Watershed Management Plan:
Land Management Component

Wetlands Management:
A Review of Policies and Practices

Serving the Battle River and
Sounding Creek watersheds
in Alberta

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Front Cover: Wetland near Ferintosh, AB

Back Cover: Small lake in Miquelon Lake Provincial Park

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Executive Summary

As part of the Battle River Watershed Alliance's dedication to the development of the Watershed Management Plan (WMP), policy research and development will be undertaken for each of the main watershed management components. This report is the background policy research for the wetland component of the WMP.

To develop effective policies and guidelines encouraging compliance on a voluntary basis, knowledge of the policies, guidelines, and monitoring resources that exist as potential support measures is crucial. Policies and guidelines set out by various sectors that affect wetlands on the international to the local level are outlined and discussed. Many policies pertain to beneficial management practices for the agricultural sector, addressing economic drivers of wetland loss, and support for wetland restoration and conservation is paramount.

Currently, most municipalities in the Battle River and Sounding Creek watersheds do not have wetland management plans, polices, or bylaws. Most programs and policies pertaining to wetlands occur at the provincial/state and federal level through several different ministries. The majority of these programs and policies focus on addressing agricultural wetland challenges, with emerging assistance for municipalities.

Some international agencies and governments have developed polices and recommendations regarding wetland management policies, plans, and programs. With a changing climate comes increased uncertainty as well as increasingly extreme weather. Wetlands play an important role in managing water in extreme events by reducing the severity of those events while keeping the health of the landscape. As such, these can be used to create policy recommendations specific to the Battle River and Sounding Creek watersheds.

Wetland management is not a new concept, especially to agricultural producers who manage ongoing challenges. Wetlands offer naturalized solutions to waste and storm water issues in growing urban areas. Selecting regionally appropriate management methods and monitoring effectiveness of those methods through the adaptive management process is the most effective way to promote implementation.

Ongoing education to address differing societal values in relation to wetlands is needed as strategic restoration and conversation efforts continue. From landowners and the public, to government commitments and polices, all need to be held accountable and empowered to ensure wetlands continue as an important part of our watershed.

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AAMDC	Alberta Association of Municipal Districts and Counties
ABWRET-A	Alberta Wetland Rapid Evaluation Tool - Actual
AEP	Alberta Environment and Parks
ALUS	Alternative Land Use Services
AUMA	Alberta Urban Municipalities Association
AWE	Agriculture Watershed Enhancement
BMP	Beneficial management practices
CE	Conservation Easement
DUC	Ducks Unlimited Canada
EPA	United States Environmental Protection Agency
ER	Environmental Reserve
ES	Ecosystem Services
NAWMP	North American Waterfowl Management Plan
PPR	Prairie Pothole Region
WMD	Wetland Management Districts
WPAC	Watershed Planning and Advisory Council
WRRP	Watershed Resiliency and Restoration Program

1 Introduction and Background

1.1 Overview and Purpose of Document

The role of policy is to provide overall strategic direction we want society to go towards. Policies include formal policies, such as government policies or policies from various organizations, as well as informal policies, such as beneficial management practices (BMPs) programs and other forms of governance. The purpose of this report is to highlight the policies, governance approaches, and management approaches that are currently in place locally, regionally, provincially, federally, and internationally that could support and contribute to the development of policy recommendations and action as they pertain to the management of wetlands in the Battle River Watershed Alliance planning area.

Riparian management is a vital component of wetland management. Loss of, and impacts to, riparian areas around wetlands decreases their ability for healthy functioning. The removal of riparian areas reduces in the ability of wetlands to filter, percolate, buffer, and retain water. Riparian areas and vegetated buffers are explicitly discussed only in part within this document. This report is about the management of wetlands as a whole on the landscape. For more information on the management of riparian areas, please see *Understanding the Policy Context for Riparian Areas in the Battle River and Sounding Creek Watersheds* (Bruneau, 2015b) report and accompanying documents.

This report is designed to be read and applied in conjunction with the additional wetland documents, *Wetlands Management: Policy Advice* and *Wetland Management: Implementation Guidelines*.

1.2 Battle River Watershed Alliance

The Battle River Watershed Alliance (BRWA) was created in 2006 as a non-profit society. Under the *Water for Life: Alberta's Strategy for Sustainability*, the BRWA was selected by Alberta Environment and Parks (then Alberta Environment) as the designated Watershed Planning and Advisory Council (WPAC) for the Battle River watershed (Figure 1). The planning area for the Battle River Watershed Alliance begins just west of Highway 2 at Battle Lake, and continues east to the Alberta-Saskatchewan border (Figure 5). The planning area boundary is defined as the portion of the Battle River watershed that lies within Alberta.

The BRWA works in partnership with communities, watershed stewardship groups, four orders of government (first nations, municipal, provincial, federal), industry, non-governmental organizations and residents, to improve the health of the Battle River and Sounding Creek watersheds using the best science and social science available.

The interplay of interests and pressures to and from governments, and the many layers of negotiation involved in instances of policymaking are of interest to the BRWA. Interests and pressure include external influences that exist in all aspects of policymaking and regulation, including those from industry, the four orders of government in Canada, other governments, and public groups of various forms. The BRWA uses a policy community approach (Bruneau, 2015a) to examine the interplay of interests and pressures between actors, and layers of negotiation involved in instances of policymaking (Atkinson & Coleman, 1992; Coleman &d Skogstad, 1990; Skogstad, 2005). In this way, we define policy making as a series of decisions made before, during and after formation of policies.

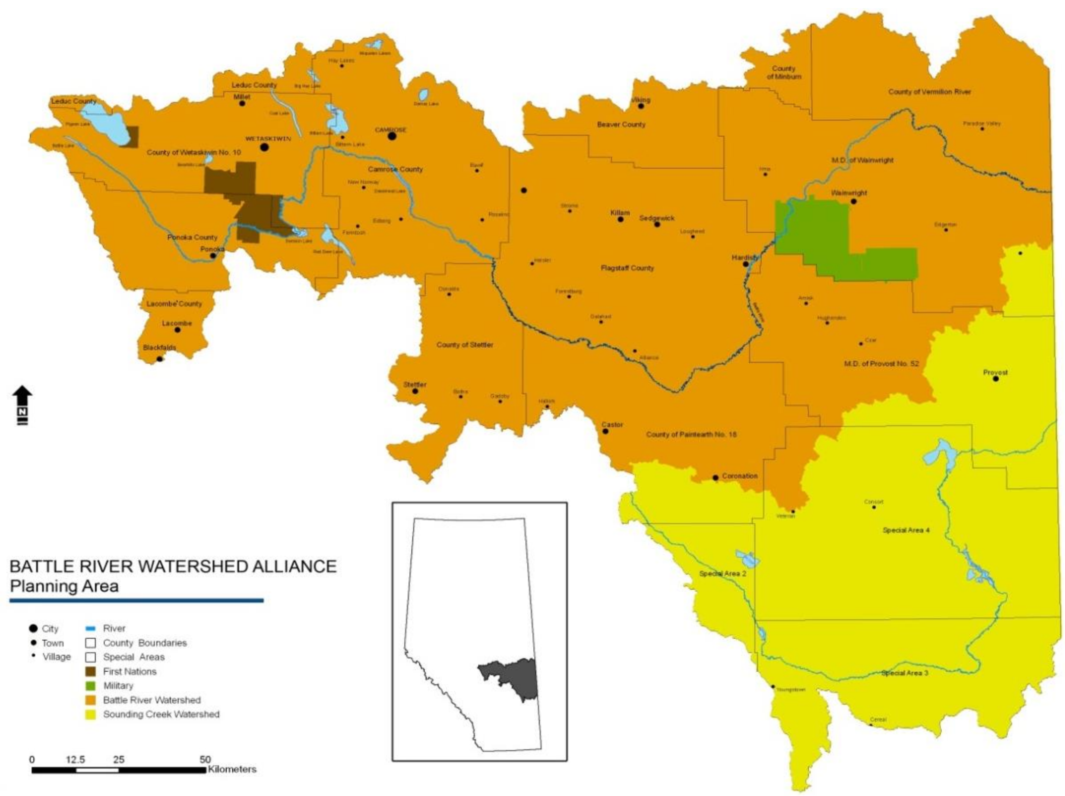


Figure 1. **Counties within the Battle River Watershed Alliance planning area with county boundaries.**

The Watershed Management Plan (BRWA, 2012) is comprised of four general topic areas: water quality, water quantity, land management, and biodiversity. Wetlands is one component under land management, but has implications for all areas (Figure 2).

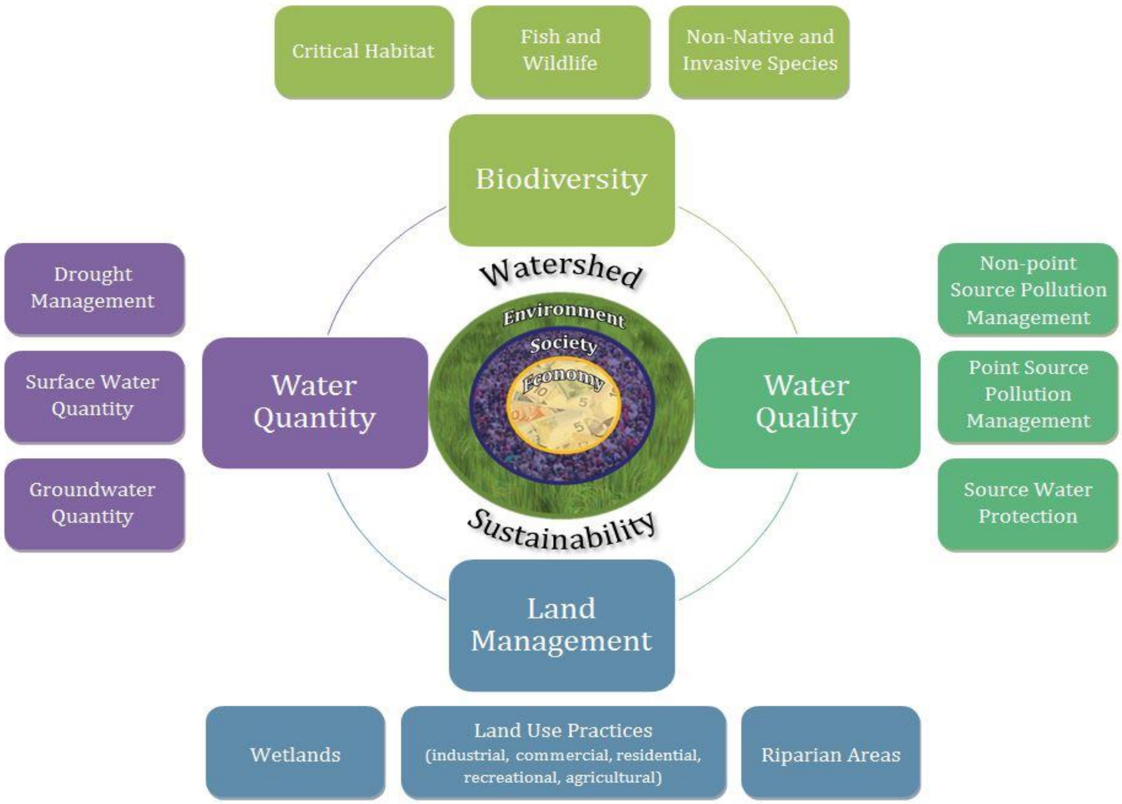


Figure 2. **Framework for watershed management planning components in the Battle River and Sounding Creek watersheds.**

Adaptive management is an approach to natural resource policy that embodies a simple imperative: policies are experiments that, over the course of the adaptive management planning cycle (Figure 3), may prove inappropriate (Lee, 1993). Adaptive management learns from these experiments in a manner that links science with social and economic values found within the watershed (Mitchell, 1997; Sauchyn et al., 2010). By adopting an adaptive management approach for watershed management planning, the BRWA acknowledges that the natural and social systems functioning within the watershed are not completely understood. Both the natural and social systems will, in the course of time, present surprises that will test the adaptive management approach. The BRWA and its partners must approach watershed management planning with the expectation that some policies and actions identified during the planning process may be inappropriate, but that the experiences and lessons learned allow us collectively to improve these watershed management approaches over time. The stages of adaptive management for watershed management planning are described in *Water for Life: Alberta's Strategy for Sustainability* (Government of Alberta, 2003).

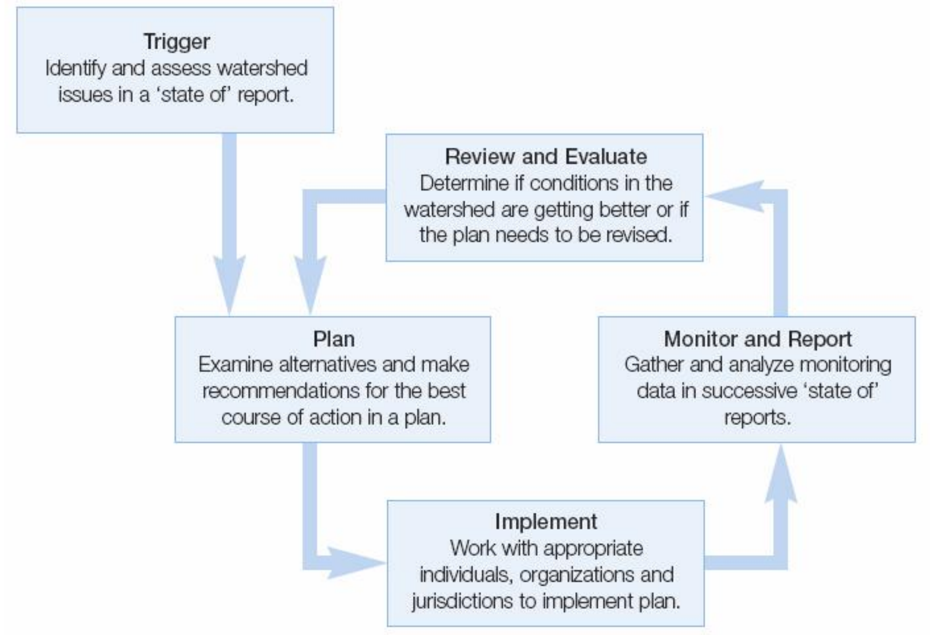


Figure 3. **Adaptive management planning cycle for watershed management planning in the Battle River and Sounding Creek watersheds (Government of Alberta, 2003).**

Adaptive management could be a very useful approach to determining effective wetland conservation and restoration configurations to optimize benefits (Zendler, 2003). Such an approach is important in agricultural watersheds where key land, and thus landowners and managers, would be required to be a part of the restoration, and not just restoration on an *ad hoc* basis.

