG

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[10] Land saturated with water to promote wetland or aquatic processes poorly drained soils, hydrophytic vegetation various kinds of biological activity (CWCS).

[11] Boreal Plain is synonymous with the Boreal Central Mixedwood Natural Subregion in the provincial ecosystem classification (Schneider et al. 2016).

emissions from all US coal-fired power plants for over 30 years (DUC, Western Hydrology Group 2006) (US Environmental Protection Agency 2016). Clearly carbon storage of this scale is an asset to Alberta, especially since emissions on this scale would require GHG emissions offsets equivalent to 30 billion barrels of oil (US Environmental Protection Agency 2016).

Boreal wetland systems are typically highly connected systems which makes them particularly vulnerable to developments that alter connectivity and hydrological conditions. The anthropogenic drivers for physical and functional loss of boreal wetland systems revolve around development and construction (e.g. road-building, oil-gas pads, oil sands development); changes in water quantity (blockage); water quality (e.g. through contamination); drainage (e.g. for peat extraction); erosion; and land use change. Wetland loss as a proportion of total landscape may be smaller in the boreal region (excluding losses in the boreal transition zone) than those experienced in either Prairie or Parkland ecoregions, however, the boreal region is experiencing extensive growth in industrial activity. It is also thought that losses in the boreal transition zone (the intersection of the boreal ecoregion and the White Zone) are comparable to PPFWMSW losses (PHJV 2014).

It has been conservatively estimated that the physical and functional loss of wetlands due to the human footprint in the boreal region is 678,441 hectares, excluding losses in the boreal transition zone and those prior to 2003[12] (DUC 2017). Additionally, it is expected that reclamation procedures in the mineable oil sands area (MOSA) will result in large-scale conversion of wetlands to upland forest, with wetlands restricted to valleys and surrounding end pit lakes (Rooney and Bayley 2011). Predicted changes in climate may limit the formation of wetlands in this landscape meaning careful management will be required for successful restoration and reclamation, and to limit further losses particularly of peatland ecosystems (Price, et al. 2013). The boreal region therefore represents an unprecedented conservation opportunity; one that integrates strategic protection of natural areas and the best possible approaches to sustainable management of ecosystems in a working landscape through avoidance and improved opportunities for minimizing impacts (i.e. development and implementation of BMPs) where avoidance of industrial activities is not possible.

2.1.3 Perennial Grasslands in the Prairie and Parkland Regions

Globally, temperate grasslands cover an estimated 9.0 – 12.5 million km^2 or 7.0 – 9.7 % of total land area, and are thought to contain 300Gt of carbon (White, Murray and Rohweder 2000). Dominated by herbaceous vegetation maintained by drought, fire and grazing, grasslands and occur in regions where there is low moisture, cold winters and deep fertile soils, and are among the most diverse and productive terrestrial biomes (Federal, Provincial and Territorial Governments of Canada 2010) (Henwood 1998).

[12] Calculated using ABMI human footprint data (2014) and DUC's wetland mapping tool – contact Alain Richard at DUC for more information

The capacity of temperate grasslands to sequester carbon is finite (Abberton, Conant and Batello 2010), and prior to rapid European settlement the grassland ecosystems of the Canadian Prairies were likely under a grazer-induced equilibrium (Wang, VandenBygaart and McConkey 2014). Historically, natural temperate grasslands in Canada covered 61.5M ha extending over broad areas of Alberta, Saskatchewan and southern Manitoba, and areas of southern Ontario and in eastern British Columbia. The single greatest impact of disturbance on C stores in grasslands is land use change, with cultivation leading to a 30-50% reduction in C stores worldwide (Burke et al. 1995). In North America, temperate grassland loss has been extensive with approximately 65 – 70% of original grassland extent converted to other uses, primarily agricultural cropland (Henwood 2010). The majority of grassland conversion occurred between the 1880s and 1930s as populations and the area of cropland in the three Prairie Provinces grew rapidly (Willms, Adams and McKenzie 2011).

The Canadian Prairie provinces, S. Ontario and B.C. collectively host approximately 19M ha (96%) of Canada's rangelands, and 3.5M ha of Canada's seeded pasture, including forage crops for livestock farming (Bork 2017). Grazing resources in this region include a combination of previously uncultivated native rangeland consisting of mosaics of endemic grassland, and various shrub and forest habitats. In Alberta, approximately 9 M ha of forage lands are used for grazing, most of which (6.5 M+ ha) is native grassland. The proportional presence of native grassland varies markedly among Natural Sub regions, ranging from as little as 10% in the Aspen Parkland, to 43% in the Dry Mixedgrass Prairie.

Current grassland loss in Alberta is estimated at 52,500 ha per year. The GHG emissions from these lost SOC stores compares to emissions of 110,000 passenger vehicles annually, excluding lost sequestration potential and land use change emissions (Gage, Olimb and Nelson 2016) (Bremer 2008) (US Environmental Protection Agency 2016). The vast extent of grasslands makes them one of the most important terrestrial carbon stores on our planet. Within the province of Alberta alone, it is estimated that the carbon stock contained in the 7 million ha of temperate grasslands is roughly equivalent to 3 times Canada's total annual GHG emissions (Bremer 2008). The collective carbon sequestration capacity of the remaining temperate grassland in Alberta could offset GHG emissions from over 1 million passenger vehicles annually (US Environmental Protection Agency 2016), if retained on the landscape.

2.1.4 Summary

Taken together, Alberta's wetlands and perennial grasslands can provide an estimated **39.2-43.3 BtCO_2e of carbon storage**, plus climate mitigation (i.e. carbon sequestration) and adaptation services for Albertans every year. There exists an opportunity to explore the role of conservation and restoration of these ecosystems to deliver natural cost-effective climate change adaptation and mitigation measures through avoided carbon emissions and enhanced carbon sequestration.

3.0 Wetlands and Grasslands as a Carbon Management Tool

Natural and managed landscapes have diverse impacts on carbon storage and GHG emissions. Employment of appropriate land management measures, and protection of natural systems and landscapes, can provide significant opportunities for reducing GHG emissions, increasing carbon sequestration and providing resilience to climate change. In the simplest terms, wetland and grassland soils sequester carbon when uptake of carbon from the atmosphere into vegetation exceeds emissions from decomposition. When these natural processes are disrupted, decomposition rates exceed carbon uptake leading to loss of soil organic carbon (SOC) stores and GHG emissions.

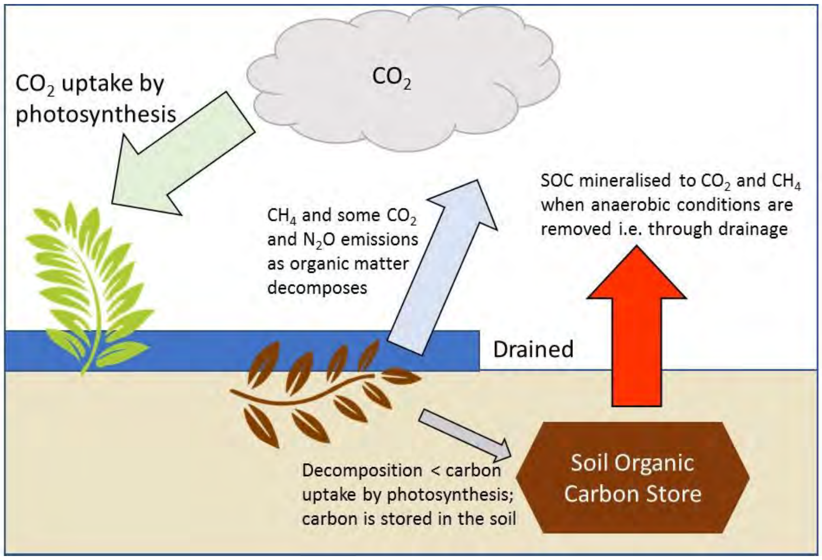

Figure 1: Simplified Wetland Carbon Cycle

At this time, Alberta does not fully account for GHG emission inducing management and loss of these ecosystems in the province's GHG inventory. This has the potential to significantly increase the province's real GHG emissions. But at the same time, **retention, restoration and effective management of wetlands and perennial grasslands can contribute favourably to reducing Alberta's GHG emissions, at a time when the province and its industries are facing social pressures**. This section provides the scientific basis for how this potential can be achieved in Alberta. Table 4 gives carbon sequestration rates for wetlands and other land use types collected from the scientific literature for reference.

Table 4: Comparison of Carbon Sequestration Rates of Land Management Methods

Land Use/Management Method	Estimated Carbon Sequestration Rate / tonnes of Carbon ha^{-1} yr^{-1} [Range]*	Location (Data Source)
Restored FWMSWs	3.05 (acc. - 10 years post-restoration) 0.89 (net)	Prairie (Euliss Jr., et al. 2006) Prairie (Badiou, et al. 2011)
Restored Perennial Grassland	**0.441 (net - carbon equivalent)** **0.447 (net - carbon equivalent)**	Alberta Dry Prairie (Government of Alberta 2013) Alberta Parkland (Government of Alberta 2013)
Retained FWMSWs	**0.9 (net)** 1.68 [0.37-3.11] (net) [1.43-5.04] (net) [2.02-4.73] (acc.) [1.00-2.80] (acc.) 2.03 [0.62-3.19] (acc.) 0.83 (acc.)	Prairie (calculated from model (Neubauer 2014)) Global (Lu, et al. 2016) Temperate Region, North America and Europe (Mitsch, Bernal, et al. 2013) Ohio (Bernal and Mitsch 2012) Global (Bernal and Mitsch 2012) Northeast China (Zhang, et al. 2016) Boreal (Euliss Jr., et al. 2006)
Retained Boreal Peatlands	0.33 (net) **0.29 [0.16 – 0.42] (net.)** [0.15 – 0.26] (acc.) [0.19 – 0.20] (acc.)	Boreal (Frolking and Roulet 2007) Boreal Canada and Russia (Mitsch, Bernal, et al. 2013) Boreal (Turunen, Tomppo and Tolonen 2002) (Yu 2012) Boreal (Wieder 2001)
Managed Temperate Grassland	**0.70 (net)**	Canadian Prairies (Wang, VandenBygaart and McConkey 2014)
Crop land (Continuous cropping, no till, Spring Wheat)	**0.063 (net - carbon equivalent)** **0.031 (net - carbon equivalent)**	Dry Prairie (Government of Alberta 2013) Parkland (Government of Alberta 2013)
Change from Conventional Tillage to No-Till Cropping Practices (SOC sequestration rate change)	0.11 (net - carbon equivalent) 0.16 (net - carbon equivalent)	Dry Prairie (Government of Alberta 2012) Parkland (Government of Alberta 2012)
Mature Trees (Canada)	1.70 (net)	Canada (Canadian Council of Forest Ministers 2003)

* acc. – accumulated SOC; does not consider GHG emissions; net. – net sequestration including GHG emissions. Bolded figures are used in calculations throughout this report

Sequestration rates within wetlands may vary substantially within and among sites depending on variability in factors controlling rates of decomposition and productivity. For example, studies have found that boreal peatlands and ephemeral FWMSWs may switch between source and sink functions among years (Wieder 2001) and among wetlands. As a result, regional or global assessments of carbon balance are quite understandably confounded by this variability which challenges any efforts to scale up (Wieder 2001). These challenges suggest a precautionary approach to managing wetlands to maintain natural processes when considering carbon management benefits. It is important to note that figures in this section are quoted as tonnes of carbon (tC), tonnes of carbon dioxide (tCO_2), or tonnes of carbon dioxide equivalent (tCO_2e), as appropriate to the subject.

3.1.0 GHG emissions and Carbon Sequestration in Parkland and Prairie Freshwater Mineral Soil Wetlands (PPFWMSWs)

3.1.1 Existing PPFWMSWs - Carbon Sequestration, Storage and GHG Emissions

Functional FWMSWs absorb carbon via complex biological processes involving aquatic vegetation and anaerobic bacteria. The anaerobic conditions created by wetlands reduce decomposition rates causing net sequestration of carbon, but also cause the production and emission of methane (CH_4) as a product of decomposition. The interplay between rates of GHG emissions and carbon sequestration determine whether an FWMSW contributes a net warming or net cooling effect on the climate, termed radiative forcing. In general, wetlands that have been in existence for some time have a net negative impact on radiative forcing, while recently restored wetlands tend to have a net positive radiative forcing impact due to elevated CH_4 emissions which diminish as ecological systems mature (see *3.1.2 Restored FWMSWs, Switchover Times and Legacy* section below).

Observed carbon sequestration rates are particularly high in restored wetlands (Table 4). Additionally, wetlands tend to have a large capacity for soil organic carbon storage meaning that absolute increases in stored carbon can be substantially higher than in other land uses.

However, as mentioned above, the anaerobic conditions created in FWMSWs are also conducive to methanogenesis and CH_4 emissions. Given that CH_4 is 25 times more potent as a GHG compared to CO_2, CH_4 emissions from FWMSWs must be considered seriously (IPCC 2007). While wetlands in general are considered large sources of CH_4 emissions, established, permanent wetlands tend to have a net negative radiative forcing (cooling) effect. Fluxes of CH_4 from these systems vary dramatically both spatially and temporally, and have been related to various hydrologic and climatological controls such as temperature, soil moisture, and degree of inundation (Crill, Harriss and Bartlett 1991) (Altor and Mitsch 2008) (Batson, et al. 2015). Additionally, other factors such as the trophic state of a wetland, the quality of substrate, sulphate concentrations, and vegetation community all play an important role in regulating the production and release of CH_4 (Pennock, et al. 2010) (Batson, et al. 2015) (Segarra, et al. 2015).

Like CH_4, nitrous oxide (N_2O) is a very potent GHG with 310 times the global warming potential of CO_2. The water-saturated and anoxic environment found in permanent FWSMWs mean that N_2O emissions are typically a minor component of the overall GHG emissions from these systems (Blais, Lorrain and Tremblay 2005). However, less permanent FWMSWs that alternate between wet and dry cycles, such as the ephemeral and seasonal wetlands found in the Prairie Pothole Region of North America, can emit substantial amounts of N_2O when wetland soils begin to dry (Pennock, et al. 2010) (Tangen, Fionocchiaro and Gleason 2015). Nitrogen-loading into wetlands, for example via fertiliser applications to surrounding cropland, can contribute to increased N_2O emissions from FWMSWs (Tangen, Fionocchiaro and Gleason 2015).