Policy background research, policy recommendations, and guidelines are developed for each watershed management component for each sub-watershed throughout the watershed management plan development (Figure 4). Policies examined incorporate formal and informal (*ad hoc*) policies, and address economic, social, and environmental impacts of the topic. Examples of short term (i.e. during the current crop year) and longer-term (longer than the current crop year) adaptations are presented by topic area.

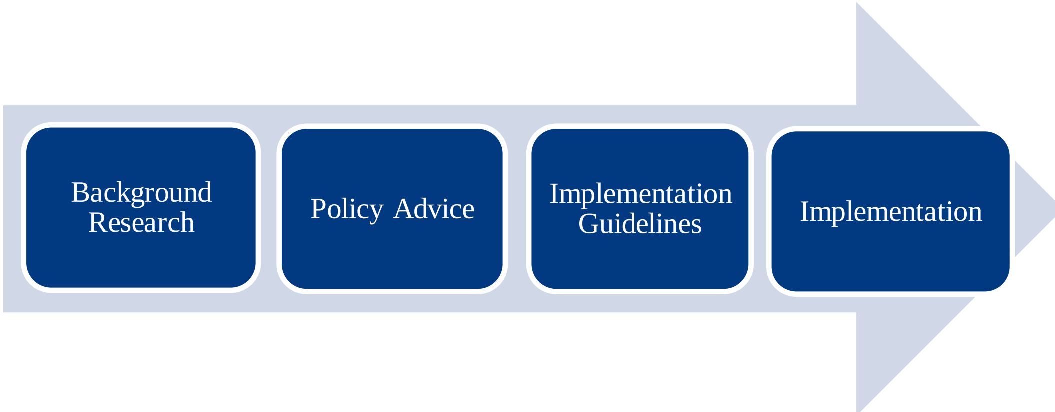


Figure 4. **Policy research and development process.**

The purpose of this report is to explore the policy context within which the management of wetlands occurs in the planning areas of the Battle River Watershed Alliance, and opportunities to learn from other jurisdictions to incorporate into our governance models. From this report, and in accordance with the watershed management plan, the Battle River Watershed Alliance has developed policy advice and implementation guidelines.

1.3 Battle River Watershed

1.3.1 Location of the Battle River watershed.

The Battle River watershed begins at Battle Lake in the west, and moves eastward into Saskatchewan, where the Battle River joins the North Saskatchewan River at Battleford. Topography defines the entire watershed, as it shapes the course and speed of water moving through the area. The boundaries of the watershed are known as drainage divides (i.e. the height of land between adjoining watersheds). Within the Battle River watershed, there are five sub-watersheds: Bigstone, Iron Creek, Paintearth, Blackfoot, and Ribstone. Sounding Creek watershed to the southeast is also part of the BRWA planning area, and incorporates Alberta's Special Areas (Figure 5) (BRWA, 2012).

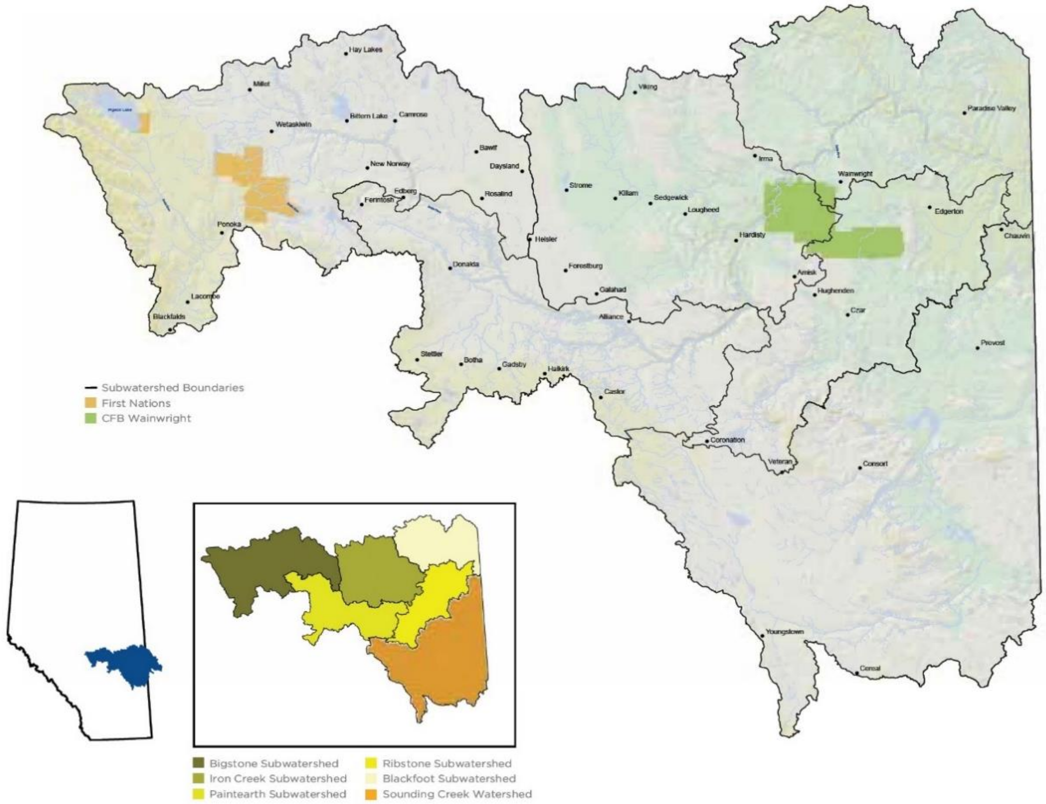


***Figure 5*. Battle River and Sounding Creek watersheds within Alberta.**

1.3.2 Natural landscape of the Battle River Watershed.

The Alberta portion of the Battle River watershed is located entirely within the province's settled "White Zone", and takes in portions of the Lower Foothills, Central Mixedwood, Dry Mixedwood, Central Parkland and Northern Fescue Natural Sub-Regions (BRWA, 2012).

The Battle River watershed is a sub-watershed of the larger North Saskatchewan River Basin, draining approximately 40 per cent of the land base of this watershed. However, the Battle River only contributes approximately 3 per cent of the water that flows in the North Saskatchewan River. There are two primary reasons for this. Firstly, the headwaters of the Battle River originate in the Western Plains at Battle Lake. This means water flowing in the Battle River originates as groundwater and surface water runoff from local snowmelt and rains, rather than from mountain and foothills snowpack runoff. Secondly, the topography of the Battle River Watershed is predominantly flat (the river's average gradient is less than 0.4 m/km) with large tracts of land that are considered non-contributing, either naturally or due to human influence. Non-contributing means that water falling as snow or rain collects in small lakes and wetlands, where the water will eventually either infiltrate into the ground or evaporate before it ever reaches the Battle River. All of this results in very low flows in the Battle River, except for a short period of time annually in April and May and periodically in summer months during major rainstorm events (BRWA, 2012).

1.4 Sounding Creek Watershed

1.4.1 Location of the Sounding Creek Watershed.

The planning area for the Sounding Creek watershed begins just east of Sullivan Lake near Highway 36 and continues east to the Alberta-Saskatchewan border (Figure 1). The planning area boundary is defined as the portion of the Sounding Creek watershed that lies within Alberta (BRWA, 2012).

1.4.2 Natural Landscape of the Sounding Creek Watershed.

The Alberta portion of the Sounding Creek watershed is entirely within the province's settled "White Zone", and takes in portions of the Central Parkland, Northern Fescue and Dry Mixed Grass Natural Sub-Regions (BRWA, 2012).

The Sounding Creek watershed is considered dead drainage. Sounding Creek begins near Hanna, Alberta and flows into Sounding Lake. The outlet from Sounding Lake is Eyehill Creek, which flows into Saskatchewan and culminates in Manito Lake. There is no outlet from Manito Lake. As outflows from Sounding Lake are believed to have only occurred one or two times in the last fifty years, the area upstream of Sounding Lake is generally considered a non-contributing area. Despite being a non-contributing watershed, it is classified by Prairie Farm Rehabilitation Administration (PRFA) as a sub-watershed of the greater North Saskatchewan River Basin (BRWA, 2012).

2 Wetlands

Alberta's wetlands provide a host of hydrological, ecological, and socio-economic benefits and are among the most productive ecosystems in the province. Within the context of watershed management, wetlands play a particularly important role in determining water quality and quantity through filtration and removal of contaminants, sediments and excess nutrients such as nitrogen and phosphorous, and by recharging groundwater, storing water, attenuating floods and contributing to base flows.

Often referred to as "nature's kidneys", wetlands are one of the Earth's most productive and beneficial aquatic ecosystems, providing numerous benefits to watersheds, communities and economies. The complex physical, chemical, and biological interactions that occur within wetlands perform many important ecological functions related to water quality and supply. Wetlands are integral to watershed health and contribute to the achievement of all three goals of *Water for Life: Alberta's Strategy for Sustainability:*

- Safe, secure drinking water
- Healthy aquatic ecosystems
- Reliable, quality water supplies for a sustainable economy

The role of wetlands in watershed health and function is well documented globally. That role is particularly evident in prairie-fed watersheds such as the Battle River and Sounding Creek watersheds. The services provided by wetlands include local and regional groundwater recharge, surface water storage, flood attenuation, tourism, wildlife habitat, recreational opportunities, economic benefits via forage production, tourism, fishing and hunting, and carbon sequestration. The also provide several water quality benefits including retention of sediments from runoff, absorption of excess nutrients such as nitrogen and phosphorous, degradation of pesticides and reduction of water-borne pathogens.

A healthy and resilient watershed requires an abundance of wetlands consisting of a variety of types and classes properly distributed throughout the watershed in order to function properly. Each wetland type and class provides unique and complimentary functions, all of which are important. Water permanence is not an indication of importance.

2.1 Definitions

2.1.1 What is a wetland?

Wetlands are defined as areas of land saturated with water for long enough periods to promote aquatic processes as indicated by the poorly drained soils, hydrophilic vegetation, and various kinds of biological activity that are adapted to a wet environment (National Wetlands Working Group, 1988). Wetlands are also considered waterbodies, many with bed and shore characteristics. As such, they are owned by the Crown. Though the government does not claim ownership of ephemeral, temporary and seasonal wetlands (Alberta Environment and Parks, 2016b), all wetlands are subject to the *Water Act,* thus any modifications to any wetland, even on private property, require approval (Government of Alberta, 2015c).

2.1.2 Types of wetlands

The *Canadian Wetland Classification System* recognizes five wetland classes, which include bogs, fens, swamps, shallow water, and marshes (Adams et al. 1987, 1997). The five classes are recognized based on the overall origin of wetland ecosystems and the nature of the wetland habitat. Almost all prairie wetlands belong to the marsh and shallow open water classes under this system. Wetland forms, subdivisions of each wetland class) are based on surface morphology, surface pattern, water type and morphology of underlying mineral soil. Many of the wetland forms apply to more than one wetland class and some can be further subdivided into sub-forms and types. Wetland types are classified according to soil type and vegetation (Adams et al. 1997).

Wetlands are also classified based on hydrology and pond permanence, or the duration of surface water in the wetland. They can be ephemeral, temporary, seasonal, semi-permanent, or permanent (Figure 6) [for definitions see Alberta Environment and Sustainable Resource Development (AESRD), 2015]. These conditions may change over time, and with land use changes. These types of wetland also have different policy and regulation status, as will be discussed later on in this document.

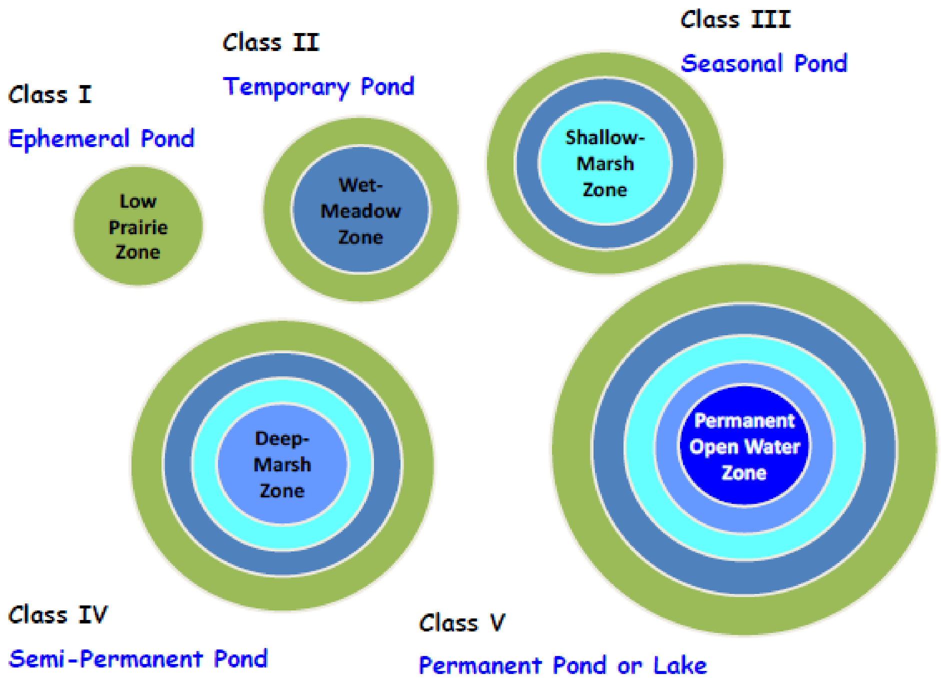


***Figure 6*. Plant and water zones for various prairie wetland classes using the Stewat and Kantrud (1971) system (from Ross & Martz, 2013). Reprinted with permission.**

The *Alberta Wetland Classification System* (AESRD, 2015) was developed to align with the *Canadian Wetland Classification System*, as well as with classification systems of Ducks Unlimited Canada and the Alberta Wetland Inventory. The *Alberta Wetland Classification System* utilizes a similar system of classification and the other two classification systems, but is based more on the criteria of Stewart and Kantrud (1971) while incorporating Alberta's flora and ranges of environmental, geological, and climatic characteristics (AESRD, 2015).

2.2 Importance of Wetlands

Wetlands are important for various ecological, social, and economic reasons. Wetlands have several key ecological functions. These include

1) Remove and store nutrients;
2) Climate stabilization;
3) Carbon sequestration;
4) Water storage;
5) Groundwater recharge and discharge;
6) Improve water quality
7) Maintain habitat and biodiversity; and
8) Create primary productivity.

These functions create and provide various products, ecosystem services (ES), and benefits we experience though health, water, education opportunities, industry, cultural heritage, agriculture, recreation, aesthetics, and tourism (Wray & Bayley, 2006). They are also important natural heritage areas, and are the focus of much scientific research.

Wetlands also support a variety of economic activities and functions. Degraded and drained wetlands have a financial cost that are incurred by society to replace the ecological goods and services these wetlands provided, such as (Wolfe, 2006, p. 2)

- Increased water treatment costs;
- Increased illness and health care costs;
- Irrigation water shortage;
- Water hauling and deeper wells required;
- Increased insurance costs due to flooding;
- Decreased property value due to degraded aesthetic qualities;
- Decreased swimming/fishing opportunities; and
- Decreased revenues from tourism activities associated with healthy ecosystems.

2.3 Wetland Loss and Cumulative Impacts

It is estimated that wetlands cover about 6% of the world's land surface (Maltby & Turner, 1983), though this is likely about half of the extent before human modifications. In North America, prairie pothole wetlands (the predominant wetland formation in the Battle River and Sounding Creek watersheds) are some of the most threatened ecosystems, largely due to drainage from land use and agricultural expansion (Badiou et al, 2011). Much of the drainage has been uncontrolled. Pre 1990, wetlands were removed from the landscape as a policy of the Alberta government encouraged landowners and producers to drain wetlands to increase land for agricultural use (AESRD, 2009). This was accomplished through various supports such as the Farm Surface Water Drainage Program, and through the operation of drainage districts. However, these likely only account for a small portion of the total drainage (<15-20%) (A. Corbett, personal communication, December 4, 2016). Approximately 60-70 percent of wetlands in the White (Settled) Area of Alberta have been lost (acreage loss about 40-50%), and loss continues at approximately 0.3-0.5 per cent of its wetlands each year (Pattison et al., 2013).

Throughout much of the Prairie Pothole Region (PPR), wetland loss has been focused on smaller wetlands (Van Meter & Basu, 2015) as they tend to be easier to drain. The high perimeter (P) to area (A) ratio of smaller wetlands translates into a disproportionate loss of wetland perimeter (Van Meter & Basu, 2015). For example, if we assume wetlands are circular, the P: A ratio for a wetland with an area of 100 meter squared (m^2) would be

0.32 m^{-1} whereas that ratio for a 1000 m^2 wetland would be only 0.11 m^{-1}. This is significant as much of the biological/biogeochemical cycling (Marton et al., 2015) and groundwater interaction (Hayashi & Rosenberry, 2002) functions of wetlands occur at the perimeter.

Wetland loss and function impairment contributes to non-point source pollution, severely affecting water quality. Part of what contributed to these impacts is that the drainage area increases. In Manitoba, Ducks Unlimited Canada, in partnership with the University of Guelph and Tarleton State University, completed a research project to determine the impacts of wetland loss and associated drainage activity in the Broughton's Creek watershed in southwestern Manitoba. The study determined that wetland loss between 1968 and 2005 increased drainage area by 31%, and had additional impacts (Yang et al., 2008)

- A 31 % increase in nitrogen & phosphorus export from the watershed,
- Peak runoff or rainfall event flow increased by 18%,
- Total watershed outflow increased by 30%,
- Average annual sediment loading increased by 41%,
- The release of approximately 34,000 tonnes of carbon, the equivalent of 125,000 tonnes of CO2 (annual emissions from almost 23,200 cars), and
- 28% reduction in waterfowl production potential

When intact, wetlands collect and store water from the surrounding landscape during rain or snowmelt, where they filter sediments, pollutants, and nutrients before slowly returning water to aquatic or groundwater systems. The local drainage area is connected to downstream flows, so when wetlands are drained, or even partly drained, this causes water carrying nutrients and sediments to move rapidly through the former wetland area and directly to downstream ditches, streams, rivers, lakes and drinking water supplies.

Isolated wetland loss is not the only issue associated with wetlands. Land use and other impacts that affect wetland function are challenges that need to be managed. These impacts can be gradual or abrupt. When many wetlands are drained or functionally impaired, the cumulative impacts can be significant, and can constrain wetland restoration efforts (Bedford, 1999). This aspect of wetland management is rarely addressed in policies and management frameworks. In addition to significant loss of wetland area, cumulative impacts associated with wetlands have resulted in several things, including disproportionate loss of certain wetland types, degradation of remaining wetlands, and the subsequent decrease in native biodiversity (Bedford, 1999). These impacts also alter the landscape and the resilience of the ecosystem (Gunderson et al., 2006). When ecosystems and landscapes undergo a certain degree of change, their resilience declines, and they can abruptly change from one state to another (Gunderson et al., 2006), called a regime shift. These shifts come with different ecosystem conditions and services, and are difficult to reverse. Combined with impacts of climate disruption, continued loss and impacts to wetlands may push our prairie and parkland ecosystems into to states.

Since cumulative impacts alter the landscape and can affect restoration efforts, an assessment the cumulative impacts of wetland loss and degradation on landscape and ecosystem functions on a watershed or subwatershed scale is needed (Bedford & Preston, 1988).

3 Battle River and Sounding Creek Wetlands

In this section, the geographic and wetland context for the Battle River and Sounding Creek watersheds are discussed.

3.1 Prairie Pothole Region

The Prairie Pothole Region (PPR) of North America is the core of what used to be the largest expanse of grassland in the world, the Great Plains of North America, extending over approximately 800,000 km^2 (Badiou et al., 2011) (Figure 7). The name comes from the geological phenomenon that left its mark beginning 10,000 years ago. When the glaciers from the last ice age receded, millions of shallow depressions were left behind that are now wetlands, known as prairie potholes (Ducks Unlimited, 2015). They are generally small, less than 50 hectares (AESRD, 2009) with an average size is about 4 acres (Dahl, 2014), and abundant. Due to the prevalence of these depressions on the landscape, much of the drainage is into these depressions rather that into streams of rivers. As a result, this area is designated as non-contributing (Shook & Pomeroy, 2011).

***Figure 7*. Prairie Pothole Region (PPR) in Canada and the United States (from Wrubleski & Ross, 2011).**

These potholes are rich in plant and aquatic life, and support globally significant populations of breeding waterfowl and other wildlife (Johnson et al., 2005). However, agricultural development has caused considerable wetland drainage in the area (Ducks Unlimited, 2015).

The majority of the area of the Battle River and Sounding Creek watersheds is located within the PPR, with a few exceptions.

3.2 Wetlands of the Battle River & Sounding Creek Watersheds

The majority of wetlands in the Battle River and Sounding Creek watersheds are mineral-based marsh wetlands associated with the Aspen Parkland ecoregion (Figure 8). However, the western portion of the watershed is located in the Boreal Transition Zone, which includes a mixture of mineral and peat based wetland types. This area contains the Cooking Lake moraine (and Miquelon Lake Provincial Park). The land in the moraine is characterized by hummocky "knob and kettle" terrain that forms a mixture of depression areas, many of which contain small lakes and wetlands (Ambrose, 2010). There are also fens in the eastern portion of the watershed in the Parkland Dunes Environmentally Significant Areas.

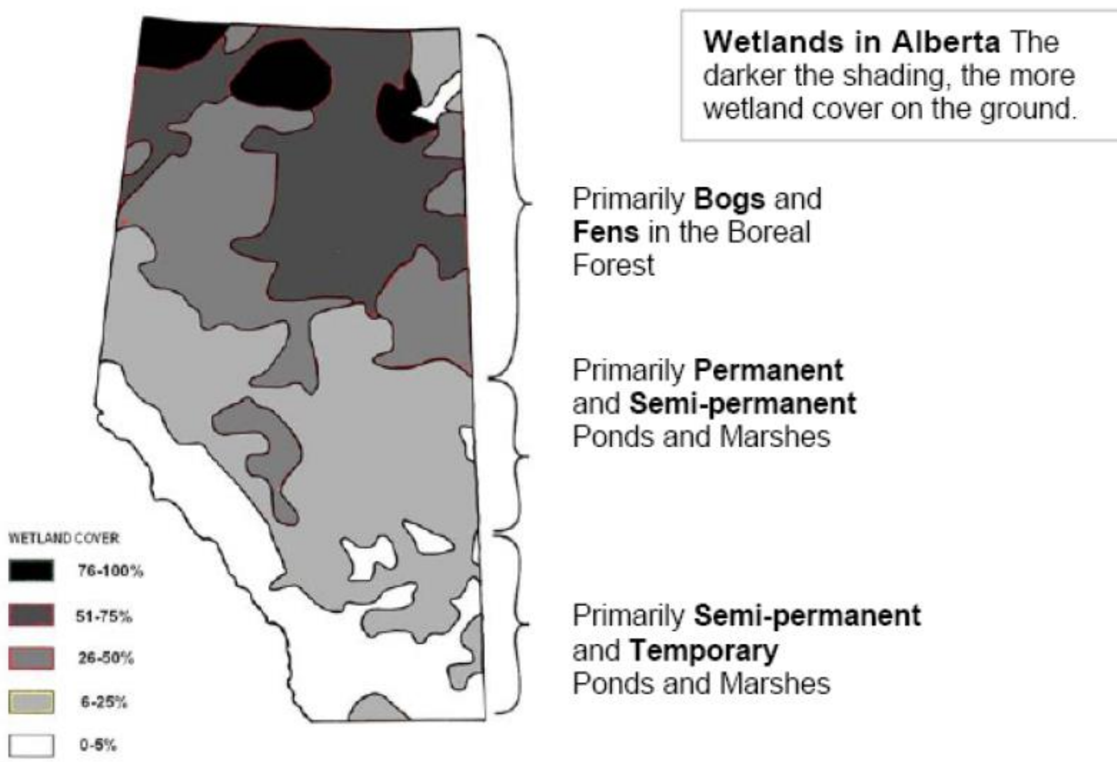


Figure 8. **Wetland type distribution in Alberta (from AESRD, 2009).**

The Battle River and Sounding Creek watersheds are located primarily within the Prairie Pothole Region. Since wetlands are a common feature on the local landscape, human activities often interact with wetlands. As of 2011, wetlands accounted for approximately 1.8% and 4% of the total land cover Battle River and Sounding Creek watersheds (respectively). This, however, does not account lost and drained wetlands. Data from the Atlas of Canada (Natural Resources Canada, 2015) indicates that in the Battle River and Sounding Creek watersheds, area of pre-settlement wetlands would comprise 5-10% of the land (Figure 9).

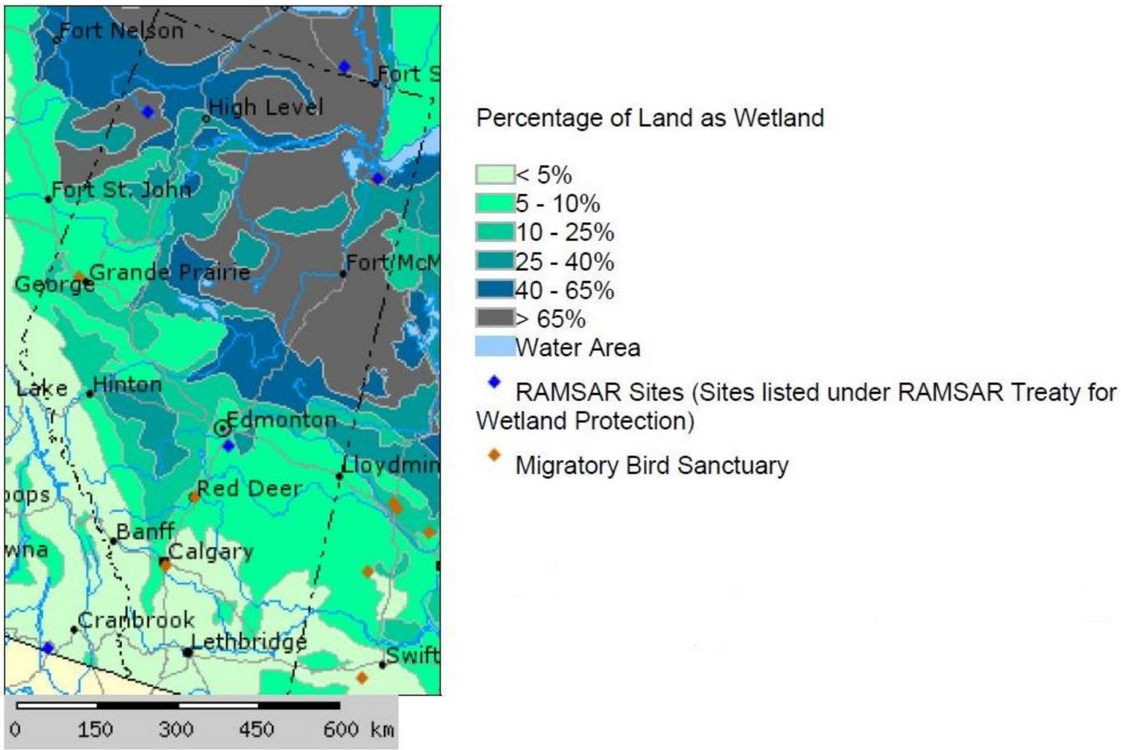


***Figure 9*. The proportion of land in Alberta classified as wetland (AESRD, 2009).**

A comprehensive regional wetland change detection study done in Alberta was the Environment Canada's *Prairie and Northern Region Habitat Monitoring Program Phase II* (Watmough et al., 2007). This study assessed wetland change between 1985 and 2001 and indicated that for this area (including the Battle River and Sounding Creek watersheds) the following trends were observed (Barr, 2011)

- gross wetland *area* loss is significant and higher in Alberta than the prairie regional average;
- gross wetland *area* loss in the North Saskatchewan Region (i.e., Aspen Parkland ecoregion) is very significant and substantially higher than the prairie regional average;
- mean size of lost wetlands is very small; and
- the *number* of wetland losses (i.e. basins) is very high.

Comparing the current area of wetland land cover to the estimated pre-settlement area of wetland land cover, the Battle River watershed has lost more wetland area than the Sounding Creek watershed. The details of where losses and impacts have occurred were identified, in part, with wetland inventory techniques.

3.2.1 Wetland Inventories

The Government of Alberta, under the direction of *Water for Life: Alberta's Strategy for Sustainability*, has identified the need to develop a comprehensive wetland inventory for the province. Two distinct inventory methodologies have been developed for use in the White Area and the Green Area of Alberta (Figure 10).