Joint management of uplands and local hydrology can therefore have a significant impact on reducing GHG emissions from FWMSWs through reduced nitrate loading to watercourses and limiting hydrological variability on a landscape scale. When GHG emissions are minimised through the application of appropriate land use management methods, the carbon sequestration capacity of FWMSWs is maximised.

3.1.2 Restored FWMSWs, Switchover Times and Legacy

In order to fully understand the role of FWMSWs with respect to climate change, it is essential to account for both changes in carbon sequestration, and GHG emissions such as CO_2, CH_4 and N_2O. As mentioned above, it is clear that wetlands typically mature to have a net cooling effect on climate (Mitsch, Bernal, et al. 2013) (Neubauer 2014). The period of time between wetland restoration and attainment of net negative radiative forcing is termed the 'switchover time'. Research to quantify switchover time is limited and ongoing, but freshwater temperate marsh type wetlands are believed have some of the shortest switchover times of all wetland types, estimated at 60-130 years after establishment (Neubauer 2014).

The complexity associated with GHG emissions and carbon sequestration highlights both the importance of retaining existing wetlands as net carbon sinks, as well as effective land use management of restored FWMSWs to shorten switchover times (Bridgham, Moore, et al. 2014) (Neubauer 2014). The initial GHG emissions associated with restored FWMSWs should not discourage restoration activities based solely on radiative forcing for a number of reasons. First, FWMSW restoration activities should take a long-term view regarding carbon management. Alberta has the opportunity to restore a potentially extensive net carbon sink for future generations, while taking advantage of the relatively short switchover times associated with FWMSWs. The climate mitigation and resiliency co-benefits associated with wetland presence on a landscape scale should also be considered in restoration activities.

Second wetland restoration should be assessed against the radiative forcing of the pre-restoration land use, and on a landscape scale. For example, drained wetlands (concave and depressional landscape features) can act as hotspots for N_2O emissions (Corre, van Kessel and Pennock 1996) and surface drainage ditches can be hotspots for CH_4 emissions (Schrier-Uijl, et al. 2011). Restoration of FWMSWs, and the subsequent alteration of landscape hydrology, may substantially increase the capacity of a wetland restoration project to have a net cooling effect on climate when considered on a landscape scale.

3.1.3 Emissions from FWMSW - Functional and Physical Losses

Drainage of FWMSWs is common practice in a number of industries (IPCC 2014). In addition to lost potential for carbon sequestration, functional and physical FWMSW loss incurs GHG emissions due to mineralisation of the SOC store, and land use change. FWMSWs account for 12% of total wetland area in Canada, and historical losses of FWMSWs have been significant; Canada-wide it's estimated that 20 million ha of FWMSWs have been lost (National Wetlands Working Group 1988).

Mineralisation of the SOC store due to physical or functional loss represents a loss of carbon back to the atmosphere that has been accumulated over centuries if not millennia, similar to the combustion of fossil fuels. A conservative estimate of the rate of carbon emitted to the atmosphere from the conversion of wetland soils in the Canadian Prairies is **89 tC/ha (326 tCO_2e/ha)** (Badiou, et al. 2011). This figure does not take into account potential emissions of other more potent GHG gases such as N_2O and CH_4 and is therefore conservative.

3.2.0 Boreal Wetlands

3.2.1 Existing Boreal Wetlands - Carbon Sequestration, Storage and GHG Emissions

Similar to PPFWMSWs, boreal wetlands (peatlands and FWMSWs) sequester carbon due to slow decomposition rates created by anaerobic conditions. While carbon sequestration rates in boreal peatlands (fens and bogs) are lower than FWMSWs (swamps, marshes, and shallow open water systems) and restored perennial grassland rates (Table 4), their abundance on the Alberta landscape means boreal wetlands are a vital tool for carbon sequestration, and an even larger carbon store (Table 5).

Also similar to PPFWMSWs, the anaerobic conditions created within boreal wetlands favour the production and emission of CH_4 gas. While on a global scale CH_4 emissions from wetlands are significant, wetlands at northern latitudes emit approximately 7% of all other CH_4 sources combined, despite the large land mass these wetlands occupy (calculated from Table 17.2 pg. 571, Mitsch and Gosselink, 2015). Local conditions such as hydrology, vegetation, and climate, can cause CH_4 emissions to vary by several orders of magnitude both within and among wetlands (Turetsky, et al. 2014) challenging our ability to make large scale generalizations (Anas, Scott and Wissel 2015).

Table 5: Measured Soil Organic Carbon Densities in Boreal Peatlands

		Peatlands of Canada Data (Tarnocai, Kettles and Lacelle 2011)		**Vitt et al., (2000)**	
	Area (ha x10^3)	**Soil Organic Carbon Density** (tC/ha)	**Total Soil Organic Carbon** (tC x 10^6)	**Soil Organic Carbon Density** (tC/ha)	**Total Soil Organic Carbon** (tC x 10^6)
Open Water*	1,641	289	474	289	474
Marsh*	567	289	164	289	164
Swamp**	4,523	289	1,308	289	1,308
Fen	5,623	1,123	6,314	1,344	7,555
Bog	2,969	1,109	3,294	1,254	3,723
Total	**15,323**		**11,553**		**13,223**

** Derived from estimates for mineral wetland soils in Bridgham et al.* (2006).

*** Below ground carbon storage in swamps is not well measured and table values are likely underestimates.*

While undisturbed boreal peatlands for the most part act as net carbon sinks (Wieder 2001), there are exceptions. Controls on the carbon balance are a result of complex relationships among vegetation, landscape position and hydrology (Petrone, et al. 2011), and these relationships are vulnerable to changes that can result in boreal wetlands becoming net sources of carbon (Wieder 2001).

Natural disturbances such as fire may result in loss of carbon stored above and below ground, and flooding (caused by anthropogenic developments such as road construction or improper drainage) can accelerate peat decomposition and outputs of dissolved organic carbon, impacting CH_4 and CO_2 fluxes to the atmosphere (Thompson, Benscoter and Waddington, Water balance of a burned and unburned forested boreal peatland. 2014) (Waddington, Kellner, et al. 2010) (DUC, Western Hydrology Group 2006). Healthy and functioning peatlands, and wider boreal landscapes, possess a number of natural features and feedback mechanisms that maintain water tables and inhibit wildfires (Kettridge, et al. 2015). However, predicted changes in boreal climate may diminish the ability of boreal wetlands to resist natural disturbances which are expected to increase. Careful management, through avoidance and minimisation of functional loss, and maintenance of natural hydrological function, will therefore be required to maintain carbon stores and avoid considerable GHG emissions from boreal wetlands in a changing climate.

3.2.2 Restored Boreal Wetlands

There are very few examples of successful physical peatland restoration projects (Graf 2009) (Timoney 2015) (Rooney, Bayley and Schindler 2016). Successful restorations have been extremely expensive and require substantial water management and selective plant reintroduction (Timoney 2015) (Rooney and Bayley 2011) (Rochefort and Lode 2006). While research into boreal wetland restoration techniques continues, restoration of physical wetland losses often results in FWMSWs, and in the establishment of upland vegetation.

Functional restoration activities may be more appropriate in many areas that have been subject to development pressures. Here, restoration often takes the form of restoring hydrological functioning of functionally impaired wetlands, such as restoring hydrological connectivity where road construction has impeded natural flow.

Since boreal wetland restoration techniques, particularly boreal peatlands, are still being researched and developed, impacts of boreal wetland restoration on climate are largely unquantified. However, modelling shows that radiative switchover times for restored peatlands are in excess of 1,200 years, further highlighting the importance of retaining and minimising functional impacts to peatlands as an irreplaceable resource (Neubauer 2014).

3.2.3 Emissions from Boreal Wetlands - Functional and Physical Losses

Drainage and functional losses of boreal wetlands causes the release of GHG's due to mineralisation of carbon stored within the wetland biomass and soil. The loss of carbon stored in boreal peatlands due to drainage is very significant, estimated between 387-1603 tC/ha (1417-5,877 tCO_2e/ha) (Rooney, Bayley and Schindler 2016); this is equivalent to annual GHG emissions from 300-1,200 passenger vehicles for every hectare of peatland that is drained (US Environmental Protection Agency 2016).

Other anthropogenic impacts can also affect whether boreal wetlands become net sources or sinks of carbon. Impacts on hydrological functioning, such as improper road and crossing design and construction that alters natural hydrological processes (Forman and Alexander 1998) (Gillies 2011) (Tague and Band 2001), and draining wetlands for development or peat extraction (Acreman and McCartney 2009), can cause functional losses and GHG emissions on a wider scale than point-source physical losses of relatively unconnected wetland systems. The development and implementation of effective best management practices are therefore key to limiting greenhouse gas emissions and carbon stores from boreal ecosystems.

3.3.0 Perennial Grasslands in the Prairie and Parkland Regions

3.3.1 Existing Perennial Grasslands - Carbon Sequestration, Storage and GHG Emissions

Carbon sequestration in temperate grassland ecosystems differs from wetlands since aerobic conditions generate higher decomposition rates with CO_2 the main form of carbon emitted to the atmosphere. However, temperate grasslands tend to effect net SOC carbon uptake due to higher rates of primary productivity than losses through heterotrophic respiration, harvest, fire, and changes in soil organic carbon stocks (Jones and Donnelly 2004). Grasslands are particularly adept at storing carbon in the soil due to the high allocation of biomass to root growth, which through progressive root development and turnover, leads to high SOC accumulation over time. A recent summary of long-term studies of soil organic carbon stock change in the Canadian Prairies conducted by Wang et al., (2014) concluded that in recent decades managed temperate grasslands sequestered a total of 5.64 Mg of C/ha on average at an estimated rate of 0.19 Mg C/ha/yr. Sequestration rates were found to vary with soil type and vegetation community, but impacts of grazing intensity on sequestration were variable (i.e. were not statistically significant).

Perennial grasslands are particularly important carbon stores with up to 97% of soil carbon stored below ground and relatively protected from short-term disturbances such as fire and grazing. Slow carbon turnover and the relatively stable soil environment can cause substantial accumulations of soil organic matter (Abberton, Conant and Batello 2010). According to (Bremer 2008) temperate grasslands in Canada store between 50 – 200 tonnes of organic carbon per ha in soils, and an additional 3 – 12 tonnes of carbon per ha in plant biomass and litter.

3.3.2 Restored Perennial Grasslands and Carbon Sequestration

Carbon sequestration in historical temperate grassland ranges can be enhanced via the conversion of arable land to permanent cover/natural grassland, and effective management of these systems (Soussana, et al. 2004). The enhanced carbon sequestration achieved through these mechanisms is due to increases in organic biomass added to the soil and/or the reduction of organic carbon losses from the soil relative to the preceding management system (Boehm, et al. 2004). Conversion of arable land to permanent cover/natural grassland provides the greatest potential for enhancing carbon sequestration.

Research into soil organic carbon change for the conversion of annual crops to perennial cover found that rates in the Canadian Prairies ranged from 0.23 - 1.40 tC/ha/yr (0.84 – 5.13 tCO_2e/ha/yr) (EcoResources Carbonne 2011). A draft, reviewed Alberta quantification offset protocol for the conversion of cropland to perennials quotes conservative values in the range of 0.01-1.47 tCO_2e/ha/yr taking into account the net effect of emissions from fertiliser use, emissions from cattle and SOC sequestration (Government of Alberta 2013). In terms of cumulative soil organic carbon stock changes, Boehm et al. (2004) found that the conversion of cropland to permanent cover resulted in a change of 18 Mg C/ha for the Brown soil zone, and 66 Mg C/ha for the Black and Gray soil zones of the Canadian Prairies.

Studies assessing the natural recovery of native grassland on previously cropped areas indicate that prairie soils have limited recovery, with Mixedgrass Natural Subregion failing to recover more than 50 years after undergoing revegetation (Smoliak and Dormaar 1985). This highlights the long-term impact of land use conversion on ecosystem properties, including SOC.

3.3.3 Emissions from Perennial Grasslands - Functional and Physical Losses

The combination of increased soil temperatures and aeration associated with native grassland conversion leads to increased SOC degradation, and net release of carbon to the atmosphere in the form of greenhouse gases. Experiments in Alberta demonstrated that a change from native grassland to continuous wheat cropping led to the release of **1.7 t C/ha/year for the first four years**, with this rate of C loss decreasing to **0.32 t C/ha/year for the next 9 years** (Wang, Willms, et al. 2010).

While the conversion of native grassland to tame forage maintains greater stores of soil carbon than conversion to cropland, reductions in soil carbon concentrations relative to grassland are still notable (32% and 20% reductions have been observed in the Mixedgrass and Foothills Natural Subregions respectively) (Whalen, Willms and Dormaar 2003). Reduced SOC has been attributed to the reduced root mass associated with some forage crops, leading to reduced accumulation of SOC (Dormaar, Adams and Willms 1994). Soil health associated with tame forage exceeds that of croplands, but remains lower than that of native grassland (Hebb, et al. In Press).

3.4.0 Integrated Resource Management

While determining the carbon value of an individual restored wetland can be challenging, wetland restoration protocols should focus on a landscape approach involving upland as well as wetland restoration and management. There are many management practices that can be applied to wetlands and the surrounding landscape that can reduce GHG emissions and increase carbon sequestration on a landscape scale. For example, conversion of cropland to grassland in association with wetland restoration, can reduce GHG emissions from the wetland by increasing the hydroperiod (time between drying and rewetting), decreasing erosional nutrient loading and therefore risk of eutrophication and N_2O emissions, and reducing the likelihood of tillage and fertilisation of depressional areas associated with N_2O emissions.