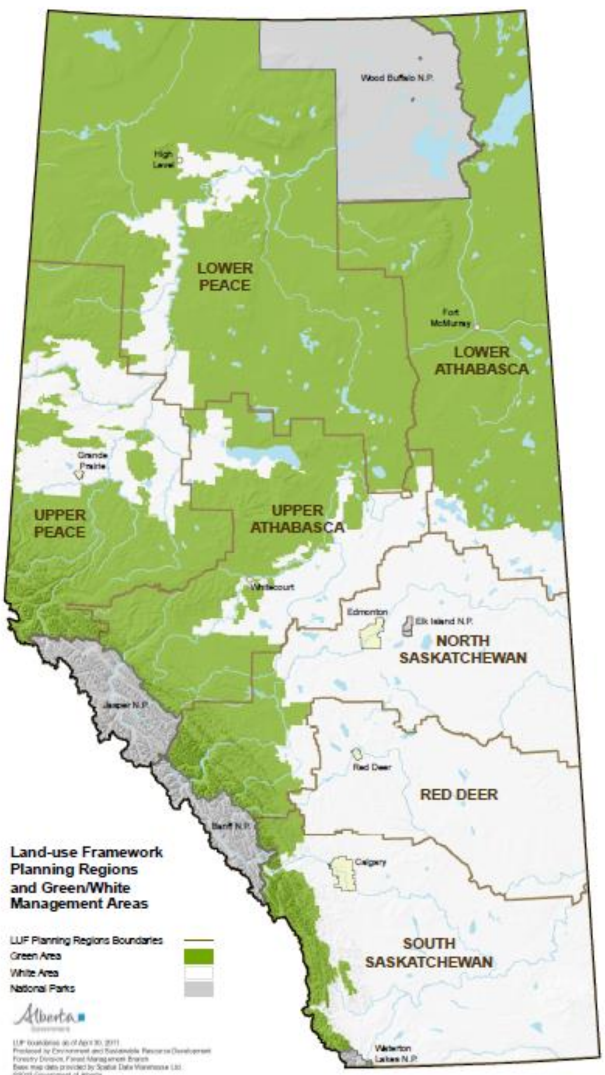


***Figure 10*. Green and White Management Areas in Alberta.**

In the White Zone (where Battle River and Sounding Creek watersheds are located), high resolution, historic, and current aerial photography is typically used to determine the change in wetland area over time. Commonly referred to as the "Comprehensive" or "Drained" wetland inventory, this differs from previous inventory methods in that it can accurately capture drained and altered wetlands, thereby accurately measuring wetland loss. This method does not typically classify wetlands remotely, but classification data can be added through inclusion of field observations.

The 2005 wetland inventory of the Iron Creek sub-watershed is an example of this method. The resulting data was utilized to develop a cartographic representation of wetland impacts and a wetland impact model as a product of the broader Water for Life Inventory. The model incorporated baseline wetland inventory collected for the entire sub-watershed based on 1963 photography. The inventory methodology was then repeated for the recent time period using 2005 photography. With two temporal representations of the abundance and distribution of wetland features in hand, a geoprocessing model was developed that would assign impact categories to each wetland basin. The model output characterizes the current state of wetland resources and the distribution of wetland impacts across the entire sub-watershed.

This data provide a valuable resource for targeting wetland conservation and restoration initiatives, and support further research into the hydrologic and ecological consequences of the impacts. According to this inventory, two-thirds of the wetlands in the Iron Creek sub-watershed have been drained, lost, or altered (Figure 11). This accounts for approximately 43 million m^3 of water (for explanation on estimating prairie pothole volume, see Hayashi & van der Kamp, 2000; Minke et al., 2010). Full wetland inventories have not yet been completed for much of the Battle River and Sounding Creek areas, though a few are complete and underway (Figure 12). The information for the Iron Creek sub-watershed, as well as other *Water for Life* inventories completed in the Battle River watershed is located in Appendix A.

The level of wetland inventory and mapping found in the Iron Creek study is useful to help determine type and extent of wetland loss, and is fundamental to planning, decision-making, objective setting and implementation in watershed and other planning initiatives. Setting appropriate wetland retention and restoration objectives greatly depends on the development of these high-resolution inventories.

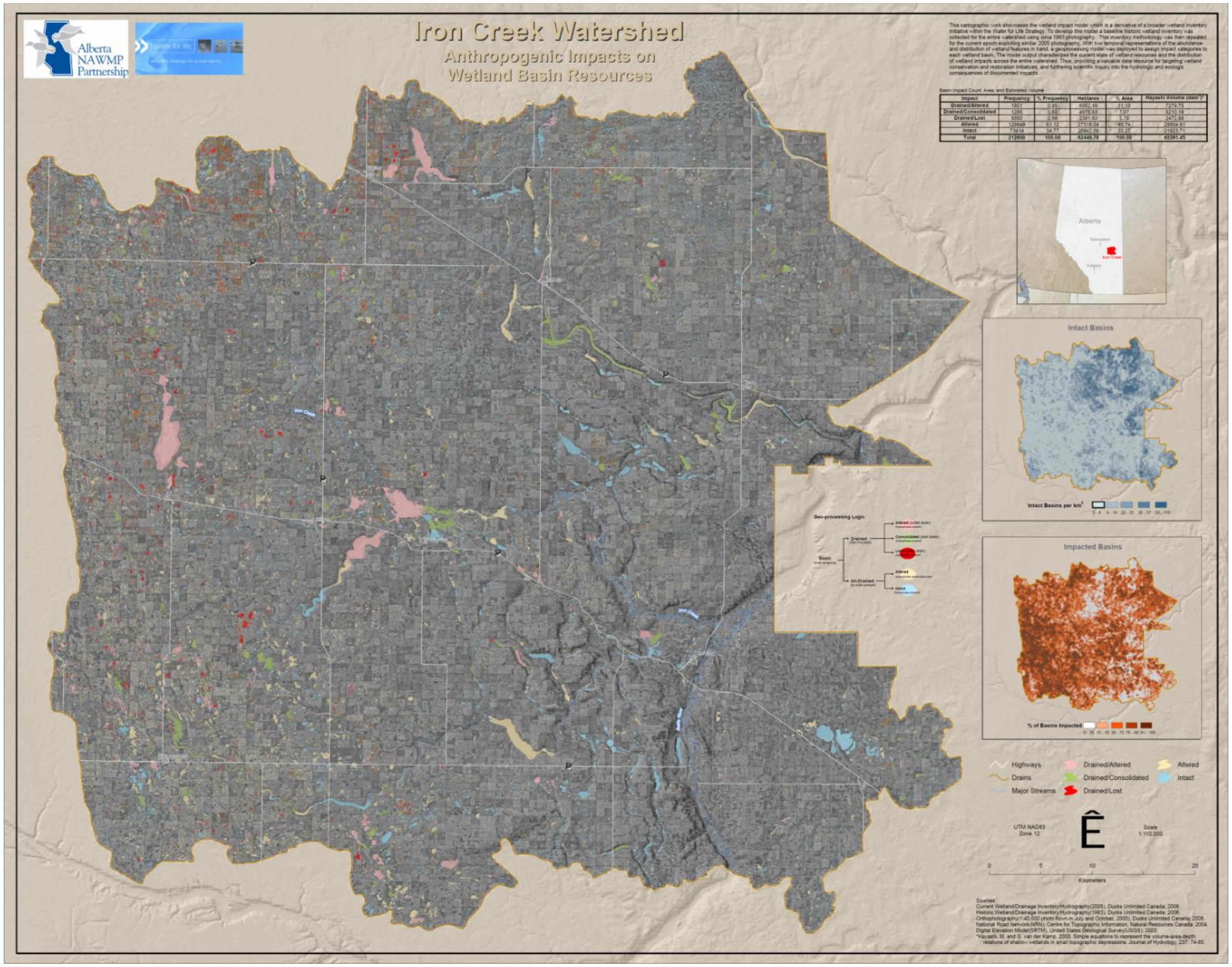


Figure 11. **Iron Creek subwatershed wetland inventory. Pink – Altered (outlet drain added); Green – consolidated (inlet drain added); Red – Lost (outlet drain added, wetland plants absent); Yellow – Altered (wetland plants absent/disturbed); Blue – Intact (wetland plants present).**

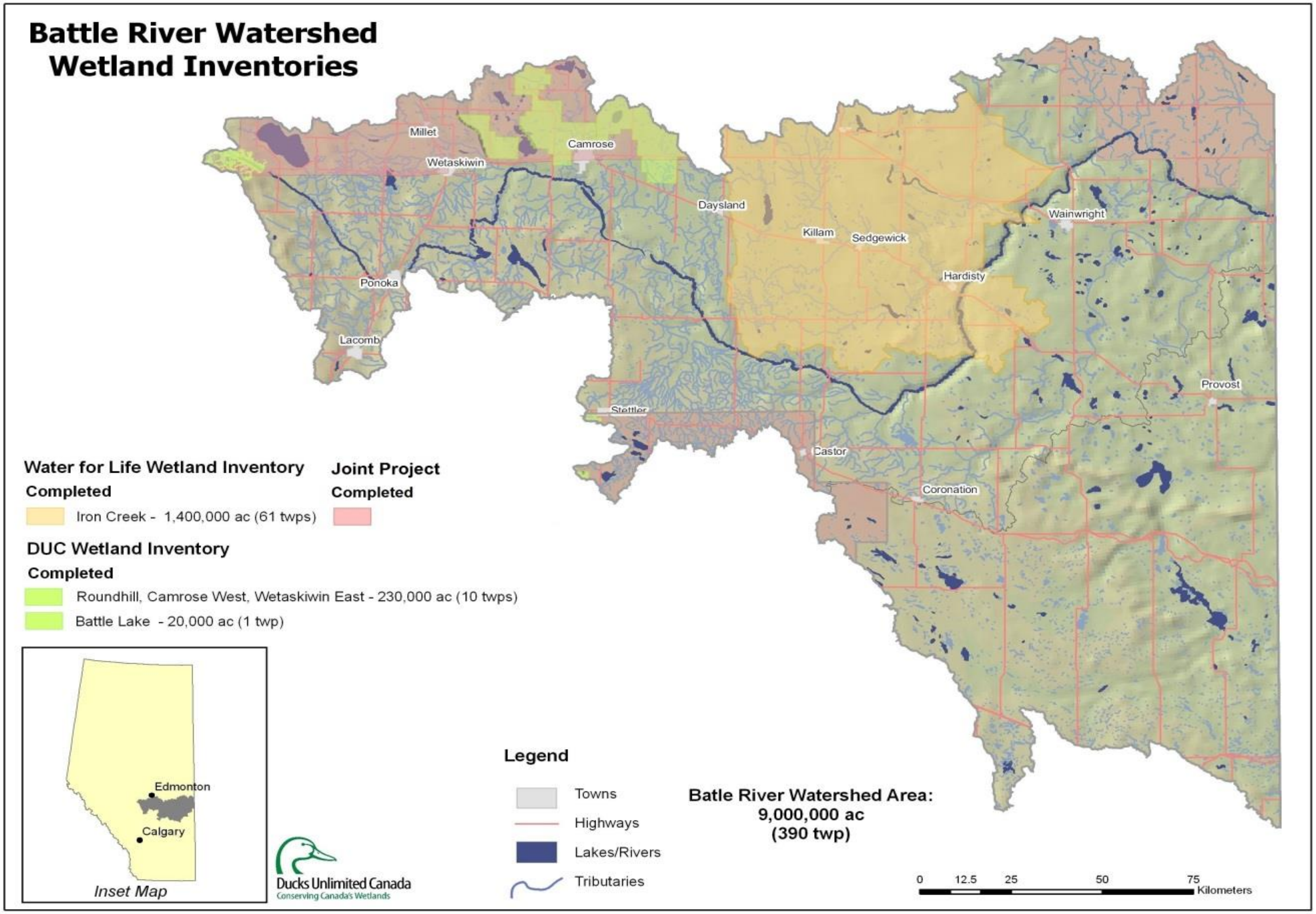


Figure 12. **Battle River and Sounding Creek wetland inventories as of 2009.**

4 Land Use

Wetlands are an integral part of the landscape. Due to the nature of wetland hydrology and functions, significant interactions and influences exist between wetlands and their wider landscapes (Maltby & Acreman, 2011). Thus, how the land is used affects wetlands. Quality, functionality, and quantity of wetlands are all impacted. Some land uses allow wetlands to co-exist with human uses, but due to poor policy oversight, and societal norms, wetlands are often destroyed or altered for convenience and economic benefit. The *Federal Policy on Wetland Conservation* reinforces the importance of interconnections of wetlands and the landscape, and should be reflected in the management strategies that are pursued:

> Wetlands and wetland functions are inextricably linked to their surroundings, particularly aquatic ecosystems, and therefore wetland conservation must be pursued in the context of an integrated systems approach to environmental conservation and sustainable development (Government of Canada, 1991, p.6)

Despite this, few wetland policies developed at any level of government or organization stipulate or mention management of surrounding land use. Some land use practices have larger impacts, and can be detected up to 4 km away (Houlahan & Findlay, 2003). As a result, small-scale buffers may not be effective.

Another challenge in managing wetlands and land use and development is the issue of wetland permanence and area. Wetlands can have catchment areas 3 to 20 times the size of those wetlands (varies with climatic and geologic conditions). Understanding this may help understand how land management may affect certain wetlands (Hayashi et al., 2016). As mentioned earlier in this report, wetlands have varying pond permanence. Whether industrial, commercial, residential, or general infrastructure development, assessing permanence is important in regards to provincial approvals for development and municipal planning. Alberta Environment and Parks have developed guidelines on assessing and determining wetland pond permanence (AEP, 2014).

4.1 Agriculture

Throughout Alberta, there has been a long history of destroying or altering wetlands for agricultural purposes to increase area of arable land. Policies promoting drainage were common in the mid-1900s (i.e. Korven & Heinrichs, 1971). Now, with the change in policy and increased societal value on wetland services, including water quality improvement, flood control, wildlife habitat, and recreation. Landowners are often not able to profit from these services because the benefits are freely enjoyed by many

(Heimlich et al., 1998). As a result, the agriculture community is facing the brunt of the impact and cost through pressure to reduce area of farmable land for restoring wetlands, as well as potential reduced re-sale value for lands where wetlands are identified. Since wetland restoration and conservation benefits society, a system where taxpayers compensate farmers for wetland restoration and conservation on their land seems justifiable (Zedler, 2003).

Many challenges remain pertaining to how landowners, crop producers, and livestock producers perceive and manage wetlands. Much of this has to do with access for crop planting and management and the additional costs with farming around wetlands (Cortus et al., 2010). With increasing size of farm machinery and implements, maneuvering around or between wetland areas, and ensuring overspray does not impact wetlands, is difficult. There are some new and emerging technologies and practices on the horizon, such as sectional and spot application spraying, along with GPS navigation, which could ease some maneuvering issues. Such methods would also reduce input costs. Wetter areas also require delayed seeding (Cortus et al., 2010).

As well, many landowners may be unaware that most wetlands (with the exception ephemeral, temporary and seasonal wetlands) (and all other waterbodies and watercourses) are owned and governed by the Government of Alberta (Alberta Environment and Parks, 2016c). Alteration to any wetland (including ephemeral, temporary and seasonal wetlands) and other waterbodies and watercourses falls under the *Water Act*, requires a permit through the Government of Alberta, even those on private property (Government of Alberta, 2015c). This lack of awareness is a fundamental issue in wetland management in Alberta that needs to be addressed. In addition, many landowners are unaware that they have wetlands on their property, especially seasonal ones, or wetlands that have been previously altered or drained.

Wetlands can be very beneficial for both crop and livestock producers. They help prevent flooding and maintain water tables and water availability during droughts through water storage, provide shelter, forage, and water for livestock, absorb excess nutrients and potential contaminants from runoff and the air, and on a local scale contribute to cloud and rain formation (Alberta Conservation Association, 2011; Alberta Environment, 2003). Such benefits can be incorporated into grazing management plans and environmental farm plans to maximize outputs.

There is increasing concern over the use of pesticides, especially the family of neonicotinoids (or neonics). Though wetlands can remove/process many pesticides (Gabor et al., 2004; Kao et al., 2002), neonicotinoid pesticides “exhibit chemical properties that enhance environmental persistence and susceptibility to transport into aquatic ecosystems through runoff and drainage of agricultural areas” (Morrissey et al, 2015, p.292). As a result, they have been found in studies across the PPR in concentrations that suggest high persistence and transport of these chemicals on the agricultural landscape (Main et al., 2014). These pesticides can harm non-target aquatic insects (Morrissey et al, 2015), thus they affect wetland aquatic ecosystems functions (Main et al., 2015). The longevity of neonics is unknown, and with possibility for high toxicity to aquatic insects in water, some scientists warn against the large-scale use of these pesticides as impacts to aquatic invertebrates and cascading food webs could be substantial (Morrissey et al, 2015). Many jurisdictions, such as several nations in the European Union (European Commission, 2013), most of the United Kingdom, the Province of Ontario, and several major Canadian cities, have banned the use of neonicotinoid pesticides because of their persistence and other issues. The United States still allows the use of most neonicotinoid pesticides.

Damage to wetland riparian areas by cattle is also a pervasive issue. Many technologies and management systems exist to reduce or eliminate damage to wetlands and riparian areas while increasing cattle condition. Offsite watering systems, or providing a non-erodible ramp allows livestock access to cleaner water and improves animal overall performance. Adoption of a controlled grazing and a rotational grazing system effectively utilizing rangeland can be used while protecting wetland and riparian habitats (Fitch et al., 2003). Programs to offset costs are available through Growing Forward 2 and other provincial/regional programs.

Other impacts of agriculture and upland management involve how different vegetation types and their management influence hydrologic processes, such as the amount and quality of water entering wetlands (Haak, 2015; Renton et al., 2015). Cultivated fields with shorter stubble allow for more surface runoff (van der Kamp et al., 2003) and snow transport (Fang & Pomeroy, 2008), increasing water volume in wetlands. Wetlands surrounded by undisturbed grassland, especially with non-native species such as smooth brome grass (*Bromus inermis*) and alfalfa (*Medicago sativa*), tend to dry up (van der Kamp et al., 2003). These species of plants use a lot moisture, have a large root system. In restoration projects, they were used to create nesting cover for wetland birds. As well, undisturbed grasslands trap more snow, and allow for more infiltration (van der Kamp et al., 2003).

Additionally, agriculture and other forms of upland management also affect waterfowl and other wildlife that rely on the area surrounding wetlands for breeding and raising young (Whited et al., 2000). These impacts are influenced not just by type of crop or vegetation, but the way it is managed, and timing of that management. Fall seeded, delayed cut hay, and grazed pasture, and perennial crops range from least to most, respectively, disruptive (Haak, 2015). The Western Winter Wheat Initiative, a collaboration between Bayer CropScience, Ducks Unlimited Canada (DUC), the Mosaic Company Foundation, and Richardson International Limited, was designed to build awareness and credibility of winter wheat as a highly productive crop option for western Canadian farmers, while also promoting waterfowl and upland game bird habitat (Western Winter Wheat Initiative, n.d.).

Wetland Management Districts (WMDs) in the U.S. allow and utilize agriculture as a land use tool through the administration of a Special Use Permit (SUP) or a Habitat Management Agreement (HMA). The WMD provides direction to the crop farmers on the types of crops that can be planted, crop shares or cash payments for farming privileges, use of pesticides, use of best management practices, timing of disturbances, and any other special conditions to ensure the farming program is conducted properly (United States Fish & Wildlife Service [FWS], 2014). This process permits farming (though in a more limited capacity) to occur, as well as promoting wildlife use of wetlands and surrounding uplands.

4.2 Urban and Rural Development

Though most historical wetland loss in Alberta was caused by agricultural practices and policies, more recent wetland loss is the result of industrial development, and urban development and sprawl (Boyer & Polasky, 2004). When urban developers remove wetlands, they are able to pay the replacement costs with lower cost rural land.

In 2013, the Alberta Urban Municipality Association (AUMA) and Alberta Association of Municipal Districts and Counties (AAMDC) developed a *Municipal Water Policy on Wetlands*. This policy was developed to provide a municipal perspective on the implementation of the new Alberta wetland policy, and help enable municipalities and their partners to conserve and restore wetlands (Alberta Urban Municipality Association [AUMA], 2013).

4.2.1 Naturalized Stormwater and Wastewater Ponds

The water filtering and storage function of wetlands is being utilized by many municipalities and organizations through the creation of naturalized stormwater and wastewater ponds. The purpose for constructed wetlands is to retain runoff (whether from urban or rural areas) for a prolonged period of time to allow for the uptake and storing on pollutants from the runoff (Alberta Environmental Protection, 1999). The question of whether or not restored and created wetlands are structurally and functionally equivalent to natural wetlands has been the focus of extensive research, with varied results (i.e. Kayranli et al., 2009; Rooney et al., 2014; Zhang et al., 2014).

As these naturalized stormwater management facilities (NSWMFs) are human-made and their primary function is stormwater collection, their shoreline slopes are often much steeper than natural wetlands, resulting in fewer, narrower wetland vegetation zones. This would have impacts on water filtration, as well as biodiversity (Forrest, 2010). Improvements on the design by integrating ecological principles have led to better and more functional NSWMFs (i.e. Forrest, 2010; Lilley & Labatiuk, 2001; Ross & Martz, 2013) that also benefit the community (Native Plant Solutions, 2012). Criteria for stormwater wetland design and other BMPs has been laid out by the Government of Alberta (Alberta Environmental Protection, 1999).

Under the new Alberta wetland policy, there is allowance for the construction of stormwater wetlands for partial credit of wetland replacement requirements (Government of Alberta, 2015b). No matter the design, some wetland ecosystem services stormwater management facilities are unable to provide due to conflicting goals (Rooney et al., 2015). As well, education and engagement is in need of to change public perception of urban wetlands, identify key wetland traits, and understand the implications of wetland compensation, and not focus solely on the aesthetics of stormwater wetlands.

Similar to stormwater management facilities, wetlands are also created to naturalize wastewater management. Research has been done internationally to look into how constructed wetlands could help municipalities, industries, as well as rural areas deal with wastewater. Such innovations could be of great benefit in developing world where inadequate access to clean water and sanitation have become the most pervasive problems afflicting people (Zhang et al., 2014).

In Canada, there have been studies pertaining to the use of wastewater wetlands to treat municipal (Anderson et al., 2013), industrial (Rozema et al., 2016), and agricultural (Kinsley, 2015) wastewater. Agricultural and municipal wastewater has also been used to restore a prairie wetland (White & Bayley, 1999). Though initial results are promising for wastewater treatment, some wetland wastewater systems have shown declines in nutrient removal after 4–5 years of continuous loadings, depending on rate of loading. This may result in eutrophication of the wetland, and degrade water quality downstream White et al., 1999).

4.3 Industry

Industrial development can have many impacts on wetlands and the landscape. One persistent issue across many industries is the matter of access roads. Several documents created by Ducks Unlimited Canada and their industry partners address how best to plan and manage access roads in relation to a variety of wetlands (Ducks Unlimited Canada et al., 2014; Partington et al., 2016).

4.3.1 Gravel Mining

Currently, more than 20 municipal, provincial, and federal acts, policies, and regulations govern gravel and other aggregate extraction activities in Alberta (Alberta Sand & Gravel Association [ASGA], 2015). For applications under both provincial (Alberta Environment, 2004) and municipal (i.e. Camrose County, 2014), wetlands and riparian areas are treated similarly, and encourage consideration of using naturally vegetated buffers for water quality and wildlife habitat. Erosion control (recommended as vegetation), in regards to preventing siltation of water bodies, is a required part of all plans (Alberta Environment, 2004). It is generally recommended, however, wetlands be avoided (Alberta Environment, 2004).

4.3.2 Oil and Gas

The Alberta Energy Regulator (AER) (2013) sets out approval standards and setbacks for the various classes of wetlands, as well as for a variety of pond permanence wetlands. These can pertain to types of industrial activity, as well as suggested setbacks for various animal types that may be of interest in the area. Applicants are also responsible for identifying potential waterbodies that may not be wet at the time of application due to climatic reason. Overall the AER supports best management practices for industrial activities that minimize "disturbance and adverse environmental effects" (Alberta Energy Regulator [AER], 2013, p.23) to environmentally sensitive areas. Any industrial activities that require disturbance or alteration of wetlands requires a *Water Act* licence.

Specifically for well pads, AER requires that the center of a well must be a minimum of 100 m from a waterbody. Any closer than the 100 m setback and special conditions must be met. Any disturbance or alteration of wetlands requires a *Water Act* licence (AER, 2011).

There are specific requirements on Tier 1 land around Battle Lake including stringent spill and contaminated runoff mitigation measures and total avoidance of wetlands. Proponents are also responsible to identify and protect any unmapped water features in these areas (AER, 2011).

4.4 Land Use Planning

Land use planning, whether on a regional or municipal scale, is a crucial piece of wetland management. This not only includes understanding how different land uses will affect wetlands or how wetlands (or removal of) affect land use, but also incorporates stakeholder establishment of wetland objectives and the identification of strategically important wetlands at a local and regional level.

4.4.1 Land Use Framework and Regional Plans

As a major regional directive in regards to land use planning, the land use regional plans being developed in Alberta are ideal opportunities to develop wetland management on a regional/watershed scale. To date, only two have been approved in Alberta, the Lower Athabasca Regional Plan (LARP) in 2012, and the South Saskatchewan Regional Plan (SSRP) in 2014. In the LARP, wetlands are mentioned only briefly in relation to the implementation of a progressive reclamation strategy which includes tools "to measure and report on the return of equivalent capability" (Government of Alberta, 2012, p.46) of various land uses, including wetlands.

The SSRP incorporates wetlands throughout of the document, and in detail. The overall importance of key wetland and riparian areas as part of an integrated approach to watershed management and health is recognized and emphasized in many of the sections, such as outdoor recreation, and sustainable municipal development (Government of Alberta, 2014). As the *Alberta Wetland Policy* was approved since the competition of the SSRP, provincial wetlands management implementation is just beginning.

The North Saskatchewan Regional Plan (NSRP), in which the majority of the Battle River watershed is located, is still underway. It is unknown how wetlands will be dealt with in light of the *Alberta Wetland Policy*. Work is underway to incorporate wetlands into the Biodiversity Management Framework of the NSRP. The forthcoming Red Deer Regional Plan will also influence land use and wetlands in the Battle River and Sounding Creek watersheds.

The North Saskatchewan Regional Plan presents several opportunities in regards to wetlands. These include improving knowledge and understanding about wetlands, to ensure wetlands are properly represented in the planning process, and to facilitate pertinent environmental, social and economic information is consolidated. Together, these actions could establish wetlands as integral to the regional plan, and ensure the services they provide are recognized (Barr, 2011).

As part of the Government of Alberta ecosystem services (ES) pilot study (Government of Alberta, 2011b), researchers suggest that there is an important link between ES assessments and regional planning. Ensuring ES assessments are nested within other planning and policy work of the regions, regional planners could apply some of an ES approach at the outset of regional plan development. This would help ensure that consideration of multi-scale services and benefits of wetlands is explicit in regional plan design, thus incorporating the ES that contribute to the quality of life for people (Government of Alberta, 2011b). Including wetlands as an essential component in planning processes and application of available methods would be useful to establish thresholds and cumulative impact management objectives, and help make trade-off decisions when other values compete with maintaining wetlands (Maltby & Acreman, 2011).

4.4.2 Municipal

Municipalities have a large role to play in land use management. Cities, towns, and counties each have a municipal development plan and/or land use bylaws. These important tools can be used to help manage wetlands on private and municipal lands. The Environmental Law Institute (2008) developed a planner's guide on wetlands. Though based on the U.S. system, this document compiles scientific literature on wetland buffers and identified some techniques used and legislative choices made by various local governments to design, manage, and monitor local wetlands and associated buffers.

Several towns and cities throughout Alberta have developed wetland conservation and management plans, and some have done it combination with riparian plans. These include Town of Cochrane, City of Calgary, Rocky View County, and City of Edmonton (list not exhaustive). Many towns and cities, including City of Camrose and City of Wetaskiwin, have bylaws regarding wetland and lake setbacks. Others group them in with environmentally sensitive areas, which often have pertinent bylaws in the form of setback requirements.

4.5 Buffers

Land use plays a role in the biodiversity of wetlands. Many land uses can negatively affect wildlife species that rely on the wetlands, such as birds (Forcey et al., 2007; Shutler et al., 2000; White & Bayley, 1999) and amphibians (Baldwin, et al., 2006; Gray et al., 2004; Houlahan & Findlay, 2003; Kolozsvary & Swihart, 1999; Lehtinen, et al., 1999; Semlitsch, 1998; Semlitsch & Bodie, 2003). The purpose of buffers (flexible, area-specific) and setbacks (usually statutory) from water bodies is to create areas that separate important remnant or wetland habitat from incompatible land uses. These area usually control development or alterations, allowing natural vegetation and processes near water bodies to remain as healthy and functional as possible, as well as to protect private property from possible flooding and loss of land due to stream erosion and bank instability. From the biological perspective, buffers provide additional habitat for wetland species, and act as corridors for wildlife movement. More importantly buffers may reduce disturbance (behavioural or physiological response of an animal to a stimulus) (Weston et al., 2009), such as from agricultural or urban activities. Development of effective buffers must consider several elements that can influence effectiveness and impact wetland function.