Implementation of beneficial management practices and sustainable resource management in the boreal region can also prevent functional and physical losses, while allowing economic development and natural resource use. For example, the proper construction and maintenance of service roads for well pads to allow hydrological connectivity would allow continued functioning of the surrounding wetland areas.

4.0 Opportunities

There are many opportunities to target retention and restoration efforts to certain locations and project types. To prioritise projects under the Watershed Resiliency and Restoration Program (WRRP), maps were developed based on three criteria: hazards, consequences, and resilience to alleviate flooding and drought risks, and improve water quality. A similar assessment of carbon management services could be undertaken to develop priority areas for the retention and restoration of wetlands and grasslands based on criteria such as:

- Likelihood/risk of development/ecosystem conversion
- Likelihood/risk of functional impairment
- Potential and existing GHG emissions, carbon storage and carbon sequestration
- Regional historical and ongoing functional and physical losses
- Increased resilience to climate change (e.g. albedo, flooding)

A centralised program for effectively and accurately monitoring ecosystem presence, loss and health is key to determine current state and areas under pressure. The GOA has shown commitment to achieving the aims of the AWP and LUF by approving a 2-year plan to develop a wetland monitoring program in Alberta (Cobbaert 2017). The primary drivers of the plan are to assess how the outcomes of the AWP are being met, how wetland objectives in Regional Plans are being met, evaluate the state-of-the-environment, and to gain an understanding of anthropogenic and climate impacts on Alberta's wetlands, year-on-year. It is also likely that the GOA will seek stakeholder input in terms of existing monitoring programs, and stakeholder needs as they relate to wetland monitoring. This is a significant statement on behalf of the GOA on their commitment to achieving provincial objectives relating to the retention and restoration of Alberta's wetlands, and the ecosystem functions they provide.

4.1 Ecosystem Retention

Studies into the GHG emissions and carbon sequestration benefits associated with Alberta's wetlands and grasslands clearly highlight the importance of retaining these ecosystems as important carbon sinks in the landscape. While the importance of wetlands and grasslands specifically as carbon sinks may not be outlined explicitly in Alberta legislation or Plans, the many other co-benefits they provide do form the basis for prioritising retention in a number of policies and regulations. For example, the *Alberta Wetland Policy* (AWP) assesses functional value and replacement requirements based on, "relative abundance on the landscape, supported biodiversity, ability to improve water quality, importance to flood reduction, and human uses" (Environment and Sustainable Resource Development 2013).

Despite all the tools in the Conservation and Stewardship toolbox, wetland and grassland losses continue to occur across Alberta, particularly in the White Zone and boreal transition zone (see Table 2 and Table 3). This is also the location of greatest historical losses of FWMSWs, and as a result, the area is already experiencing the impacts of lost ecosystem services, such as increased flooding risk and water quality issues. The boreal region is coming under increasing pressure from development; the risks of peatland loss and functional impairment in this area are significant due to their vast carbon stores and difficulties with restoration.

"Alberta's vision is for a healthy and clean province where Albertans are leaders in environmental conservation and protection, enjoy sustainable economic prosperity and a great quality of life" (AEP 2017)

An opportunity exists to align conservation tools to target retention activities to authorised and unauthorised losses, focusing on locations under the greatest development pressures. As shown below, retention activities are very cost-effective and provide better quality ecosystem services. Quality monitoring systems, already under development, are essential to enable the GOA and other stakeholders to effectively target resources for retention activities.

4.2 Restoration

In terms of carbon management, and co-benefits provided by wetlands and grasslands, retention is always preferable, a premise that is reflected in the language used in the applicable policies and legislation. However, historical losses have contributed to both GHG emissions and loss of ecosystem services (see Table 2). Increasing pressures on boreal wetlands means the potential exists for significant physical losses and even greater functional impairment. This highlights the need for research, education and implementation of beneficial management practices regarding development and restoration in the boreal region. Without the development of successful peatland restoration methods, it is likely that physical boreal wetland losses will be replaced by FWMSWs leading to further CH_4 emissions and loss of peatland ecosystem services including critical habitat (Timoney 2015). Similarly, conversion of natural grasslands has led to loss of SOC stores and may have contributed to greater GHG emissions on a landscape scale through changes to local hydrology, nutrient loading, and erosion (Verhoeven, et al. 2006).

While restored FWMSWs may take a number of years to become net GHG sinks, restoration, especially in areas of historical loss, is important both for reestablishment of lost ecosystem services in the short-term, and in the wider context of providing long-term sustainability for future generations when considering FWMSWs as a carbon management tool.

"Environment and Parks works to protect and enhance the Alberta environment and ecosystems throughout the province to ensure a sustainable future, making life better for Albertans." (AEP 2017)

The presence of wetlands on local and regional scales impact local and regional climates, providing a humidifying and cooling effect, with increased and stabilised precipitation regimes (Yunlong, et al. 2011). It is predicted that the central and southern Canadian Prairies in particular will experience significant warming as a result of global climate change (Lemmen and Warren 2004). Therefore, while restored FWMSWs may initially become net sources of GHG emissions, a greater presence of FWMSWs on the landscape could present the prairie region with an opportunity for adaptation to a changing climate. The resiliency and adaptability of this region in a changing climate becomes even more apparent when considering its importance in the Canadian agricultural sector.

Relative to restored wetlands, restored grasslands typically do not emit comparable amounts of methane, even when grazed by ruminants, relative to the gains in soil carbon if sustainably managed, creating a net carbon sequestration benefit. However, studies assessing changes in soil properties following the natural recovery of native grassland on previously cropped areas indicate that prairie soils have a limited ability to recover, with Dry Mixedgrass prairie soils failing to recover more than 50 years after undergoing revegetation (Smoliak and Dormaar 1985). Therefore careful establishment of restored native grassland, and then effective ongoing management of restored grasslands, is key to success.

5.0 Tools for Retention and Restoration

Many systems and policies are being employed at all levels of government to reduce GHG emissions and maintain/enhance carbon sequestration. The multi-faceted nature of land use planning with respect to wetlands and grasslands, and the many co-benefits they provide alongside carbon management, means that these ecosystems impact on many societal and governmental priorities.

Several existing tools and funding streams could be leveraged to achieve wetland and grassland retention and restoration. The promotion of incentives, programs or policies that specifically incent the carbon sequestration benefits of wetlands and grasslands, emphasise avoiding conversion, and minimise functional losses, is recommended. The existing mechanisms that could be employed to support wetland and grassland retention and restoration as a key part of Alberta’s carbon management package are summarised in Table 6. A brief outline of the existing tools available for retention and restoration of wetlands and grasslands in Alberta, divided into regulatory approaches to encourage retention is provided, and incentive-based approaches to incent retention and restoration activities are identified. The ‘Implementation Roadmap’ report gives greater detail on how each of these tools could be used to retain and restore Alberta’s wetlands and grasslands.

Table 6: Existing Regulatory and Incentive-Based Approaches for the Retention and Restoration of Ecosystems

Regulatory Alignment **(Legislation, Policy, Strategy, and Existing Tools)**
Policy and Legislation
The GOA has a number of regulatory and enforcement tools to aid the retention and restoration of wetland and grassland ecosystems, including the *Alberta Wetland Policy* (AWP) **(Government of Alberta 2013)**, *Alberta Water Act*, *Public Lands Act*, *Municipal Government Act, Alberta Land Stewardship Act*, and the *Environmental Protection and Enhancement Act (EPEA)*. Wetlands and grasslands are afforded some protection under these regulations, either through designation as a protected area (*Municipal Government Act*), or ownership of the waterbody and riparian areas by the Crown (*Public Lands Act*). In conjunction with the *Alberta Water Act*, the AWP provides a strong legislative tool that prioritises avoided conversion of wetlands as the preferred standard, and requires developers to fund replacement of lost or degraded wetlands to an equivalent or greater functional value. While retention is preferable to replacement, the AWP 3:1 functional replacement (mid-point) goal will work towards replacement of lost climate mitigation and adaptation benefits. Regulatory approval, including mitigation, is required prior to wetland disturbance. With such a diverse and extensive landscape, consistent enforcement remains a challenge. This may account for the discrepancy between the number of wetland conversion approvals, and the number of observed wetland losses in Alberta. These regulatory tools do not explicitly deal with the GHG emissions and carbon sequestration, but do provide the basis for protection, improving on beneficial management practices, and restoration of lost or converted ecosystems.
Frameworks and Strategies
The *Land Use Framework* (LUF), backed by the *Alberta Land Stewardship Act (ALSA)*, is a key development allowing provincial policies and priorities (healthy economy and ecosystems supported by land and natural resources) to be translated to the regional scale through the development of *Regional Plans* and the provisions for conservation and stewardship tools (e.g. transferable development credits, conservation offsets, conservation directives, and pilot projects (see section *10.5 Provincial Land Use Framework)*). *Regional Plans* are in various stages of development, with the Lower Athabasca Regional Plan (LARP) and South Saskatchewan Regional Plan (SSRP) being completed. The implementation of the SSRP speaks to the need for establishment of wetland and grassland conservation and management objectives via management frameworks and regulatory details. An opportunity exists to take a proactive, long-term stance on

land use management and wetland and grassland retention and restoration via the setting of measurable regional objectives for ecosystem retention and restoration. Such an approach would provide the greatest potential for carbon sequestration from these ecosystems, in addition to the many co-benefits described throughout this report (Government of Alberta 2014) (Government of Alberta 2017).

These approaches set an important precedent in the development of ecosystem objectives in successive *Regional Plans*, for example in the implementation of the LARP and Boreal wetlands retention and restoration.

Funding will be required to achieve these objectives; recognition of the carbon storage and sequestration capacities of these ecosystems could release funds from developing federal and provincial carbon initiatives directed to ecosystem retention and restoration (e.g. the next Agricultural Policy Framework and Pan Canadian Carbon Plans).

The *Alberta Caribou Recovery Plan* also links strongly with ecosystem retention. The *Plan* recognises the importance of wetland habitat to caribou conservation efforts, in addition to being a carbon sink.

Carbon Pricing and Offsets

The *Specified Gas Emitters Regulation* (SGER) regulates large GHG emitters in Alberta to reduce and/or offset emissions through the purchase of verified offsets in the Alberta carbon market, or payments into the CCEMC/ERA. Additionally, Alberta has implemented a Carbon Levy on the combustion of non-renewable fuels. The SGER and Carbon Levy will form the basis of Alberta's Carbon Competitiveness Regulation (CCR). Currently GHG emissions from land use change are not included in compliance GHG emissions under SGER's facility-based approach, yet there are similarities between the GHG emissions from the combustion of fossil fuels and the loss of SOC stores from wetland and grassland degradation. Under the new output-based allocation of the CCR for large final emitters, the regulatory approach would include emissions generated from land use change, for example where operations were draining peatlands in the boreal region.

Conversely, the development of a wetland retention and grassland retention and restoration carbon offset quantification protocol, would allow the generation of carbon offsets. Under the Wetland Offset Program, retention of wetlands is not an eligible project type, potentially enabling an opportunity to consider a carbon offset protocol, without violating additionality principles under the AWP.

The cost-benefit analyses below show that wetlands and grasslands are cost-effective carbon offset tools that could be employed on a large-scale by regulated entities to meet their compliance targets through private investment, such as the International Civil Aviation Organisation (ICOA).

In the past, offset protocols for avoided conversion of wetlands and grasslands, and restoration of grasslands have been unsuccessful. An alternative measure might be to include the GHG emissions incurred by ecosystem conversion in existing carbon offset protocols. Such an approach would reduce the offsets gained through beneficial management practices if anthropogenic ecosystem conversion on the same land parcel was having a negate impact on GHG emissions. Incorporating wetland and grassland retention in this way could avoid concerns over additionality, and incent retention.

Other Conservation and Stewardship Tools

The province is developing a Conservation Offset Policy that will act as an umbrella policy for current and future offset programs. There is an opportunity to start a conversation in aligning carbon management and climate resiliency outcomes in the developing umbrella Offset Policy. There is also a Caribou Habitat conservation offset project being developed where retention and restoration of boreal wetlands could be aligned.

Conservation Easements (CEs) are a voluntary legal requirement placed on a parcel of land requiring the land owner to protect the land's natural features in perpetuity (see section *10.5 Provincial Land Use Framework*). DUC employs two programs (Conservation Easement Program and Revolving Land Conservation Program) that utilise CEs to avoid wetland and grassland conversion, thus preserving SOC stores and maintaining carbon sequestration capacity.

Conservation Directives are a tool enabled under the ALSA that allows the protection of a specific area for a specific purpose (protection, conservation or enhancement), through Regional Plans (see section *10.5 Provincial Land Use Framework*). Conservation Directives could be developed for Regional Plans and used in areas under significant development pressure, such as the boreal region. Tradable Development Permits and conservation offsets are other tools developed under the ALSA (see section *10.5 Provincial Land Use Framework*). The criteria listed in the Opportunity section above could be used as part of the criteria to identify which areas should remain protected from development, when establishing the development permit system.

Incentive-Based Approaches

(Programs, Education, Financial Incentives)

Government Administered Incentive-based Programs

Incentive-based programs tend to work better than regulatory approaches to target land owners in retaining, restoring and managing ecosystems located on their land through shared stewardship and/or financial support and education.

The Watershed Resiliency and Restoration Program (WRRP) and Agricultural Watershed Enhancement Program (AWEP) are good examples of how wetland values can be applied to achieve provincial priorities, and have seen significant uptake since their instigation (see section *10.7 Flood/Drought Management*). While the focus of each program is different, and does not include carbon management benefits, projects funded by each program achieve positive outcomes through the recognition of ecosystem services provided by wetlands.

It is clear that such incentive-based land use management programs are successful in Alberta and could provide impetus to land-owners to continue the work already started. This could be done in partnership with the federal government in developing programs under the New Agricultural Policy Framework (e.g. the Greencover Program in APF1) and Pan Canadian Framework green infrastructure programming.

The Water for Life strategy, aims to improve education and engagement on watershed issues, including running wetland restoration programs, through Watershed Planning and Advisory Councils, Watershed Stewardship Groups and the Alberta Water Council. A consideration of increased funding for restoration programs would help advance ecosystem management. Management plans also provide advice to governments and agencies on land and resource management from a watershed perspective.