Size is an important element of buffers. Some policies, regulations, and bylaws stipulate buffer width and the type of setbacks required in relation to waterbody type, geology and geography, industry type and land use purposes. However, buffer size, enforcement, and application of these bylaws are not uniform.

In conjunction with buffers, considering the Critical Function Zones (CFZ) of a wetland will expand the wetland functions area (Figure 13). The CFZ is used to define the "non-wetland areas within which biophysical functions or attributes directly related to the wetland occur" or the "functional extension of the wetland in to the upland" (Environment Canada, 2013a, p.25). This could include the upland waterfowl nesting habitat, or the foraging habitat for amphibians and insects around a wetland.

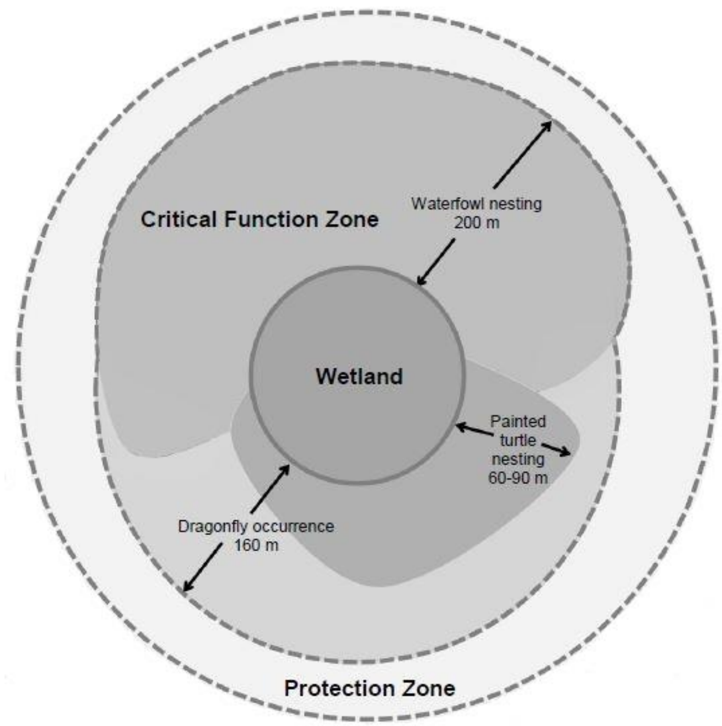


***Figure 13*. Critical Function and Protection Zones. Copyright Environment Canada, 2013a.**

Riparian areas, buffers, and Protection Zones (PZ) (Environment Canada, 2013a) can assist in the maintenance of the function of wetlands by protecting the wetland and its functions from stressors related to surrounding land use change. Width of these areas will vary, and depends on the surrounding land use, what function(s) will be preserved, and the degree to which wildlife habitat is considered (Environment Canada, 2013a).

Buffer width varies according to the extent to which the buffer is designed to protect and maintain wildlife habitat. Different wildlife groups have different habitat requirements that dictate the size of the buffer. The common 20m or 30m setbacks contributes minimally to wildlife habitat, except for small rodents and shrews. Most amphibians ideally require at least 50 m (Hannon et al., 2002) though, for the Northern Leopard Frog (*Lithobates pipiens*), it extends to 100m (Government of Alberta, 2011c). Songbirds, avian raptors, ungulates, and mammalian carnivores (species ranging in size from cougar to weasel) all require much larger buffers, ranging between 100-400m (AESRD, 2012b; Environment Canada, 2013a; Hannon et al., 2002). Species at risk and other sensitive species may have specific recommendations. Other setback and buffer guidelines for wildlife and hydrologic function can be found in in *Stepping Back from the Water* (AESRD, 2012b).

Various methods for determining buffers or setbacks are site-specific and land-use specific, making them inappropriate to apply on a more regional or watershed scale. Setbacks or buffer on a broader scale can be delineated using aerial videography as described previously. Riparian assessments such as those provided by Cows and Fish would be more localized. As well, the field manual created by Agriculture and Agri-Food Canada on buffer designs (Stewart et al., 2010) is more site-specific, but is designed for landowners to do their own assessment.

The Riparian Setback Matrix Model (RSMM) (White & Gray, 2007) has been utilized as a planning tool by a handful of municipalities in Alberta to establish policies for wetlands. Town of Strathmore, Rocky View County, and Lakeland County all have policies for protection of riparian and/or wetlands based on this model. The RSMM delineates the width of an environmental reserve(ER) based on the slope of the land, height of banks, groundwater influence, soil type, and vegetative cover. If no vegetation exists, the ER is determined from the edge of water (White & Gray, 2007).

Alberta Riparian Habitat Management Society, known as Cows and Fish, also has produced wetland assessment tools used to evaluate the health of wetlands and their surrounding riparian areas (Ambrose et al., 2009). These tools were designed to assist in training people, such as farmers, ranchers, lakeshore residents, landowners, land and resource managers, to assess quickly riparian health for water bodies and interpret the results of a health evaluation. This guide is often used in conjunction with the *Alberta Lentic Wetland Inventory* and *Alberta Lentic Wetland Health Assessment (Survey)* documents.

In addition to the size of buffers, vegetation composition is also important. As with any healthy riparian area, vegetation in a variety of sizes, growth habits, and types are important. In addition to this, a diversity of native vegetation (versus non-native species) is ideal, both in regards to conservation and restoration. Some non-native grasses commonly used in wetland restoration are water-intensive and can negatively affect water levels in wetlands. In addition, native vegetation, especially the aquatic and semi-aquatic types, reduce the amount of pesticides present in wetlands (Main et al., 2015).

5 Ecosystem Functions

As mentioned earlier in this report, wetlands provide many important ecosystem functions. Ecosystem functions are actions that occurs naturally in ecosystems because of the interactions between the ecosystem structure and its physical, biological, and chemical processes. Wetlands in the PPR are disproportionately abundant in ecosystem function and goods & services, especially in regards to waterfowl and other migratory birds (Gren et al., 1994; Johnson et al., 2005). As a result, management decisions need to incorporate the preservation of a mixture of land-use types to ensure a mix of services and multiple benefits, including social, economic, and ecological to ensure the continued healthy functioning of wetland ecosystems.

Natural and undisturbed wetlands generally have a greater ability to sustain these functions than restored wetlands, including supporting biodiversity. Better wetland and riparian restoration and construction techniques and design, together with time, can restore many natural functions to some degree, providing the landscape with functional wetlands again (Gleason et al., 2008).

5.1 Biodiversity and Habitat

As one of the hallmark characteristics of healthy wetlands, habitat for a diverse and abundant group of species and phyla of organisms in healthy wetlands is an important rationale for conservation and beneficial management practices. It also provides a basis for establishing regional wetland objectives, connectivity, and networks. Maintaining hydrodiversity helps maintains biodiversity (van der Kamp & Hayashi, 2009). Globally, many species of concern are associated with or dependant upon wetlands (Millennium Ecosystem Assessment, 2005). In Canada, wetlands provide habitat to over 600 species of plants and animals, and globally are second only to rainforests in the level of biodiversity (Ducks Unlimited Canada, 2006). In Alberta, about 80% of all wildlife use riparian areas for all or part of their lifecycle (Fitch et al., 2003). Riparian areas and associated upland forests are also important corridors and provide connectivity on the landscape for many wetland fauna species in fragmented landscapes (Nelner & Hood, 2011).

Loss of wetlands can lead to increases in habitat fragmentation (Johnson, 2001), affecting bird, mammal, and amphibian species. Many birds rely on wetlands for various stages of their life cycle. The wetlands of the PPR are, globally, the most productive habitat for waterfowl (Johnson et al., 2005). Annually, potholes produce almost half of North America's waterfowl (Batt et al., 1989; Smith et al., 1964). Aside from waterfowl, many other groups of birds rely on wetlands for breeding and food, including various raptor species and upland birds, shorebirds, colonial species, bitterns, herons, grebes, and rails

(Naugle, 1997; Shutler et al., 2000; White & Bayley, 1999; Whited et al., 2000). Approximately 250 bird species depend on wetland environments in Alberta for some part of their life cycle, or use wetland areas for feeding, nesting or cover (Alberta Environment, 2003). Habitats with wetlands nearby have higher diversity and quantity of raptors and other upland birds than those that do not (Shutler et al., 2000; White & Bayley, 1999).

Wetlands provide important habitat for other animal groups such as amphibians, reptiles, and mammals. Reptiles often forage in aquatic or semi-aquatic habitats, but migrate upland for nests, basking, and hibernating (Semlitsch & Bodie, 2003). In Alberta, about 15 species of amphibians and reptiles rely on wetland habitat to survive (Alberta Environment, 2003). The provincially and nationally listed northern leopard frog (*Lithobates pipiens*) is found in the Battle River watershed (AESRD, 2012a), and utilizes a few wetlands at CFB Wainwright (S. Mascarin, personal communication, September 15, 2016). As this species requires three different habitats in close proximity to carry out its lifecycle, land use changes have resulted in large decreases in populations across the country, including Alberta (AESRD, 2012a, Environment Canada, 2013b; Pope et al., 2000). Other species of amphibians, including wood frogs (*Rana sylvatica*) (Baldwin et al., 2006) and tiger salamanders (*Ambystoma tigrinum*) (Semlitsch, 1998), require healthy wetland and well as surrounding riparian areas.

Prairie potholes also play an important role in the life cycles of many mammals. Mammal species that utilize wetlands are quite diverse. Though there are few wetland obligate species, many forage and seek shelter in wetland and riparian areas, and thus are impacted by wetland health and functions. In Alberta, 17 species of mammals depend on wetland habitat to survive, with around 44 fur-bearing mammals that use wetlands (Alberta Environment, 2003). In the Miquelon Lake Provincial Park area, at the edge of the Battle River watershed, beaver-modified wetlands foster high biodiversity among many types of mammals, even in winter (Nelner & Hood, 2011). These include deer, weasel species, moose, coyote, pine marten, snowshoe hare, red squirrel, red-back vole, and various shrew species. The muskrat is an example of an animal found throughout the PPR. Muskrats inhabit all types of wetlands (at least temporarily), but only thrive in wetlands deep enough to allow for activity under the ice throughout the winter (Fritzell, 1989).

Small, isolated, restored wetlands can also be important mammal habitat. Work done to study the role of mammals as bioindicators for restored wetlands suggests that species richness and composition does not differ largely between natural and restored wetlands (Kurz et al., 2013). Well-designed and maintained restored wetlands with forested areas may be a feasible solution for at least some of the ecological impacts associated with wetland loss (Kurz et al., 2013).

5.2 Water Quality

Water quality in wetlands is determined and influenced by many factors. Surrounding land use, vegetation (amount and type), type of wetland, pond permanence, landscape position, hydrogeologic characteristics, flood and drought cycles, as well as temporal factors such as season all influence the chemical, physical, and biological processes that influence wetland water quality (Brunet, 2011; Gabor et al., 2004). Surface water runoff can be a large contributor to varying water quality depending on the surrounding land use. It is important to remember that many of the elements that contribute to water quality challenges, such as nitrogen and phosphorous, are essential elements of living systems. It is the quantity of these substances, and where they are ending up that contribute to challenges.

Wetlands have different combinations of salts, often related to location of the wetlands, groundwater inputs, or soil characteristics (van der Kamp & Hayashi, 2009; Brunet, 2011). Concentration of these salts varies seasonally as evaporation exceeds precipitation (Brunet, 2011). Variations in salts and dissolved organic carbon in wetlands are linked to hydrological processes, such as runoff, evaporation, and shallow groundwater interactions (Brunet, 2011).

Much of the excess nutrient run off, and accompanying sediment and pesticides, from surrounding urban and agricultural land use can be stored in wetlands (up to around 98% of sediment) (Gabor et al., 2004). Wetlands convert and store much of the nitrogen and phosphorous in sediments, in the water column, in organic material, or is given off into the atmosphere (Brunet, 2011; Gabor et al., 2004). Studies have suggested that in a wetland, there can be a reduction of nitrogen and phosphorus by 91% and 94%, respectively (Gabor et al., 2004). As a result of biological processes, dissolved oxygen content in wetlands vary with type, size, temperature, and depth of the wetland (Brunet, 2011).

Coliforms occur naturally in soil and water systems. Snowmelt and large precipitation events can cause large amounts to enter waterbodies. Populations of semi-aquatic mammals and waterfowl also produce coliforms. Large quantities of animal waste coliforms could also come from cattle operations or through use of manure in field fertilization (Brunet & Westbrook, 2012). Wetlands manage the levels of coliforms, as well as nitrogen and phosphorous, through biological, sorption, and hydrological processes (Brunet, 2011). Some studies have suggested that natural wetlands can reduce coliforms up to 99% (Gabor et al., 2004).

High levels of biological productivity in wetlands, especially the abundance of submerged and emergent plants, aids in the dissipation of pesticides (Kao et al., 2002). The aquatic and hydrophilic vegetation increases the available surface area for pesticide adsorption, plant sequestration, microbial degradation, and exposure to light (Gabor et al. 2004). In addition, the generally shallow character of wetlands allows for further light penetration, allowing some chemicals to be broken down by the light (photolysis) (Gabor et al. 2004). In general, common pesticides of surface and groundwater tend to disappear rapidly from wetlands (Gabor et al. 2004), though whether this is true for neonics is still being studied.

Drainage of wetlands, rural and urban, reduces water quality on a watershed scale. Drainage not only allows excess nutrients and other pollutants from the current year to flow freely off the landscape, but excess nutrients and potential contaminants stored in the soils of the former wetland also leech out during runoff and heavy precipitation events. This has implications for nutrient loading and eutrophication in watercourses and waterbodies downstream (Venterink et al., 2002; Brunet, 2011; T. Scott, personal communication, October 31, 2016). With increased drainage also comes increased soil erosion and more inputs from surface water runoff.

Wetlands play a key role in capturing surface water runoff and filtering out harmful contaminants. By providing and maintaining multiple natural barriers to contaminants and excess nutrients, we can help ensure a safe, clean and reliable supply of water. Wetlands are an essential component of this "multi-barrier" approach to source water protection. Many source water protection plans, including the *Camrose Source Water Protection Plan* (City of Camrose & Camrose County, 2016) and the *North Saskatchewan River Source Water Protection Plan* in Saskatchewan (North Saskatchewan River Basin Council, 2008), incorporate wetland conservation and management to minimize certain risks pertaining to water quality.

5.3 Water Quantity

Since most wetlands are replenished from snowmelt and runoff, changes in the quantity of precipitation affect wetlands, including water quality. By their nature, wetlands help mitigate extreme events such as flood and drought. As most prairie potholes typically lack surface connections to streams at average water levels, this makes them effective at flood mitigation (Hubbard & Linder, 1986; Murkin, 1998). During higher than average precipitation years, some wetlands may join and form stream channels, temporarily increasing the drainage area (Shook & Pomeroy, 2011) (Figure 14). When ditches are created and wetlands are drained, this artificially increases the contributing area of the new channels, increases the likelihood of ongoing downstream flooding (Gabor et al., 2004; McCauley et al., 2015).

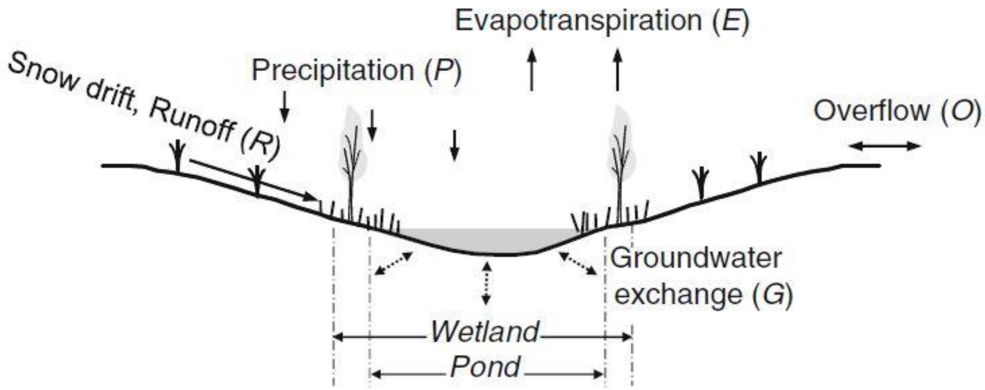


***Figure 14*. Diagram of the water balance components of a prairie wetland. Dashed arrows indicate the exchange of groundwater with surface water. The pond is a wet area within the wetland. Adapted from "Hydrology of Prairie Wetlands: Understanding the Integrated Surface-Water and Groundwater Processes" by M. Hayashi, G. van der Kamp, & D.O. Rosenberry, *Wetlands, 36 (Suppl.2)*, p. 245. Copyright 2016 by Springer. Reprinted with permission.**

Periodic drying of wetlands is also to be expected. Drought years where potholes dry up or partially dry are important for cycling within the wetland, allowing oxygen to re-enter the system, organic matter to break down and release nutrients, and reinvigorate the plant communities by allowing new seeds to germinate (Brakhage, n.d.; Zenner & Hancock, 2012.). Overall, periodic drying leads to increased wetland productivity when water returns (Brakhage, n.d.). Groundwater infiltration functions are not greatly impacted by drought (Fang & Pomeroy, 2008).

Shook and Pomeroy (2011) described hysteresis, or a memory effect, in wetland systems in the Canadian prairies. Wetland complexes 'remember' their initial conditions, where the storage of water may cause 'memory' in the system, where the response of the system at any time depends on the history of inputs and outputs. This has implication in terms of wetland hydrological resiliency to drought events and keeping water on the landscape.

5.3.1 Wetland Drainage, Consolidation, and Surface water Connectivity

With the interim Alberta wetland policy (Alberta Water Resources Commission, 1993), destroyed wetlands were compensated for based on acreage. As a result, fewer larger wetlands were constructed in the place of several small wetlands. Drainage and ditching of small rural wetlands resulted in much the same conditions. However, whether through drainage or as compensation, consolidation of wetland area became standard practice (Rooney, 2014), which reduces the perimeter to area ratios (larger wetlands), and their associated functions. This includes decreased habitat for all species, such as aquatic invertebrates and waterfowl (and other migratory birds) by reduced spatial variability in wetland conditions (McCauley et al., 2015; Wiltermuth, 2014).

The preferential loss of small upland wetlands, especially seasonal and temporary ones, has led to the homogenization in the size of wetlands. This has negative repercussions for ecosystem services. Decreases in the perimeter to area ratio reduces biochemical processes and groundwater exchange (Van Meter & Basu, 2015). In addition, these losses isolate remaining small wetlands, with distances almost double from historic distribution. This has implications for dispersal and migration of wetland species, as well as in terms of wetland connectivity. Migratory birds often overlook landscapes with low wetland density as potential habitat (Van Meter & Basu, 2015).

As mentioned earlier, increasing consolidation and surface water connections limits the ability of wetlands store water and increases the likelihood of ongoing downstream flooding (Gabor et al., 2004; McCauley et al., 2015). These impacts, in addition to warming temperatures, increased rainfall fraction, earlier snowmelt, and more multiple day rainfall events as impacts of climate change, could result in an overall dramatic increase in flows generated from snowmelt, rain-on-snowmelt, and rainfall runoff processes (DeBeer et al., 2016).

In short, wetland drainage and consolidation causes significant changes in wetland and watershed hydrology, as well as associated functions and ecological services. The *Watershed Resiliency and Restoration Program* (WRRP) (Alberta Environment and Parks, 2015) works to address issues of natural watershed functions in Alberta through restoration of natural/green infrastructure (riparian areas and wetlands). The primary objective of the WRRP is to "increase the natural ability of the province's watersheds to reduce the intensity, magnitude, duration and effects of flooding and drought through watershed mitigation measures" (Alberta Environment and Parks, 2015, para. 6) by promoting natural infrastructure on a watershed scale. Additionally, the program addresses the impacts of past flooding and/or droughts through the restoration of degraded priority areas of watersheds (Alberta Environment and Parks, 2015). Though the program is voluntary, grants are available, especially for designated priority areas.

5.4 Groundwater Connectivity

Recharge of groundwater is an extremely important function of some wetlands. Prairie wetland hydrology is extremely complex (Woo & Rowsell, 1993; Hayashi et al., 1998b; van der Kamp et al., 2003; Fang et al., 2010; Pomeroy et al., 2010) with multiple factors and connections involved. Depending on the landscape position of wetlands, variations in climate, configuration of water tables, and the hydraulic conductivity of the underlying substrate, the amount of groundwater recharge and hydrologic connectivity varies

(Hayashi et al., 2016; van der Kamp & Hayashi, 1998). As a result, prairie potholes can have either groundwater recharge, flow-through, or discharge function (Hayashi et al., 2016; van der Kamp & Hayashi, 1998) (Figure 15).

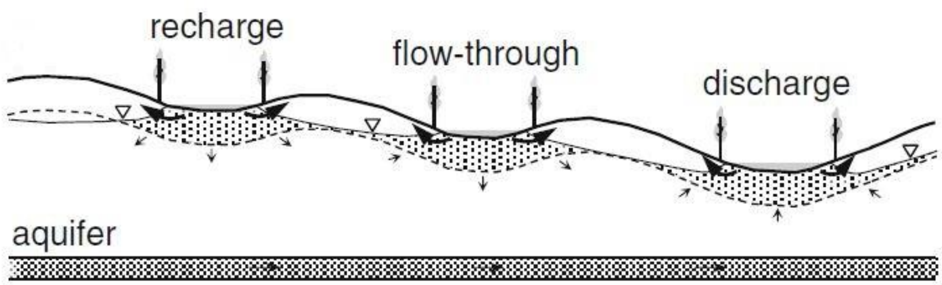


***Figure 15*. Diagram of groundwater flow under wetlands. Dashed lines indicate the boundary between sediments with high and low hydraulic conductivity. Solid arrows indicate the water table, stippled area indicate the effective zone of groundwater flow, and the size of arrows of arrows indicate relative magnitude of flow. An inter-till sand aquifer underlays the wetland complex. Adapted from "Hydrology of Prairie Wetlands: Understanding the Integrated Surface-Water and Groundwater Processes" by M. Hayashi, G. van der Kamp, & D.O. Rosenberry, *Wetlands, 36 (Suppl.2)*, p. 245. Copyright 2016 by Springer. Reprinted with permission.**

Research conducted by Hayashi et al. (2003) determined that ephemeral wetlands in small closed depressional areas could play an important role in the hydrology and ecology of many landscapes, by storing runoff water, recharging soil moisture and shallow groundwater, and by providing food and habitat for many organisms. The clay-rich soils of the prairies have low hydraulic conductivity, and they are even lower when they are frozen. Water in most small prairie pothole wetlands readily, but slowly, percolates to shallow groundwater, but deep aquifer recharge is negligible because of clay-rich soils throughout much of the PPR (van der Kamp & Hayashi, 2009). Prairie wetland groundwater recharge rate to shallow aquifers range from 5-40 mm/year (van der Kamp & Hayashi, 1998; Hayashi et al. 1998a).

As a result of significant snowmelt runoff occurring over the frozen soil in early spring, small (<1000 m2) depressions can store a large portion, or all, of snowmelt runoff in their respective watersheds (Hayashi et al., 2003). Each depression has a small storage capacity, but they collectively provide significant retention capacity, which adds up to significant water storage, flood attenuation and groundwater recharge capacity. Most of these wetlands only have out flows when their storage capacity is exceeded through heavy rainfall events (van der Kamp and Hayashi, 1998). Ultimately, Hayashi et al. (2003) demonstrated that ephemeral wetlands have several important functions including the retention of snowmelt runoff, soil moisture replenishment, and shallow groundwater recharge providing a cumulative benefit to the watershed.

Diversity in wetland hydrology is important for maintaining biodiversity (Hayashi et al., 2003). As such, the wetland complex and their drainage basins in a given area (i.e. local watersheds) should be approached as an interconnected hydrologic unit crucial for integrated wetland ecosystem management (Hayashi et al., 2016; van der Kamp & Hayashi, 2009).

5.5 Carbon Storage

Globally, wetlands account for 20-30% of total terrestrial carbon storage in soils (Mitsch & Gosselink, 2007), with North American freshwater mineral soil wetlands holding around 18% of that (Bridgham et al., 2006). The high productivity of prairie pothole wetlands enables them to accumulate organic carbon faster than some other types of wetlands (i.e. peatlands) (Badiou et al., 2011), making them net carbon sinks for carbon despite some methane emissions. In a study done in the Broughton Creek watershed in Manitoba, it was suggested that wetlands store the equivalent of 4 tons of CO_2 per year (Yang et al., 2008).

Carbon, along with oxygen and hydrogen, form the base of life, and contributes to the biodiversity in wetlands. Organic carbon in the water column is exchanged with air, sediment interstitial water, and biomass through biological processes. It can also settle out of the water column. Prairie potholes tend to be naturally high in dissolved organic carbon (DOC), though amounts can vary temporally with evaporation. Seasonal wetlands also tend to higher concentrations of DOC (Brunet, 2011). It is also important to note that natural wetlands have higher carbon sequestration capacity than constructed wetlands, and it may take several decades for restored and constructed wetlands to reach comparable levels (Kayranli et al., 2010).

6 Ecosystem Services

Ecosystem services provided by wetlands are important elements to include in education and societal understanding of the value of wetlands. Ecosystem services (ES) are defined as “the benefits people obtain from ecosystems” (Millennium Ecosystem Assessment, 2005, p. v). They can further be distinguished as provisioning, regulating, cultural, or supporting services. Wetlands are important areas for the provision of ecosystem services. Within the wetland complex, different wetlands have different functions and values. To maintain these functions, ecosystem services, and values, wetland polices need to consider the integrated value of wetland diversity (Hayashi et al., 2016). No net loss policies should not only pertain to acreage or wetlands, but also to ecosystem functions, values, and services.

Stakeholders at different spatial scales can have very different interests in ecosystem services. A study conducted by Hein et al. (2006) suggests that ecosystem services such as fishing and hunting are important at the municipal level, while recreation is most relevant at the municipal and provincial level. However, nature conservation is often only important in particular at the national and international level, though there are exceptions. This scale differential in valuation of ecosystem services is important to consider in application of support for the formulation or implementation of ecosystem management plans (Hein et al., 2006).

In the United States, the *Wetland Ecosystem Services Protocol for the United States (WESPUS)* was developed as a standardized method for use in rapid assessments of ecosystem services (functions and values) of all wetland types throughout temperate North America. It assesses services at the individual wetland scale, rather than across large landscapes. However, WESPUS incorporates many landscape factors, especially as they relate to the values of a wetland’s functions (Adamus, 2011). It is intended to provide wetland managers with “consistent and accurate numeric estimates of the relative ability of a wetland to support a wide variety of functions and values important to society) (Adamus, 2011, p.1). WESPUS was used to develop a similar method for Alberta, the *Wetland Ecosystem Services Protocol for Southern Alberta (WESPAB)* (Adamus, 2013), currently known as ABWRET-A (Government of Alberta, 2015d).

6.1 Valuation and Ecological Services

The value of ecological areas in terms of ecological services (ES) and the valuation of those services have been heavily studied since the 1970s. However, the value of ecological goods and services has not been fully developed for wetlands, primarily as land value changes, societal norms and values vary, and services are varied for wetlands types.

Wetlands supply a variety of services. Some values are more quantifiable, and some are not as quantifiable but may be more important on a larger scale (Mitsch & Gosselink, 2000). Often, primary consideration is given to the value of the provisioning services (natural resources i.e. fiber, peat, growing food, animal meat) and the regulating services done by natural systems (filtering, producing oxygen, flood protection, etc.). Odum (1979) discussed how this might look in terms of types of wetland functions or values, and how well their value can be quantified (i.e. monetarily). At the local and population level, fish & wildlife, land value, and other component values are easily accounted for, yet make up a relatively small part of the total value. At the ecosystem level, hydrologic and biological productivity functions/values are hard to quantify, but increasing research in this area has led to progress. Lastly, global scale functions and values, such as waste and pollution assimilation, chemical cycling, and atmospheric stability have primarily externalized economic value (Odum, 1979).

However, there are also the health, well-being, and cultural services (i.e. inspiration for art, recreation, aesthetics, etc.) provided by wetlands. Cultural and non-use values have traditionally been difficult in the economic valuation of ecosystem services and are often excluded. In 2011, the Government of Alberta conducted a pilot study on ecosystem services approaches for wetlands east of the City of Calgary. Several reports were written, each focusing on different types of ES assessment approaches and values (Government of Alberta, 2011b). The purpose of the study was to develop and operationalize an ES approach as a tool to enhance wetland management decision-making to include a variety of ES values, including cultural and non-use ecosystem services.