NGO Administered Incentive-based Programs

The Wetland Restoration Lease Program (WRLP) and Forage programs employed by DUC are good examples of NGO-based incentive programs that utilise funding to enact ecosystem retention and restoration activities (see section *6.0 NGO-Sponsored Programs in Canada*). In addition, the Eco-Gift program allows NGO's and others to protect lands if they are designated under the program.

There is potential to utilise funding from provincial and federal green infrastructure funding to implement similar programs focused on wetland and grassland retention and restoration as a cost-effective carbon management and climate adaptation tool.

Carbon Pricing and Offsets
To allow voluntary or compliance market access for GHG offsets generated through wetland and grassland retention and grassland restoration, an approved carbon offset protocol will need to be developed. Examples exist in the American Carbon Registry and the Verified Carbon Standard, and are being developed for the Ontario/Quebec carbon market (California Environmental Protection Agency 2017) (Regional Greenhouse Gas Initiative 2017). Company and industry leads see value in voluntarily offsetting their GHG emissions to improve social license and public image, and report against sustainability goals to increase the competitiveness and marketability of their products. There is also interest in carbon financing, where 'carbon funds' are built with private and public investment through a private entity of an NGO, such as NatureVest, with an interest in sustainability and conservation. Carbon funds are effectively small-scale carbon markets that invest in projects that achieve carbon sequestration and emissions reductions, as well as other environmental and social benefits, to generate offsets. The funds generated from offset sales are then utilised to compensate investors and land owners at a guaranteed rate.
Insetting
Similar to offsetting (see above), insetting utilises the value of voluntarily offsetting GHG emissions to improve social license and public image, and increase competitiveness and marketability for companies. However, insetting differs from offsetting in a number of ways. Insetting projects can be seen as an investment by corporations in their supply chain with benefits to staff, suppliers, customers and neighbours. Insetting also does not require the development of a verified carbon offset protocol, which reduces expenses associated with protocol development and verification, while reductions are viable and align with offsetting principles of additionality, uniqueness, measurability and verifiability (Davies 2016). Large companies within the forestry, agricultural, and food industries are becoming increasingly interested in insetting projects and additional benefits in traceability, transparency and supply chain efficiencies.

6.0 NGO-Sponsored Programs in Canada

"Strategic partnerships support the ministry in achieving its outcomes by providing collaborative forums to leverage resources, capacity and a shared responsibility for environmental stewardship." (AEP 2017)

For nearly eight decades Ducks Unlimited Canada has been the leading organisation in the retention and restoration of wetlands and perennial grasslands in Alberta and Canada, and is the largest Canadian NGO partner under the North American Waterfowl Management Plan (NAWMP). DUC works in partnership (through NAWMP and other means) with governments, academia and industry towards achieving conservation objectives and ensuring sustainable land use through effective policies, programs, and best management practices implemented in an adaptive management framework. Some of the programs being utilised to enact retention and restoration of wetland and grassland ecosystems are presented in Table 7 below; more detailed descriptions can be found in the Implementation Roadmap report. The success of these programs has led to significant gains in wetland and perennial grassland restoration and associated carbon management.

DUC's activities in the boreal region focus on retention of wetlands and advancing sustainable land use through collaboration with various levels of government and industry. Retaining wetlands and minimising the impacts of development provide a substantially greater opportunity for return on investment in the boreal region, as outlined in the *Costs and Benefits* section below. Beneficial management practice and knowledge exchange is a key component of DUC's boreal operations:

- providing industry and government partners with science-based knowledge of the ecosystem services provided by boreal wetlands, such as hydrological management, biodiversity and carbon storage,
- informing land use planning, supporting provincial priorities and policies such as the wetland policy,
- supporting sustainable industry practices (e.g. Forest Stewardship Council and Sustainable Forestry Initiative certification).

Utilising a combination of beneficial management practices, information management tools, conservation planning products (outlining full ecosystem services), and knowledge exchange, DUC is working towards facilitating the retention of carbon management and carbon storage capacity provided by boreal wetlands, in coordination with industry and government partners.

Table 7: Ducks Unlimited Canada Wetland and Grassland Retention and Restoration Programs

Program	Description	Program Impacts Area (ha)	Carbon Management*
Conservation Easement Program	Conservation easements are acquired either through payment or as a donated interest. Under the terms of the conservation easement, the landowner commits to restricting future development, in particular breaking or tilling perennial uplands and/or draining or ditching or wetlands, for perpetuity. This program is effective in retaining functional ecosystems as carbon management tools and preventing SOC losses.	**Retained** *Purchased* Upland: 6,481 Wetland: 1,290 *Donated* Upland: 4,672 Wetland: 727	Avoided GHG emissions (tCO_2e) – *Purchased + Donated*: Upland: 111,500 Wetland: 658,000 Retained carbon sequestration capacity (tCO_2e/ha/yr.) – *Purchased + Donated*: Upland: 7,800 Wetland: 6,700
Revolving Land Conservation Program	The Revolving Land Conservation Program involves the purchase of land, restoration of its wetlands and grasslands, and resale on the real estate market with a conservation easement to protect restored ecosystems in perpetuity while retaining agricultural use. The program allows greater integrated upland and wetland restoration impacts on a landscape-scale.	**Restored** *Purchased* Upland: 2,483 Wetland: 723 *Donated* Upland: 466 Wetland: 26	
Long-term Purchase	DUC owns and retains approximately 100,000 acres (40,500 ha.) of land in Alberta as a long-term hold on the land. The restored and retained wetlands and grasslands contained within the owned land are managed and protected by DUC. The program retains ecosystems, associated carbon stores, and sequestration services which protected from development.	**Retained** Upland: 22,158 Wetland: 6,519 **Restored** Upland: 22,779 Wetland: 10,658	Avoided GHG emissions (tCO_2e): Upland: 221,600 Wetland: 2,125,200 Retained carbon sequestration capacity (tCO_2e/ha/yr.): Upland: 15,510 Wetland: 21,510

Wetland Restoration Lease Program	DUC purchase a lease from a landowner (typically 10 years) to restore drained wetlands, and retain existing wetlands. The landowner continues to manage the land with restricted agricultural activities, for which landowners are compensated. Upon lease expiration, the retained and restored wetlands and grasslands are regulated by the *Alberta Water Act* and reported to Alberta Environment and Parks (AEP). The landowner is required to adhere to the requirements of the *Alberta Water Act*, with future impacts subject to replacement requirements.	**Retained** Upland: 2,656 Wetland: 974 **Restored** Upland: 1,240 Wetland: 644	Avoided GHG emissions (tCO_2e): Upland: 26,560 Wetland: 317,400 Retained carbon sequestration capacity (tCO_2e/ha/yr.): Upland: 1,860 Wetland: 3,210
Forage Program (with support from Crop Production Services – CPS)	Incentives are given to participating producers in critical habitat zones to assist in the purchase of forage seed and to encourage sowing managed grasslands. The program promotes best management practices for land use through the establishment of grassland ecosystems, and avoiding drainage of wetlands for an agreement term of 10 years.		

* Figures exclude restored area as the time since restoration for each project is unknown.

The total impact of DUC programs, excluding impacts in the boreal region, in terms of avoided GHG emissions is approximately 3.5M tCO_2e, comparable to avoided GHG emissions from consumption of 8.1 million barrels of oil. The total preserved carbon sequestration capacity as a result of DUC programs is approximately 57,000 tCO_2e/yr., equivalent to GHG emissions from 12,000 passenger vehicles per year (US Environmental Protection Agency 2016).

Boreal Programs

Table 8: DUC's programs in the Boreal Forest Region of Alberta that have positive implications for carbon management.

Program/Activity	Description	Program Impacts	Carbon Management
Conservation Products	Comprehensive Wetland Inventory/maps classifying 19 wetland types conforming to the AB Wetland Classification Standard	Mapped distribution of wetlands as a tool for direct input into various land use planning initiatives (LUF, forestry, protected areas)	Key input for avoidance and minimization of impacts on wetlands to maintain sequestration and retention of carbon stores
	Wetland connectivity and water flow characteristics	Provides spatial representation of water movement in wetlands for input into various land use planning initiatives	Key information to ensure hydrologic connectivity to maintain sequestration and retention of carbon stores
	Mapped wetland carbon store estimates (beta version)	Provides spatial representation of estimated subsurface wetland carbon stores	Allows for planning to maintain high carbon store areas (e.g. accounting for carbon offset interests)
Best Management Practices (BMPs)	Development of various recommended BMPs to avoid and minimize negative impacts on wetlands	Planning and operating practices for use by industry	Practices that maintain and minimize impacts to wetland carbon stores (i.e. minimize GHG emissions)
	Resource Roads and Wetlands	Recommended practices to maintain hydrologic connectivity in wetlands	Carbon sequestration and storage are maintained when roads cross wetlands (i.e. minimize GHG emissions)
	Forestry Planning	Guiding principles for forest planning to avoid and minimize impacts on wetlands	Wetland Carbon sequestration and storage are maintained during forestry operations (expands current forestry carbon accounting protocols)

Other NGOs involved with wetland and grassland retention and restoration include the Nature Conservancy Canada (NCC), TNC Canada, and the Alberta Conservation Association (ACA). While not strictly an NGO-based program, GOC's Ecogift is a federally-enabled program that enables NGOs to perform habitat retention and restoration activities on donated land. Land owners can generate a tax credit for donations of ecologically sensitive land, or a partial interest in ecologically sensitive land, to a qualified recipient. Qualified recipients are usually NGOs with conservation values who then ensure that the land's environmental heritage is protected in perpetuity, for example through the placement of an easement. The Ecogift program therefore provides a mechanism by which NGOs can enact the retention of wetlands and grasslands, and protect them in perpetuity to maintain carbon storage and sequestration benefits, along with other ecosystem services.

The ACA hosts several land management projects that enable grassland and wetland retention and restoration. Retention programs include the Landowner Habitat Program which compensates landowners for signing legally-binding habitat retention agreements for 5-20 years, and the Provincial Habitat Securement Program which secures land through purchase, donations and protective notations on Crown land to protect in perpetuity. The Riparian Conservation Program carries out on-the-ground restoration projects and outreach and education initiatives on riparian areas, in collaboration with landowners, industry, government, watershed groups and other stakeholders.

TNC Canada's programs in the boreal region closely mirror those of DUC, through education, collaboration and negotiation with key stakeholders to enact sustainable, results-oriented, land use informed by science.

7.0.0 Business Case

7.1.0 Costs and Benefits

There are several drivers of land use change that lead to ecosystem functional and physical loss. In the White zone and boreal transition zone industrial development, agricultural development and market forces are key drivers of land use change. For example, increased beef prices may incent the retention or restoration of grassland areas for pasture, while incentives for biofuel crops may amplify pressures to increase productive cropland (Prairie Habitat Joint Venture 2014). The expansion of urban areas has also led to functional and physical loss of wetlands and grasslands as land is cleared and re-zoned for development (Prairie Habitat Joint Venture 2014). Similarly, energy and natural resource market prices influence the extent of development activity within the boreal region.

To meet Canada's Nationally Determined Contribution (NDC), as set out in the 21st COP meeting in Paris, 2015, it is expected that without land-based reductions, a gap of 68Mt CO_2e would be met through the purchase of globally produced offsets under Article 6 of the Paris Accord (Sawyer and Bataille 2017) (UNFCC 2015). If the carbon reduction potential for Canadian wetlands and grasslands is realised and accounted for – both from a retention and a restoration perspective - Canada's reliance on purchasing international offsets will be reduced, alongside costs to the taxpayer. Conversely, if the current rate of conversion of these ecosystems continues, the GHG emissions associated with conversion will impact on Canada's ability to meet its NDC, and on current efforts being employed to reduce GHG emissions in other sectors. The next section discusses the contribution that these lands could make towards Alberta and Canada's stated emission reduction goals, if accounted for.

7.1.1 Value of Carbon Retained from Ongoing Sequestration Services – Cost:Benefit Analysis

Existing functional ecosystems are known to sequester carbon at various rates; in Alberta PPFWMSWs were assumed to exhibit a net sequestration rate of 3.30 tCO_2e/ha/yr., perennial grasslands 0.70 tCO_2e/ha/yr., boreal FWMSWs 2.2 tCO_2e/ha/yr, and boreal peatlands 1.1 tCO_2e/ha/yr. (see *Table 4*, note figures given here are CO_2 equivalents whereas figures in *Table 4* are given in tonnes of carbon).

DUC's Conservation Easement, Revolving Land Conservation, and Wetland Restoration Lease programs involve protection of wetland and grassland ecosystems in perpetuity through the placement of conservation easements. From these programs, DUC estimates that retention costs are approximately $1,850/ha for both FWMSW and grassland ecosystems. Assuming that these ecosystems are protected from development for 100 years through a conservation easement, costs of retention can be assumed to be $18.50/ha/yr. The cost of retention in the boreal region is difficult to determine due to variable land prices, ownership and land use. However, the same $1,850/ha cost was applied to boreal wetlands in this analysis for comparison.

Applying the cost of retention to carbon sequestration rate only, gives a cost for carbon sequestration of \$6/tCO_2e per year for PPFWMSWs, \$8/t$CO_2$2 per year for boreal FWMSWs, \$17/tCO_2e per year for boreal peatlands, and \$26/tCO_2e per year for perennial grasslands (see *Cost Calculations* in *Appendix 1: GHG emissions and Cost Benefit Calculations*) . These values are lower than the current and forecast values of carbon in the Alberta and Canadian carbon markets (Sawyer and Bataille 2017), which has three important implications:

- Development of offset quantification protocols to allow generation of offsets for avoided conversion are feasible in Canadian carbon markets price ranges.
- It will likely be more economical to generate carbon offsets through retained wetland and grassland ecosystems than to purchase globally-sourced offsets to meet Canada's NDC targets.
- The domestic benefit of additional ecosystem services and enhanced climate resiliency accrues within Canada and Alberta.

7.1.2 Value of Carbon Stored in Existing Lands – Cost:Benefit Analysis

When we include the GHG emissions associated with ecosystem conversion averaged over a 100-year period to model the value of biologically stored carbon, and include emissions due to land use change to cropland, we get an indication of the value of carbon stored within these ecosystems. Retention costs fall to \$2-3 per tonne CO_2e per year for retained PPFWMSWs, and \$9-14 per tonne CO_2e per year for perennial grasslands when GHG emissions and land use change are also considered. Land use change emissions were not included in analysis of boreal wetlands due to variable land use drivers in the boreal region. However, applying stored carbon estimates averaged over a 100-year period gives a cost of \$3 per tonne CO_2e per year for retained boreal FWMSWs and just \$0.44 per tonne CO_2e per year for boreal peatlands. While these figures could be improved, they highlight the relative cost of biologically-based GHG emission reductions and sequestration compared to current and predicted carbon prices.

Figure 2:Value of Carbon Sequestration Provided by Ecosystems in Alberta

Figure 2 shows the value of the carbon sequestration services currently provided by Alberta's wetlands and perennial grasslands. In total, **Alberta's ecosystems sequester enough carbon to offset 7 million average passenger cars in North America every year** (US Environmental Protection Agency 2016). Despite expected sources of error in ecosystem area and calculation of sequestration capacity, it is clear that the value of carbon sequestration as an ecosystem service provided by existing wetlands and perennial grasslands is a significant asset to Alberta, collectively worth over $2.5 billion per year on average, and up to $27 billion over a 12-year period, based on predicted carbon prices to 2030 (see *Appendix 1: GHG emissions and Cost Benefit Calculations* for calculation) (Sawyer and Bataille 2017).

7.2.0 Value of Carbon Lost due to Conversion - Cost:Benefit Analysis[13]

The ongoing loss of ecosystems within Alberta is leading to GHG emissions from the loss of carbon sequestration and storage within the soil and biomass, the soil organic carbon (SOC) store. Ongoing loss rates are difficult to determine, however, the best available data for PPFWMSWs in Alberta shows a loss

[13] Based on the Predicted Value of Carbon in Canada to 2030

rate of 2,825 acres/year (1,143 hectares/year) (Prairie Habitat Joint Venture 2014), although there is some uncertainty due to a relatively small sample size, and a sample period from 2001-2011; a conservative estimated loss rate of 1,000 hectares/yr. was assumed. Estimates for ongoing boreal wetland losses were evaluated by comparing ABMI footprint data from 2007 and 2014 and calculating areal losses over the seven-year period. Annual losses in boreal region FWMSWs were calculated as 10,300 ha/yr., and losses of boreal peatlands was calculated as 8,500 ha/yr. for the period 2007-2014. Best available data for ongoing loss of temperate grasslands in Alberta shows a loss of 52,500 ha/yr. based on an annual loss rate of 0.75% (Gage, Olimb and Nelson 2016) and a total area of approximately 7,000,000 hectares (Bremer 2008). Data was also collected on wetland losses approved through the *Alberta Water Act* with compensation.

Averaged data from 2005-2016 from various sources suggest that in Alberta, annual approved wetland losses incurring compensation are in the region of 120 ha/yr (Environment Canada 2017). Excluding GHG emissions associated with land use change, it is estimated that approved wetland losses could account for annual GHG emissions of up to 39,100 tCO_2e, and an annual loss of up to 396 tCO_2e in carbon sequestration capacity. If this rate of loss were to continue to 2030, the average cost of GHG emissions and lost carbon sequestration could be up to $2.4 million per year, excluding land use change emissions. However, it should be noted that compensation of wetlands converted within the approval framework will aid the restoration of some ecosystem services and climate adaptation benefits.

Emissions associated with a change in land use should also be considered. For this analysis, it was conservatively assumed that PPFWMSWs and perennial grasslands were converted to no-till, continuous cropping of Spring Wheat[14]. Data taken from the draft Alberta carbon offset protocol “Conversion of Annual Cropland to Perennials” (Government of Alberta 2013) suggest that net emissions associated with no-till continuous cropping of Spring Wheat are 0.51 tCO_2e/ha/yr. in the Dry Prairie ecoregion, and 1.23 tCO_2e/ha/yr. in the Parkland ecoregion. Land use change emissions were not included in calculations of boreal wetland losses since land use changes associated with the loss of these wetlands is varied; applying an average land use change is therefore inappropriate.

Estimated GHG emissions due to ongoing ecosystem losses in Alberta are given in Table 9. A financial value of the cumulative lost sequestration capacity and GHG emissions due to ecosystem conversion was calculated to 2030 using predicted values for carbon (Sawyer and Bataille 2017). These values give an indication of the potential cost of ongoing losses (due to the purchase of globally sourced offsets), and the potential value of carbon to be gained through preventing ongoing ecosystem loss. Please note that the calculations below use GHG emissions from SOC store losses averaged over a 100-year period in order to model the value of carbon *stored in retained ecosystems*, and not the absolute GHG emissions that occur due to annual ecosystem losses.

[14] Spring Wheat cropping has a relatively high carbon sequestration rate, and fertilizer use comparable with many crops. No till field management was also assumed. Net GHG emissions from Spring Wheat are therefore conservative.

Table 9: Financial Value of Carbon Sequestration and GHG Emissions being Lost due to Ongoing Ecosystem Loss in Alberta

Ecosystem	PPFWMSW – Dry Prairie	Boreal FWMSWs	Boreal Peatlands	Perennial Grasslands – Dry Prairie
Annual Losses (ha)	1,000	10,300	8,500	52,500
Lost Carbon Sequestration (tCO_2e/yr.)	3,300	22,750	9,300	36,750
Average annual value of lost sequestration to 2030	$204,000/yr.	$1,408,000/yr.	$576,000/yr.	$2,276,000/yr.
GHG emissions due to loss of SOC stores (tCO_2e/yr.)	326,000	3,368,000	34,684,000	525,000
Average annual value of GHG emissions from SOC loss to 2030	$20.2 million/yr.	$208.6 million/yr.	$2.148 billion/yr.	$32.5 million/yr.
GHG emissions from land use change (Dry Prairie – Parkland) (tCO_2e/yr.)	514 – 1,228	NA	NA	26,985 – 64,470
Average annual cost of GHG emissions from land use change (Dry Prairie – Parkland)	$32,000-76,000/yr.	NA	NA	$1.7 – 4.0 million/yr.
Total value of carbon management lost annually	$20.4 – 20.5 million/yr.	$210 million yr.	$2.15 billion/yr.	$36.5 – 38.8 million/yr.

The above data show that ongoing ecosystem losses could incur GHG emissions and lost carbon sequestration worth up to $2.4 billion per year between 2018-2030. These figures can be interpreted as the potential cost of purchasing international GHG emissions offsets to account for losses (assuming external purchases at the 2030 Canadian base-rate for carbon), or as the cost of the carbon management services provided by these ecosystem services being lost annually.

The GOA is taking significant steps towards reducing the province's GHG emissions. Current efforts detailed in the Alberta *Climate Leadership Plan* are largely focused on the energy sector and energy efficiency (Leach, et al. 2016). While emission reductions in the energy sector are essential to meeting reduction targets, GHG emissions associated with ongoing ecosystem losses may be negating the progress being made in the energy sector. Figure 3 and Table 10 show the annual GHG emissions associated with ecosystem losses, and the amount of renewable electricity that would need to be generated on the Alberta grid to offset these emissions. Since wind-generated electricity is expected to increase significantly under the Renewable Electricity Program (AESO 2016), it is interesting to analyse the wind electrical generation capacity required to offset GHG emissions from ongoing ecosystem losses, and the cost associated.

7.2.1 Impact of Ongoing Ecosystem Losses on Current Efforts to Reduce GHG Emissions in the Energy Sector

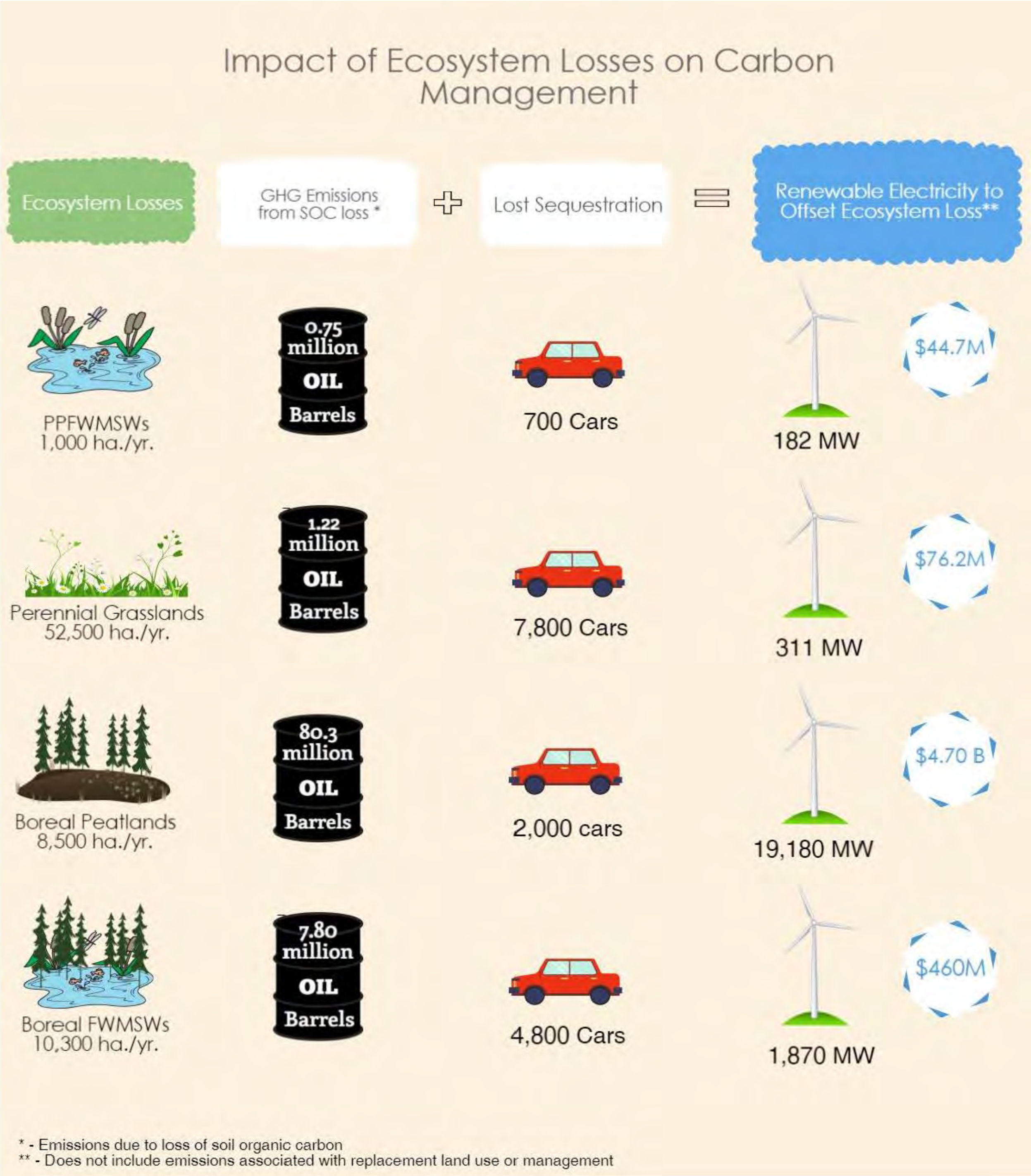

Figure 3: The Impact of Annual Ecosystem Losses on Carbon Management Services Provided by Ecosystems in Alberta

Table 10: Capacity and Cost of Wind-generated Electricity Required to Offset GHG Emissions due to Ecosystem Losses

	PPFWMSW	Boreal Peatlands	Boreal FWMSWs	Perennial Grassland
GHG emissions and lost sequestration incurred by annual ecosystem losses* (tCO_2e/yr.)	330,000	34,690,000	3,390,000	560,000
Renewable electricity required to offset ecosystem losses* (MWh/yr.)	558,000	58,801,000	5,747,000	952,000
Additional renewable electricity capacity required to offset GHG emissions due to ecosystem conversion* (MW/yr.)	182	19,179	1,875	310
Cost of electricity required to offset GHG emissions from ecosystem losses at $80/MWh for wind-generated electricity* (AESO 2016) ($/yr.)	$44.7 million/yr.	$4.70 billion/yr.	$460 million/yr.	$76.2 million/yr.

* Includes lost sequestration and absolute GHG emissions, not averaged over a 100-year period, to reflect actual annual GHG emissions.

The Renewable Electricity Program aims to increase renewable electricity capacity in the Alberta electric grid by 5,000MW by 2030 (AESO 2016). **If ecosystem losses are allowed to continue at the current estimated rate, excluding losses of boreal peatlands, the GHG reductions achieved through the Renewable Electricity Program will be negated in just over 2 years.**

Estimated GHG emissions and lost sequestration capacity due to annual ongoing losses of boreal peatlands in Alberta are particularly significant. According to these calculations, **annual losses of boreal peatlands negate the REP's additional 5,000MW renewable electricity capacity target nearly four times over**. While these estimates are considered conservative, even accounting for inaccuracies this is a significant finding that further highlights the importance of preserving carbon stores in Alberta's peatlands, and the magnitude of ongoing losses in terms of impacts on climate change efforts.

8.0 General Discussion on Costs of Restoration

The high degree of variance and ongoing research involved in modelling wetland switchover times means that it is unfeasible to calculate the financial implications of wetland restoration activities. While additional research is required, Neubauer (2014) estimates switchover times for FWMSWs in temperate regions between 60-130 years, among the shortest of any wetland type. Permanence of restored wetlands is an important consideration when dealing with such timeframes. Additionally, the impacts of previous land use should be considered when calculating net radiative forcing of restoration activities.

Boreal peatlands are modelled to have even greater switchover times than temperate region FWMSWs at 1,200 (Neubauer 2014). Restoration of boreal peatlands that have been subject to functional disturbance is challenging and specific to each site, requiring expert hydrological management to restore water table functioning. Additionally, restoration of peatland that has been subject to substantial physical disturbance (e.g. horticultural peat extraction), is extremely challenging and expensive, requiring intensive water management and selective plant reintroduction (Timoney 2015) (Rooney and Bayley 2011) (Rochefort and Lode 2006). Therefore, restoration activities regarding boreal peatlands is limited to restoration of functional losses via hydrological management, or replacement with upland habitat or FWMSWs. For these reasons, the benefits of retention and minimisation of functional impacts where developments in boreal peatlands are concerned, are clear.

Compared to wetlands, restored perennial grasslands, rapidly become net radiative sinks due to lesser CH_4 emissions (if grazed). A report by Eco Resources Carbonne (2011) found that most studies in the Canadian Prairies obtained carbon sequestration rates generally above 0.4 Mg C/ha/yr. (1.47 tCO_2e/ha/yr.) in restored grasslands. Using predicted carbon prices to 2030, the additional carbon sequestration capacity of restored grasslands is valued at $81/ha/yr. Considering emission reductions from changes in land use (continuous cropping, no till, Spring Wheat 0.514-1.228 tCO_2e/ha/yr.) increases the value of restored grassland as a carbon management tool to $110-150/ha/yr - this gives a coarse indication of the revenue that could be generated from restored perennial grasslands under a carbon offset protocol.

Perhaps more importantly, the mitigating impacts of climate cooling and humidification on local and regional scales, should be considered in the carbon management and climate impact discussion surrounding restoration activities. Given these benefits, other ecosystem services, and relatively short switchover times, wetland restoration activities should be seen as having a net benefit in terms of carbon management and climate change adaptation. Additionally, the provision of a net carbon sink for future generations through wetland and grassland restoration is important when considering sustainability.

9.0 Additional Benefits

A key advantage of wetland and grassland retention and restoration is the additional ecosystem services they provide aside from carbon management. Investing in wetland and grassland retention and restoration will provide significant benefits to Albertans as a cost-effective strategy for adaptation to, and mitigation of, a changing climate; economical water quality and quantity management; ecological benefits to biodiversity, including recovery strategies for species at risk; indigenous cultural and traditional land use interests; and consequent socio-economic gains. Many of these benefits and ecosystem services align well with GOA and federal priorities and are already recognised by legislation and programs.

"*Utilizing [Alberta's natural resources] in an environmentally responsible and sustainable way enhances land stewardship for the benefit of all Albertans, including Indigenous peoples, and is important for the province's current and future economic development*." (Alberta Agriculture and Forestry 2016)

Financial assessment of other ecosystem services provided by wetlands and grasslands is outside the scope of this report. However, to provide context, a study of the wetlands in the Lake Winnipeg watershed valued ecosystem services at $939.10 - $1,567.47 /ha/yr., and estimated that wetland losses have reduced ecosystem services by 36-80%, with an estimated value of $0.11-1.36 billion/year, compared to pre-settlement (Voora and Venema 2008). Similarly, a study by Kullshreshtha et al., (2015) evaluating the ecosystem services associated with grasslands in Manitoba, estimated the socio-economic value of these systems at $0.7 billion to $2.5 billion annually ($292 and $1,050 per hectare per yr.).

9.1 Climate Mitigation and Adaptation

"… as the frequency and severity of catastrophic events such as wildfires, flooding and drought increase, Albertans are looking to the government to ensure the province is well prepared for natural disasters to minimize their economic, social and environmental impacts and costs… Research and knowledge transfer targets the development of mitigation and adaptation strategies to effectively respond to climate change effects" (AEP 2017)

The presence of wetlands on a landscape is known to impact local and regional climates through enhanced humidification and cooling of the atmosphere, and increased albedo (Bonan 1995) (Krinner, 2003) (Yunlong, et al. 2011) (Liu, Sheng and Liu 2015) (Kurz, et al. 2013). The Canadian Prairie ecozone has seen extensive historical wetland losses, and conversion is ongoing. The Canadian prairies are predicted to experience some of the most significant warming as a result of climate change, and are particularly susceptible to future drought events (Lemmen and Warren 2004) (Warren and Lemmen 2014). The Prairies ecozone is an important resource to the Canadian agricultural sector, accounting for 62% of Canada's total farm area, and is the most heavily farmed ecozone in the country (Statistics Canada 2014). Agriculture and agri-food sectors accounted for 6.4% of Canada's GDP in 2010, and 12.1% of total employment (Statistics Canada 2014). It follows that any adverse impacts on the Prairie ecozone as a result of climate change will likely have important socio-economic impacts.

Pressures on boreal wetlands are also increasing as a result of industrial development and rural land use opportunities. Meanwhile, the frequency of extreme weather events is predicted to increase while increases in temperature and altered precipitation regimes will likely reduce the resiliency of wetland ecosystems to these changes. Natural disturbances such as wildfires are also expected to increase with resultant GHG emissions from lost carbon stores; an important climate feedback mechanism (Price, et al. 2013). Functional peatlands with a well-maintained water table can act as a natural firebreak and inhibit wildfire frequency, intensity and deep burning (Waddington, Thompson, et al. 2012). The presence of functional peatlands on the boreal landscape can therefore not only reduce GHG emissions from wetland and upland ecosystem caused by natural disturbances, but can limit the impacts of natural disturbances (flooding and wildfires) on human infrastructure.

Alberta's wetlands are an important and cost-effective tool to mitigate and adapt to a changing climate, and may exhibit multiplier effects when considering the economic value of local and regional climate mitigation to the Canadian economy. Further losses to Alberta's wetlands will not only impact the province's GHG emissions and carbon sequestration capacity, but will also reduce its ability to adapt to a changing climate.

9.2 Flood and Drought Alleviation

It is well known that wetlands and grasslands are an efficient means of providing the regulation of water quantity (Zedler 2003). Changes to precipitation patterns are being observed on a global scale, and the frequency of extreme precipitation and drought events is predicted to increase in a changing climate (Warren and Lemmen 2014).

By regulating the flow of water, increasing infiltration and groundwater recharge, lowering peak flow, and reducing erosion, wetlands and grasslands can reduce the risks and impacts of flood and drought events in a changing climate. In particular, wetlands associated with the Western boreal forest are considered an important "safety net" when droughts are limiting prairie habitat (PHJV 2014). Peatlands in particular are key systems for storing moisture during drought periods, maintaining forest health (with important economic implications for managed forests) and important in predicting wildfire impacts (Thompson and Waddington 2013). The conservation of the Western boreal forest and the regulating role they play in water budgets over vast scales, will depend on large scale systematic conservation planning that considers climate change impacts (Stralberg, et al. 2015). Many reports have been written on the clear benefits of all wetland types to flood and drought alleviation in Alberta, including the DUC report on "Wetland Conservation and Restoration as Flood Mitigation Tools in the Bow River Basin" which outlined potential solutions to flood risks in the province (DUC 2014).

9.3 Water Quality

While effective upland nutrient management is essential to avoiding nutrient loading to watercourses, the presence of wetlands and grasslands on the landscape reduces erosion and provides a buffer between areas of nutrient application and watercourses susceptible to nutrient loading (Zhu, et al. 2015). Additionally, mobilisation of other pollutants such as heavy metals and oils is reduced with effective upland management and grassland presence on the landscape. Wetland ecosystems can sequester excess nutrients and pollutants, reducing impacts on the wider environment (Davidson, et al. 2015).

The water quality improvement attributes of wetlands are arguably one of the most important and economically valuable benefits wetlands can provide. In the absence of this ecosystem service, stakeholders may be required to pay for additional water treatment, or may be unable to use downstream water resources due to contamination. Planners are becoming increasingly aware of the potential for green infrastructure to provide cost-effective ecosystem services, and the use of wetlands and effective upland management are now common practice to improve water quality.

9.4 Biodiversity

Wetlands and grasslands provide important habitat for numerous biota, both resident and transitory. Temperate grasslands represent one of earth's major biomes and are one of the most imperilled ecosystems on the planet (Hoekstra, et al. 2005) (Henwood, An overview of protected areas in the temperate grasslands biome. 1998), while wetlands are known to be second only to rainforests in terms of biodiversity richness. Most species of Canadian wildlife rely on wetlands and grasslands during at least some portion of their lifecycle. These ecosystems provide important habitat for species of interest to naturalists, tourists, scientists and hunters. Many species protected under the *Species At Risk Act* (*SARA*) are threatened by the loss of Alberta's wetlands and grasslands upon which they depend, including endangered species: Whooping Crane, Piping Plover, Burrowing Owl, Swift Fox and Sage Grouse (Government of Canada 2017). PPFWMSWs and grasslands in the prairie pothole region are important for a number of migratory species and wildfowl. Assessment of individual sites for development may not capture the importance of losses on a landscape scale, particularly when species are not resident.

Nearly 50% of Canada's Western Boreal Forest is considered waterfowl habitat and is used by millions of ducks annually (Prairie Habitat Joint Venture 2014). Wetland associated species are among those most at risk in boreal Alberta including iconic SARA listed species such as Woodland Caribou, Wood Bison, Yellow Rail, Rusty Blackbird, and Olive-sided Flycatcher (Government of Canada 2017). Much of the remaining critical woodland caribou habitat, including the boreal population, is located in the boreal region. The boreal population is particularly reliant on various mineral-based wetlands and peatland habitats, and have suffered population declines due to habitat loss, degradation and fragmentation (Government of Canada 2012).

Wetlands in boreal, prairie and parkland regions are an important ecological resource providing critical habitat for at risk species. The biodiversity associated with Alberta's wetlands and perennial grasslands also impacts additional ecosystem services valued by society. Pollination is a good example of such a service which is enabled and enhanced through the presence of a variety of natural habitats on the landscape. Pollinator species are known to decline with increased distance to natural or semi-natural habitats from agricultural areas (Kumar 2011). Increases in natural pollinator species and numbers reduce the reliance of agricultural producers on commercial bee imports, increase local resilience at a time when commercial bee colonies are under threat, improve and maintain crop yields, provide pollination of non-agricultural plants and are a food source for other species of interest (Raudsepp-Hearne, Claesson and Kerr 2011) (National Research Council 2007).

9.5 Socio-economic

Wetlands and grasslands are an integral component of Alberta's landscape. Each add economic and cultural value and diversity to Alberta. It is difficult to comprehensively calculate a financial value for the educational, recreational, spiritual and tourism services provided by these ecosystems, but it is clear that the socio-economic value is significant.

In a survey of stakeholders carried out by the GOA (2011), the cultural services provided by wetlands, including aesthetic enjoyment and science and education opportunities, were ranked as high priorities for management. The same study estimated the potential recreational value of wetlands associated with the Ralph Klein Park and Inglewood Bird Sanctuary (Calgary) at $4,390,000 per year, based only on the recreational opportunities for birding. Boreal wetlands provide additional economic benefits through the peat extraction industry, sales from which have been valued at approximately $69 million in 2013 (Kienlen 2013).

Similarly, Alberta's grasslands are important for both recreational opportunities (e.g. camping, wildlife watching and hunting), spiritual and aesthetic values, and economic opportunities (e.g. ranching and forage harvesting). When sustainably managed, grasslands can provide both socio-economic (agricultural) and ecosystem service benefits described throughout this section.

The cultural value of grassland and wetland environments to First Nations communities, in terms of food and medicine provisioning, and traditional practices (hunting, trapping, fishing, harvesting etc.), cannot be easily assessed financially. However, retention of these environments will also preserve the traditional knowledge and heritage of the First Nations and indigenous communities, and further improve our scientific understanding and cultural diversity.

Opportunities for research and education are key to developing our knowledge of how wetlands and grasslands provide critical ecosystem services, and to inspire scientific advances. Other socio-economic values such as heritage and aesthetics are even more difficult to assess financially, but are given high-value by local stakeholders, mirrored by increased property prices with proximity to wetland areas (Raudsepp-Hearne, Claesson and Kerr 2011).

10.0 Links with Provincial and Federal Priorities

The *Pan Canadian Framework* details how Canada aims to reach GHG emission reduction targets and build resilience and adaptation to climate change (Government of Canada 2017). Ecosystem conservation and restoration have been identified as key components to achieving these targets, particularly through natural/green infrastructure investments. The federal and provincial regulations, policies, and funding schemes outlined in this section confirm regional and national commitment to achieving climate change goals under the *Pan Canadian Framework*.

10.1 Transition to a Low-Carbon Economy

A key focus of federal and provincial governments is transitioning Canada and Alberta to a low-carbon economy. Motives behind such a transition are numerous including international obligations, building economic resiliency, and improving competitiveness of Canadian products on global markets. In particular Canadian and Albertan oil and gas, forestry and agricultural industries are coming under increasing socio-environmental scrutiny. In the past, conversion of natural ecosystems was subsidised. While policy focus has changed substantially, education on legal issues and the many benefits provided by functional wetlands and grasslands is needed to enhance retention of these ecosystems and reduce GHG emissions associated with conversion.

> "*The emerging low-emission economy is creating new challenges and opportunities. As a significant supplier of biobased products, the agriculture and forest sectors are positioned to capitalize on a competitive advantage, supported by Alberta's unique scientific and research capabilities and biomass availability*." (Alberta Agriculture and Forestry 2016)

Halting wetland and grassland ecosystem conversion, and restoring historical losses, aligns with the government's goal of transitioning towards a low-carbon economy by reducing GHG emissions associated with land use change. Consideration of the carbon management capabilities provided by retained and minimised impacts to wetland and grassland ecosystems will also improve the public image of Alberta's key industries, and enhance the competitive advantage of Alberta-produced products in an increasingly environmentally conscious marketplace. Economic and environmental resiliency to climate change would also be improved through the provision of ecosystem services.

10.2 Federal Green Infrastructure Fund

The Pan Canadian Framework on Clean Growth and Climate Change states that, “living natural infrastructure (e.g. constructed/managed wetlands and urban forests) can build the resilience of communities and ecosystems and deliver additional benefits, such as carbon storage and health benefits”. This “green infrastructure” is central to both carbon management and climate change adaptation. Recognising the importance of natural/green infrastructure investments in meeting greenhouse gas emission reduction targets and in providing climate change resiliency, the federal government announced significant investments in natural/green infrastructure in the 2017 national budget for Canada (Government of Canada 2017).

The national Green Infrastructure Fund aims to support GHG emission reductions, enable climate change adaptation and resilience, and ensure the provision of clean air and safe drinking water, through investments in green infrastructure (Government of Canada 2017). The retention and restoration of wetlands and grasslands aligns with each of these aims in a cost-effective manner, through providing an effective carbon sink, improving water quality and reducing treatment costs, and providing resiliency to the predicted impacts of climate change in terms of flood and drought alleviation and influences on local climate. For these reasons, wetland and grassland retention and restoration projects could be included as a key activity in phase two of the Green Infrastructure Fund.

10.3 The Next Agricultural Policy Framework

While still under development, the next Agricultural Policy Framework (APF) is expected to align with both carbon management and climate adaptation benefits provided by wetland and grassland retention and restoration (Government of Canada 2016). The APF will assess priorities for programs and funding within the agricultural sector.

Environmental sustainability and climate change is a key priority area of the APF. The impacts of reducing greenhouse gas emissions, and adapting to a changing climate, including extreme weather events, water availability and quality, soil health and pest and disease outbreaks to productivity and economic growth are all recognised. Wetland and grassland retention and restoration activities can achieve these aims through providing flood/drought alleviation, reducing soil erosion, improving water quality, and enhancing biodiversity in agricultural areas.

Risk management is another key priority area which includes risks posed as a result of extreme weather events (flood and drought). The policy is likely to promote proactive strategies to prevent and mitigate risks. The strategic retention and restoration of wetland and grassland habitats on a landscape scale can help alleviate risks to agricultural producers to ensure growth and stability in one of Canada's largest economic pillars.

10.4 Aichi Conservation Targets

Canada has committed to a number of biodiversity targets under the UN Aichi Biodiversity Targets (CBD Secretariat 2017). The retention and restoration of wetland and grassland ecosystems is essential to achieving Canada's targets by 2020, in particular:

- to protect "*at least 17% of terrestrial areas and inland water … through networks of protected areas and other effective area-based conservation measures*."
- "*wetlands are conserved or enhanced to sustain their ecosystem services through retention, restoration and management activities*."

Protected areas should be representative of all ecologically important systems. To date larger wildlife/natural areas and parks have made the majority of protected areas towards achieving Aichi conservation targets, and, excluding the Foothills and Rocky Mountain regions, protected areas in Alberta in particular appear to be sparse compared to other provinces and territories. An opportunity therefore exists to align the retention and restoration of wetland and grassland ecosystems in contributing to the achievement of national biodiversity targets under the UN Convention on Biodiversity.

10.5 Provincial Land Use Framework

The Provincial *Land Use Framework* (LUF), enabled through the Alberta Land Stewardship Act (ALSA) outlines three main outcomes (Government of Alberta 2008):

1. A healthy economy supported by land and natural resources.
2. Healthy ecosystems and environment.
3. People-friendly communities with ample recreational and cultural opportunities.

The retention and restoration of wetlands and grasslands can achieve each of the desired outcomes of the LUF. For example, the capacity for grasslands and wetlands to improve water quality and sequester excess nutrients reduces water treatment costs, improves aquatic habitat and biodiversity, and allows for recreational activities in downstream waterways that may otherwise be limited due to water quality concerns. This is only a single example of the potential of these management activities to optimise natural resources to support multiple and broad benefits.

Sustainability is a key guiding principle of the LUF which aims to balance economic, environmental and social benefits for future generations. The carbon sequestration potential of retention and restoration of grasslands and wetlands is a significant inter-generational benefit, despite longer radiative switchover times associated with restoration. Retention of existing landscapes, and restoration of historically lost landscapes aligns with the outcomes of the LUF by providing an important carbon sink for the benefit and sustainability of present and future generations.

Several Conservation and Stewardship Tools have been developed to achieve the outcomes of the LUF, enabled through ALSA:

- Conservation Easements – Voluntary legal agreement between a landowner and a qualified organisation to enhance and protect ecologically significant areas in perpetuity. The legal agreement means that retained and restored wetlands and grasslands on lands under a conservation easement are retained in perpetuity along with carbon management, climate adaptation and other ecosystem services, while allowing certain land use activities, such as sustainable grazing, to continue.
- Conservation Directives – Areas of ecologically significant land specified for protection in Regional Plans (see *10.6 Regional Plans – Regional Environmental Management Frameworks and Biodiversity Management Frameworks* below). Precise details regarding the reasons and purpose of the directive are outlined in the Regional Plan. Land owners receive compensation for any loss in land value incurred as a result of the directive. Conservation Directives could be used to implement wetland and grassland conservation objectives in alignment with Regional Plans.
- Conservation Offsets – Enables industry to offset adverse impacts of their activities through the conservation of other areas. Work is underway to develop an offset tool for the buying and selling of conservation offsets. In particular conservation offsets could be a significant tool to offset expected developments in the boreal region, but should consider the needs and requirements of all stakeholders including local indigenous communities that are directly affected.
- Transfer of Development Credits – Allows both conservation of a specific area while offering incentives for relocating development activities. This allows municipalities and the provincial government to designate wetlands and grasslands at risk of development as conservation areas to align with Regional Plans and the outcomes of the LUF.

10.6 Regional Plans – Regional Environmental Management Frameworks and Biodiversity Management Frameworks

Regional Environmental Management Frameworks (REMFs) mirror the broad aims set out in the LUF, and provide more region-specific objectives and context for management of cumulative impacts of development. To date, *Regional Plans* for the South Saskatchewan (SSRP) and Lower Athabasca regions have been fully developed.

Biodiversity management frameworks (BMFs) are a key component of the REMFs which outline key indicators and triggers for enhanced management requirements. To date the South Saskatchewan Region (SSR) is the only region to have developed a BMF (Government of Alberta 2017). Objectives of the SSR BMF include:

- *"Terrestrial and aquatic biodiversity are maintained;*
- *Long-term ecosystem health and resiliency is maintained;*
- *Species at risk are recovered and no new species at risk are designated;*
- *Intact grasslands habitat is sustained; and*
- *Biodiversity and healthy, functioning ecosystems continue to provide a range of benefits to communities in the region and all Albertans, and there is sustainable use of Alberta's biodiversity resources."*

Recognising historical losses of wetlands and associated ecosystem services in the region, the SSRP REMF has outlined the intention to put in place wetland objectives as a proactive management measure, to ensure that wetlands are retained and restored on the landscape. This is a key development in the management of wetlands which has often taken a reactive approach.

Cumulative effects management and conservation of grasslands are described as two of the key biodiversity concerns in the SSRP; grassland and aquatic native cover, including ephemeral wetlands, are key triggers for enhanced environmental management. The retention and restoration of wetlands and grasslands will assist the achievement of each of the objectives in the SSRP and maintain the biodiversity of the region along with the many other co-benefits discussed within this report.

The nutrient, pesticide and metal sequestration functions facilitated through the retention and restoration of wetland and grassland ecosystems also align with the aims of the *Surface Water Quality Management Frameworks*. To date *Surface Water Quality Management Frameworks* have only been developed for the South Saskatchewan and Lower Athabasca regions (Alberta Government 2014).

10.7 Flood/Drought Management

The WRRP is an incentive-based program developed in response to the June 2013 flooding in southern Alberta, and aims to preserve and increase the natural ability of the province's watersheds to reduce the effects of flooding and drought events (Government of Alberta 2017). The program realises the ability and economic value of using 'non-structural' or 'green infrastructure' in long-term flood and drought alleviation. The program provides a direct example of how stakeholder engagement was key to exposing the benefits of natural/green infrastructure investments as tangible, cost-effective solutions to provincial priorities (DUC 2014).

The south of the province, in particular, has seen significant historical wetland losses, and it is thought that regional-scale losses contributed to the June 2013 floods and other flood and drought events in the area. The majority of the Prairie and Parkland regions within Alberta are classed as high priority areas for funding under the program to preserve, manage and improve drought and flood resiliency, and water quality. Wetland preservation and restoration projects, in conjunction with education on effective stewardship of wetlands, are key instruments to achieving the desired outcomes of the WRRP in priority areas.

The AWEP is an incentive-based program which aims to achieve wetland restoration within the White Zone by incenting agricultural producers to undertake restoration projects to improve water quality. Substantial uptake of the AWEP and consequent depletion of funding has led to the joining of AWEP and WRRP funding. While the uptake of wetland restoration projects under the AWEP is encouraging and shows the interest of stakeholders to develop these projects, it is clear another funding stream would allow more of these projects to be undertaken, to align with carbon management and climate adaptation priorities.

While the WRRP and AWEP do not consider project impacts on carbon management, the programs provide a template for the development of a similar, long-term, incentive-based program aimed at wetland and grassland retention and restoration as tools for carbon management and climate adaptation.

10.8 Caribou Recovery Strategy

Caribou are an iconic species listed as threatened under the Species At Risk Act (SARA) that rely heavily on wetland habitat, particularly in the boreal region. Alberta's Caribou policy, "A Woodland Caribou Policy for Alberta", describes the need for the GOA to work in partnership with the private sector and stakeholders to retain and restore critical habitat.

A conservation offset for caribou habitat is also being developed. Depending on implementation, the restoration of functionally impacted boreal wetland ecosystems, and offsetting of physical wetland losses will align well with the creation of caribou habitat and carbon management and climate adaptation priorities. However, consideration of retention and minimisation of functional and physical wetland losses will also be important in the development of an effective program that aligns with carbon management and climate adaptation priorities.

There is significant potential here to achieve multiple wins in the retention of boreal wetlands and restoration of functionally impacted wetlands within critical caribou ranges.

10.9 First Nations and Indigenous Groups

"*Integrated environmental policy encourages the adoption of beneficial management practices for sustainable resource development and enhances stewardship of traditional lands.*" (Alberta Agriculture and Forestry 2016)

Consideration of First Nations and other indigenous groups in land use planning, and the value placed on natural lands to hunt, trap and fish, as well as culturally significant sites providing an abundance of ecosystem services and life systems, including carbon management and climate adaptation. All stakeholders will need to work together to develop policies and programmes that incentivise wetland and grassland retention and restoration to benefit all Albertans.

10.10 Social License/Sustainability

The province of Alberta is increasingly coming under pressure from international, national and local stakeholders, particularly with respect to the environmental impacts of some of its main industries, including manufacturing, energy, forestry, agriculture, and food. Negative impacts on Alberta's image can impact the province's economy. It is a key priority of the GOA to maintain and improve Alberta's economic competitiveness through enhancing the social license and sustainability and resiliency of the province's industries and products (Leach, et al. 2016). GOA Ministries have been working with industry sustainability roundtables as well as developing social license strategies to ensure beneficial practices and approaches towards environmental stewardship and sustainability.

The retention of existing wetlands, the minimisation of impacts to functional capacity, and the retention and restoration of grasslands, provide an opportunity to improve the social license of Alberta's industries, and of the province as a whole. Mobilisation of the substantial carbon sequestration potential associated with wetland and grassland ecosystems will aid the improvement of Alberta's environmental image and sustainability values. Additionally, restoration and long-term protection of historically lost wetlands could improve the environmental image of Alberta's key industries in markets that are increasingly environmentally competitive.

11.0 Conclusion

Alberta possesses a major natural resource to facilitate local climate change adaptation and reduce provincial GHG emissions. Historical and ongoing physical losses and functional impairments of Alberta's wetlands and grasslands have led to depletion of these resources, along with critical ecosystem services. Continued losses have significant negative impacts on the province's GHG emissions which cannot be easily replaced or offset by other means. To preserve the natural advantage that Alberta has, expanded incentives are recommended to support the retention of remaining wetlands and grasslands and their sustainable and effective management to maintain the significant carbon stores within, alongside other ecosystem services. This will help to ensure a holistic approach to addressing climate change, with the expansion of the suite of existing conservation tools.

Restoration activities are important to restore historically lost carbon management capacity for future generations, and to limit the impacts of a changing Alberta climate, through flood and drought management, wildfire risk reduction, ambient climate mitigation, and ecological resiliency. The presence of wetlands and grasslands on the Alberta landscape also have important social and economic implications for the agricultural industry's resilience to climate change, as well as through the ecosystem services they provide in regulating water quality, tourism, and biodiversity preservation.

Wetlands and grasslands provide carbon management and many additional benefits to society at a very cost-effective rate. Considering the carbon management attributes of retained ecosystems alone provides a strong case for their inclusion in the Alberta *Climate Leadership Plan* as an essential carbon management tool, despite the value of climate adaptation and other ecosystem services. Conversely, continued losses, whether approved or not, are likely to have a detrimental impact on the good progress being made in other areas towards a low carbon economy for Alberta.

There is an opportunity to highlight and align wetland and grassland retention within existing conservation tools and in addition minimize functional impacts where development cannot be avoided as a last resort. Restoration activities can also be prioritised to recoup historically lost ecosystem services, increase resiliency in a changing climate, and provide a legacy carbon management tool for future generations. There are a number of ways this could be achieved through improved planning tools, education, regulatory approaches, and incentives. Recognising the long-term carbon management value of these activities could release funds from federal and provincial green infrastructure funds and private investors. As land-based biological offsets become more prominent, the GOA could look again to implement an Alberta-based offset protocol for avoided ecosystem conversion, or inclusion of GHG emissions incurred by ecosystem conversion in existing protocols, to retain offsets within the Alberta carbon market and decrease Canada's reliance on globally-sourced offset credits.

12.0 Recommendations

To achieve the greatest benefits in terms of carbon management, the retention of wetlands, and retention and restoration of perennial grasslands are key. Wetland and grassland losses constitute both a loss in carbon sequestration capacity and emitted GHGs. To gain the highest benefit, wetland and grassland restoration activities need to be thought of in the long term; to provide carbon management tools for future generations, long-term landscape resiliency to climate change, and achievement of Alberta and

Canada's climate goals. To realise these aims, the following strategies could be considered, and are explored further in the complementary Implementation Roadmap report:

- Inclusion of wetlands and grasslands as a cost-effective and key carbon management and climate adaptation tool in the suite of measures described in the Alberta *Climate Leadership Plan*.
- Leverage of federal and provincial funds aligned with GHG emission reduction, climate adaptation and green infrastructure development to incentivise wetland and grassland retention and restoration programs and strategies. Examples include the development of disaster risk mitigation strategies that utilise green infrastructure, and implementation of best practices and sustainable land use to minimise impacts and functional losses, particularly in the boreal region.
- Utilisation of regulatory tools and incentive-based programs to prevent ecosystem losses while addressing the real economic cost of practice change on high value lands.
- Inclusion of GHG emissions accounting from converted and functionally impacted ecosystems, and the carbon sequestration and storage of retained ecosystems, in the Alberta's carbon policies and plans. This could be achieved through the development of protocols to support avoided conversion of wetlands and grasslands using examples from other jurisdictions, or inclusion of GHGs emitted as a result of ecosystem conversion as a quantifiable source in existing carbon offset protocols.
- Proactive management of ecosystems through the development of measurable wetland and grassland objectives and tools in *Regional Plans*, as part of the *Land Use Framework*.
- Development of a provincial monitoring system to measure wetland and grassland presence on the landscape and to better direct resources for regulatory approaches, incentive-based programs and education.
- Look to private investors to invest in the carbon management resources available in Alberta's green infrastructure assets as a way to improve public image and economic resiliency.

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Appendix 1: GHG emissions and Cost Benefit Calculations

NOTE: due to rounding, performing the calculations as given below may not return exact results shown.

NOTE: GHG emissions from the loss of SOC stores are estimated at 326tCO_2e/ha for FWMSWs (including boreal, prairie and parkland regions), 10tCO_2e/ha for perennial grasslands, and 4,118tCO_2e/ha and 4,066 tCO_2e/ha for boreal fens and bogs respectively. The value of carbon stored within these ecosystems is more accurately modelled by taking an average over a longer time period due to the potential for future loss of stored carbon (due to anthropogenic or natural factors). In the calculations below, the value of SOC stores are averaged over a 100-year period (consistent with global warming potentials), whereas costs of GHG emissions due to annual ecosystem losses are taken as absolute values.

Table 11: Emissions data for Ecosystem conversion

Data Point		PPFWMSWs and Boreal FWMSWs	Perennial Grasslands	Boreal Peatlands	Boreal FWMSWs
Net Sequestration Rate (tCO_2e/ha/yr.)		3.30*	0.70 (Wang, VandenBygaart and McConkey 2014)	1.10 (Mitsch, Bernal, et al. 2013)	0.59**
Initial GHG emissions due to conversion (tCO_2e/ha)		326 (Badiou, et al. 2011)	10 (Wang, VandenBygaart and McConkey 2014)	Fen: 4,118 Bog: 4,066 (Tarnocai, Kettles and Lacelle 2011)	326 (Badiou, et al. 2011)
Biological carbon stored, 100-year average* (tCO_2e/ha/yr)**		3.26	0.1	Fen: 41.18 Bog: 40.66	3.26
Net cropping emissions in Dry Prairie (tCO_2e/ha/yr.)******		0.51 (Government of Alberta 2013)	0.51 (Government of Alberta 2013)	NA	NA
Net cropping emissions in Parkland (tCO_2e/ha/yr.)******		1.23 (Government of Alberta 2013)	1.23 (Government of Alberta 2013)	NA	NA
Carbon management in retained ecosystems (tCO_2e/ha/yr)	Dry Prairie	7.07	1.31	NA	NA
	Parkland	7.79	2.03	NA	NA

NOTE: Dry Prairie and Parkland figures are given separately due to variations in cropping emissions; annual ecosystem losses in each ecoregion are unavailable. The data above **should not be interpreted as total ecosystem losses, but rather as a range** of the potential GHG emissions due to ecosystem losses.

*PPFWMSW sequestration rate was calculated by inputting DUC data on restored Prairie wetlands to the Neubauer (2014) model and taking the constant sequestration rate at 250 years post-restoration.

** Due to a lack of data on boreal FWMSW sequestration rate, this figure was estimated as the mid-point between boreal peatlands and PPFWMSWs. It is expected that boreal FWMSWs are less productive and therefore exhibit a lower sequestration rate than PPFWMSWs due to boreal climatic conditions, but are more productive than peatland systems.

***All mineralised carbon was assumed to be emitted as CO_2 to remain conservative

**** Emissions due to cropping practices are based on data from the draft protocol “Conversion of Annual Cropland to Perennials” (Government of Alberta 2013) and uses data for the no-till, continuous cropping of Spring Wheat, including soil carbon sequestration, and emissions associated with fertiliser production and distribution.

Cost Calculations

Costs of retention were estimated from DUC programs that are expected to exist in perpetuity due to the placement of conservation easements: the Conservation Easement Program, and Revolving Land Conservation Program. On average, one hectare of land costs $1850 under these programs, and protects both wetland and upland features. It was therefore assumed that costs for retention were $1850/ha for PPFWMSWs and $1850/ha for perennial grasslands. Since these programs are expected to retain these ecosystems in perpetuity, costs were averaged over a 100-year period, ($18.50/ha/yr.). These costs were applied to avoided GHG emissions and sequestration rates (see Table 11) to obtain a price per tonne CO_2e due to retention of these ecosystems in Table 12.

Table 12:Average Cost per tonne CO_2e due to Ecosystem Retention

	Cost of net GHG sequestration **due to retained ecosystems at $18.50/ha/yr. (land costs are averaged over 100-year period) ($/t$CO_2$e)**	**Cost of retention including** retention of SOC stores (100-year average), GHG emissions from Land Use Change, and Carbon Sequestration **at $18.50/ha/yr. (land costs are averaged over 100-year period) $/t$CO_2$e)**
FWMSW – Dry Prairie	5.61	2.62
FWMSW – Parkland	5.61	2.38
Grassland – Dry Prairie	26.43	14.08
Grassland – Parkland	26.43	9.12
Boreal Fens*	16.82	0.44
Boreal Bogs*	16.82	0.44
Boreal FWMSWs*	8.41	3.39

NOTE: Dry Prairie and Parkland figures are given separately due to variations in cropping emissions; annual ecosystem losses in each ecoregion are unavailable. The data above **should not be interpreted as total ecosystem losses, but rather as a range** of the potential GHG emissions due to ecosystem losses.

* Figures for boreal wetlands do not include avoided GHG emissions from land use change since land use changes and physical losses are too varied to deduce an appropriate average land use change. Vast SOC stores in these ecosystems drive down the cost of retention, showing the value of these ecosystems as carbon stores.

Sequestration capacity of current ecosystems in Alberta

The predicted carbon price to 2030 was applied from Sawyer et al. (2017), using a carbon price floor of $50/tCO_2e in 2022, rising to $100/tCO_2e in 2030 (Table 13).

Table 13: Predicted Price of Carbon to 2030 Calculated from Sawyer & Bataille (2017)

Year	Assumed Price of Carbon
2018	30
2019	30
2020	30
2021	40
2022	50
2023	56
2024	63
2025	69
2026	75
2027	81
2028	88
2029	94
2030	100

Average sequestration rates for each ecosystem were applied (see Table 11) to the predicted prices of carbon from Sawyer & Bataille (2017) in Table 13 above. Output data are given below in Table 14.

Table 14: Value of Existing PPFWMSWs, Boreal Wetlands and Perennial Grasslands in Alberta, as Carbon Sinks

	PPFWMSW	Boreal Wetlands		Perennial Grassland
		Peatlands	FWMSWs	
Estimated Remaining Area in Alberta (Hectares)	1,326,000 (Prairie Habitat Joint Venture 2014)	8,592,000 (Smith, et al. 2007)	6,731,000 (Smith, et al. 2007)	7,000,000 (Bremer 2008)
Net carbon sequestration capacity in Alberta (tCO_2e/yr.)	4,376,000	9,451,000	14,808,000	4,900,000
Cumulative financial value of carbon sequestration to 2030*	$3.5 billion (average $271 million/yr.)	$7.6 billion (average $585 million/yr.)	$11.9 billion (average $916 million/yr.)	$3.9 billion (average $303 million/yr.)

* (US Environmental Protection Agency 2016)

Ongoing Losses

Annual PPFWMSW losses were estimated using data from the Prairie Habitat Joint Venture Implementation Plan 2013-2020: The Prairie Parklands (PHJV 2014). The report gives an average annual loss rate of approximately 2,825 acres (1,143 hectares) between 2001-2011 in Alberta. It is assumed there have been some reductions in annual loss rates since the implementation of the *Alberta Wetland Policy*, an estimated annual loss rate of 1,000 hectares was assumed in this analysis. It should also be noted that these figures are based on a small sample area and therefore include uncertainty, but that these are the best available data at the time of writing.

Annual loss of perennial grassland area is estimated from an annual loss rate of 0.75% from Gage et al. (Gage, Olimb and Nelson 2016) and a total estimated area of 7 million hectares of temperate grasslands in Alberta from Bremer (Bremer 2008). To estimate the value of lost carbon sequestration and GHG emissions associated with conversion to cropland, the predicted carbon price to 2030 was applied from Sawyer et al. (2017), using a carbon price floor of \$50/tCO_2e in 2022, rising to \$100/tCO_2e in 2030 (Table 13).

Table 15: Average Costs of Carbon Associated with Ongoing Ecosystem Loss

	PPFWMSW – Dry Prairie	PPFWMSW – Parkland	Boreal FWMSWs	Boreal Peatlands	Perennial Grasslands – Dry Prairie	Perennial Grasslands – Parkland
Annual Losses (ha)	1,000	1,000	10,300	8,500	52,500	52,500
Lost Carbon Sequestration due to annual losses (tCO_2e/yr.)	3,300	3,300	22,700	9,300	36,750	36,750
Average annual value of lost sequestration due to ecosystem losses to 2030	$204,300/yr.	$204,300/yr.	$1,407,600/yr.	$576,000/yr.	$2,276,000/yr.	$2,276,000/yr.
GHG emissions due to annual losses of SOC stores (tCO_2e/yr.)	326,000	326,000	3,368,000	34,684,000	525,000	525,000
Average annual value of GHG emissions from SOC loss due to ecosystem losses to 2030	$20.2 million/yr.	$20.2 million/yr.	$208.6 million/yr.	$2.148 billion/yr.	$32.5 million/yr.	$32.5 million/yr.
GHG emissions from land use change due to annual losses (tCO_2e/yr.)	514	1,228	NA	NA	26,985	64,470
Average annual cost of GHG emissions from land use change due to ecosystem losses	$32,000/yr.	$76,000/yr.	NA	NA	$1.7 million/yr.	$4.0 million/yr.

NOTE: Dry Prairie and Parkland figures are given separately due to variations in cropping emissions; annual ecosystem losses in each ecoregion are unavailable. The data above **should not be interpreted as total ecosystem losses, but rather as a range** of the potential GHG emissions due to ecosystem losses.

Wind Electricity Generation and Annual Ecosystem Losses

Table 16: Input Data for Wind-Generated Electricity

Input Variable	Value
Emission reduction factor due to wind-generated electricity supplied to the Alberta electricity grid (tCO_2e/MWh)	0.59 (Environment and Sustainable Resource Development 2015)
Estimated cost of wind-generated electricity ($/MWh)	80 (AESO 2016)
Wind capacity factor in Alberta	0.35 (AESO 2017)
Cost per tonne CO_2e offset by wind electricity ($/$tCO_2e$)	136

Table 17: Additional Wind-Generated Electricity Capacity Required to Offset Ongoing Ecosystem Losses in Alberta

	PPFWMSW - Dry Prairie	PPFWMSW - Parkland	Grassland - Dry Prairie	Grassland - Parkland	Boreal FWMSWs	Boreal Peatlands
Annually Lost Sequestration Capacity (tCO2e/yr.)	3,300	3,300	36,750	36,750	22,700	9,300
Annual GHG Emissions due to SOC store loss (tCO_2e/yr.)	326,000	326,000	525,000	525,000	3,368,000	34,684,00
Additional GHG emissions due to Annual Land Use Change (tCO_2e/yr.)	514	1,228	26,985	64,470	NA	NA
MWh required to offset lost sequestration (MWh/yr.)	5,600	5,600	62,000	62,000	38,500	15,800
Additional capacity required to offset lost sequestration (MW/yr.)	1.8	1.8	20.3	20.3	12.6	5.1
MWh required to offset GHG emissions from SOC store loss (MWh/yr.)	552,500	552,500	889,800	889,800	5,708,900	58,787,000
Additional capacity required to offset GHG emissions from SOC store loss (MW/yr.)	180	180	290	290	1,900	19,200
MWh required to offset Land Use Change emissions (MWh/yr.)	870	2,000	46,000	109,000	NA	NA
Additional capacity required to offset Land Use Change emissions (MW/yr.)	0.3	0.7	15.0	35.6	NA	NA
Total Cost to offset GHG emissions from SOC store loss, and lost sequestration, by installing wind power ($/yr.)	44,650,000	44,650,000	76,170,000	76,170,000	459,792,000	4,704,218,000
Total Cost to offset GHG emissions, lost sequestration and land use emissions by installing wind power ($/yr.)	44.7 million	44.8 million	80.0 million	85.0 million	460 million	4.70 billion

NOTE: Dry Prairie and Parkland figures are given separately due to variations in cropping emissions; annual ecosystem losses in each ecoregion are unavailable. The data above **should not be interpreted as total ecosystem losses, but rather as a range** of the potential GHG emissions due to ecosystem losses.

*PPFWMSW and perennial grassland loss rates are described above.

**Includes lost sequestration, GHG emissions from ecosystem conversion (loss of SOC) and emissions associated with no-till, continuous cropping of Spring Wheat (see Table 11).