6.2 Human Health and Wellbeing

In many countries around the world, wetlands are involved in complicated situations of water safety, and perceptions as sources for vector-borne illness (Horwitz & Finlayson, 2011). In Canada, these worries are minimal due to our water treatment facilities and our relative distance from wetlands in most cases. Interactions with wetlands and shallow groundwater stores would be the exception.

However, as more work is done on how to manage and live with wetlands, as well as understanding and appreciating their value, this work is incorporated into the movement towards a wider recognition of the meaningful relationships that exist between the well-being of people and the state of the environment they live in (Horwitz & Finlayson, 2011). This suggests that values attributed to wetlands (as well as other ecosystems) ought to incorporate overall human well-being. One aspect includes the psychosocial well-being and mental health impact. For many, especially landowners or those who visit particular wetlands regularly, wetlands are a part of their sense of place, and a change in these wetlands can have a strong impact of mental health (Higginbotham et al., 2007; Horwitz & Finlayson, 2011). Factors of lifestyle are also related to the ecosystem services, such as leisure, recreation and sporting activities, and education, provide both physical and mental health, given natural affinities for wetlands, lakes, and watercourses (Horwitz & Finlayson, 2011).

6.3 Cultural Values

As part of the human well-being aspect of wetlands, cultural and spiritual values are also important to consider as these can be linked to mental well-being. Many individuals and cultures hold a spiritual significance of water (Horwitz & Finlayson, 2011) and the natural systems in general. Spiritual, inspirational, and place values are not products of one kind of experience, but result from different kinds of experiences associated with ecosystems (Chan et al., 2012), including wetlands. Specifically, for many cultures and individuals, water has a spiritual significance (Horwitz & Finlayson, 2011).

Social and economic wetland values are often intertwined, or at least overlap, especially in the agricultural context (Graymore & McBride, 2013). Some farmers already understand the benefits of wetlands and already implement conservation measures to enhance those benefits. As a result, natural resource management organizations involved in wetland management should develop stronger relationships with landowners. In conjunction with adaptive management strategies that acknowledge existing conservation measures being implemented, integrating the knowledge of these other stakeholders keeps them as allies and important resources.

As part of the ES pilot study, (Government of Alberta, 2011b), discussion was given to cultural services and benefits associated with wetlands as "long term consequences for cultural benefits are greater than the loss of individual wetlands" (Government of Alberta, 2011b, p.71). These losses are not directly compensated for through the creation of another wetland in another location.

The cultural services and benefits of wetlands and the experiences they provide come from single wetlands, as well as from the wetland landscape. As a result, these cultural perspectives help people, and decision makers, consider the cumulative and long-term effects on wetlands. Loss of and impacts to wetlands influence people's ability to use and appreciate wetlands and wetland landscapes locally and regionally, and over the long term. Understanding more about cultural services also adds support to avoidance, mitigation and compensation decisions (Government of Alberta, 2011a).

6.3.1 Recreation

Recreation and aesthetic values of wetlands, and their associated activities are often undervalued in management plans and policies. Public wetlands are often important sites for other tourism and recreation activities, such as fishing, canoeing, photography, hiking, bird watching, nature study, cross-country skiing, scientific study, camping, and picnicking. Private and public wetlands can also be a significant source of revenue regionally, especially from hunters (Johnson, 1984). As the net economic benefits associated with wetlands-based recreation may be substantial, recreational functions provided by wetlands must be considered for wetlands policy and management (Bergström et al., 1990).

Though many recreational uses of wetlands exist because of high biodiversity at wetlands, some recreational activities can foster conflicts between wildlife and human use. Some types of recreation disturb wildlife and water bird nests (i.e. water-based activities), while other types of recreation can negatively influence and degrade buffers, altering the function of buffers. This can be especially true for urban wetlands where trails and paths are often placed within the buffers/riparian areas (Weston et al., 2009).

A growing area of concern is the use of off-highway vehicle (OHV) in wetlands. Aside from the impacts on vegetation and disruption of wildlife, OHV use in wetlands can increase sedimentation and turbidity, altering the hydrology of the wetland (Ouren et al., 2007). Contaminants could also enter wetlands through direct flushing of exposed contaminants from fuel, oil, and emissions. There is also a concern about the potential for adsorbed contaminants to be transported with precipitation runoff and into wetlands, along with absorbed contaminants in plant materials. Erosion from riparian and upland use of OHVs can also occur (Ouren et al., 2007).

Few regulations exist pertaining to OHV use in wetlands. Though the Alberta government encourages OHV operators to avoid wetlands and cross only at bridges and other designated crossings (Alberta Environment and Parks, 2016b; Alberta Transportation, 2010), only the SSRP (Government of Alberta, 2014) has regulatory details outlining OHV use on various public lands.

Nova Scotia, under its *Off-highway Vehicles Act* (2010), does not permit the operation of off-highway vehicles in or on wetlands, swamps, or marshes unless they have a permit to do so, or unless the wetland is covered by compacted or groomed snow of at least thirty centimetres deep. This is the only Canadian example of strict prohibition of OHVs from wetlands.

Management of wetlands through a management framework and process could help to alleviate conflict and maximise the value of a site for wildlife and human recreation interests as much as possible (Kirby et al., 2004). However, it is important to acknowledge that in some cases this may not be possible.

6.4 Payment for Ecosystem Services

Many studies have been conducted to identify, examine, and approximate monetary values for the spectrum of wetland services (i.e. Boyer & Polasky, 2004; Brander et al., 2013; Cai et al., 2013; Gascoigne et al., 2011; Gren et al, 1994; Grygoruk et al., 2013; Mann et al., 2014; Musamba et al., 2012; Pattison et al., 2011; Rafiq et al., 2014; Söderqvist et al., 2000; Thompson & Young, 1992; Turner et al, 2000;). Of all the ecosystems, wetlands seem to have attracted most of the attention of this approach, more than riparian areas or even uplands (though past programs have targeted uplands and native prairie), especially in the Prairie provinces. Though some studies can approximate the value of the land plus the multitude of functions and their value, wetlands are complex systems and likely have synergistic relationships that are almost impossible to reduce to their components. In addition, there are the non-use and cultural/spiritual values and functions that are arguably invaluable.

There are several reasons research into the valuation of ecosystem services began. First, it was done to have a way to get those who destroy ecosystem services to pay compensation and/or restoration. Secondly, it was to create a business case for conservation and protection to society in general or for a certain sector, but also to create a basis for the idea of compensating landowners to protect or manage the ecosystem services (i.e. riparian areas, wetlands) for the rest of society. As well, it was important for regulators in order to implement better regulation around wetland removal and compensation.

Though the services and functions of wetland ecosystems are increasingly recognized as important from policy and management perspective, they are still considerably under-valued by society (Badiou et al., 2011). Some of this may be due to the perceived negative aspects of wetlands and the management of those challenges.

7 Additional Challenges in Wetland Management

Though wetlands provide many important benefits, functions, and services, there are some additional significant challenges pertaining to wetland management. Whether they are based on perceptions, human interference, or changing climate, these topics deserve attention, and need to be understood in light of managing wetlands.

7.1 Beavers

Beavers, as a keystone species, modify the habitat of wetlands (or create wetlands) to make them more beneficial for beavers, as well as for other species. Though beavers are much maligned by some for the flooding effects of beaver ponds, appropriate land use for long-term benefit can allow for co-existence and is essential for sustainability. Cows and Fish (2013) developed a tool for decision-making about potential concerns and opportunities developed a beaver management matrix for agricultural producers regarding beavers on their land.

Beavers, through their channeling, dredging, and damming activities in wetlands, increase the amount, and duration, of water storage in wetlands with implications for drought and climate instability (Hood & Bayley, 2008). As well, beaver ponds tend to have higher biodiversity the wetlands without beavers. This is true for invertebrates Hood & Larson, 2014a), amphibians (Anderson, 2013; Anderson et al., 2014; Stevens et al., 2007), waterfowl (Bromley & Hood, 2013; Shutler et al., 2000), and mammals (Nelner & Hood, 2011). Beaver channels increase the complexity of the bed and shore, increasing habitat for invertebrates at the base of the food chain. Increased complexity created by beavers increases perimeter length, leading to higher perimeter to area ratios. In the Miquelon Lake Provincial Park area, at the edge of the Battle River watershed, beaver-modified wetlands foster higher levels biodiversity among many types of mammals than at non-beaver-modified wetlands, both in the protected area and in an agricultural setting (Nelner & Hood, 2011).

Despite their benefits, living with beavers can be challenging. Many areas have recognized the place of beavers in maintaining ecosystems, and have developed ways on working with them. Multiple states in the U.S. have seen the value of beavers, and have developed different management techniques to achieve their desired results (see Needham & Morzillo, 2011; Pollock et al., 2015; Tippie, 2010; Utah Division of Wildlife Resources, 2010). Similar management efforts are beginning in Alberta. The Miistakis Institute (Haddock, 2015), and Beaver County in collaboration with University of Alberta (Hood & Yarmey, 2015), have been working on strategies on how to incorporate the use of beavers in watershed stewardship and climate change adaptation.

There have also been discussions about implementing beaver restoration in some location. This is often connected with the desire of wetland restoration and restoring the species dependant upon wetland habitat. Though restoring wetlands and riparian areas may bring beavers through migration, the idea of translocating beaver to assist with wetland restoration has been proposed. Though some American jurisdictions allow (or at least do not regulate) beaver translocation, it will be important to understand how beaver restoration could fit into Alberta's Wetland Policy and wetland restoration, especially from a wetland replacement perspective (Haddock, 2015). It is also extremely important to consult with all stakeholders who would be affected by such measures. Currently, it is prohibited to have possession of a wild animal without a permit, or to release an animal from captivity (*Wildlife Act*, 2000), as well as regulations on trapping beavers. No guidelines exist on trapping and relocation of beavers, such as holding requirements, suitable release habitat, and minimum distance from source location, or follow-up monitoring (Specht, 2015).

7.2 Mosquitoes and Wetlands

Aside from beavers, the other type of organism commonly associated with wetlands that can foster hostility and annoyance is the mosquito. Though mosquitos are vectors for diseases, such as the West Nile virus in Canada (and many other countries around the world), several studies suggest that mosquito control has primarily been needed in constructed wetlands or stormwater ponds (i.e. Jackson et al., 2009). This is likely due to several factors. Firstly, these waterbodies are where humans are most concentrated and where a lot of recreation occurs, unlike in the remote peatlands or other natural wetlands. Secondly, most naturally occurring wetlands have established ecosystems with well-developed natural feedback mechanisms, such as predator-prey interactions, which tend to keep opportunistic species (i.e. mosquitoes) in check (Chase & Shulman, 2009; Greenway, 2005; Jackson et al., 2009). These natural checks and balances are not easily duplicated in artificial systems. Most natural wetlands, especially beaver-modified wetlands (Butts, 2001, 2004; Hood & Larson, 2014a), have fewer larval mosquitoes. This may be due to healthy populations of predators (Chase & Shulman, 2009), or unfavourable habitat characteristics (Hood & Larson, 2014a).

7.3 Invasive Species

Over the years, invasive species have become an issue in many altered or disturbed wetlands, as well as those that are used as recreation sites in Alberta and throughout North America. As defined in a report by Skinner (forthcoming), invasive species are non-native species "whose introduction and spread causes or may cause harm to the local environment, human health, society, and economic activity" (p.8). They often are able to spread rapidly with few or no natural predators, and limited control mechanisms for them exist. Though no records of invasive aquatic plants or animals have been reported in wetlands of our watersheds, they may be there already, or could appear at any time. Appropriate prevention and management actions are required at all times to ensure these species do not gain a foothold in our watershed.

Invasive species are problematic biologically as they often out-compete native species, leading to a decline in biodiversity an ecosystem function. They can also damage or overtake the land and substrate. Up until recently, most of the recognized problematic species have been plant species. Some of the more common/problematic invasive aquatic plants in wetlands and riparian plants are (Alberta Invasive Plants Council, 2012):

- Purple loosestrife (*Lythrum salicaria*) (shore)
- Eurasian watermilfoil (*Myriophyllum spicatum*) (aquatic)
- Flowering-rush (*Butomus umbellatus*) (shore)
- Yellow flag Iris (*Iris pseudacorus*) (shore)
- Curly leaf pondweed (*Potamogeton crispus*) (aquatic)
- Himalayan Balsam (*Impatiens glandulifera*) (shore)
- Didymo (*Didymosphenia geminate*) (aquatic)
- European common reed (*Phragmites australis australis*) (shore/aquatic)
- Salt Cedar (*Tamarix* spp.) (shore)
- Hydrilla (*Hydrilla verticillata*) (aquatic), and
- Brazilian Elodea (*Egeria densa*)

Within the last decade, fish species, such as goldfish and Prussian carp (*Carassius gibelio*), and bullhead catfish have become greater concerns, and are some of the prohibited species in Alberta. Aquarium owners often release these fish species (as well as some of the invasive aquatic plants) into ponds, wetlands, and lakes. In the past, triploid (sterile) grass carp (*Ctenopharyngodon idella*) were used for weed control in urban waterbodies and rural dugouts and ponds in Alberta. Though this species is now prohibited across Canada (Skinner, 2016), remnant populations may still persist.

The presence of zebra mussels in Lake Winnipeg has become a concern for Alberta. As this species is now present in the watershed we are connected to, zebra mussels could travel to our reaches through water connectivity, as well as via their most common mode of transport – hitchhiking. These mussels, along with many invasive aquatic plant species, can attach to boats, fishing gear, or caught in propellers. The *Fisheries (Alberta) Act* (2015) has a list of 52 prohibited aquatic species, many of which could pose a threat to wetlands.

Wild boar has become an issue in the Prairies. They damage upland habitat, and could be potentially quite destructive for wetlands. Wild boars often make nests from cattails and other wetland grasses. As they root and dig, they eat large amounts of native vegetation, and even eat nesting waterfowl (Nature Conservancy of Canada, 2015). No reports of wild board have been issued within the Battle River or Sounding Creek watersheds, but as this species expands its range, it may enter our area.

Stormwater wetlands (and ponds) have recently become sites of concern for invasive/exotic species through the intentional release of aquarium pets. This has led to goldfish infestations of stormwater sites in various locations throughout Alberta (K. Wilson, personal communication, December 8, 2016). Though this has not yet been an issue in the Battle River and Sounding Creek watersheds, the potential exists. It is illegal to intentionally release aquarium pets into the wild (Alberta Environment and Parks, 2016a; *Fisheries (Alberta) Act*, 2000). Some aquarium plant and fish/animal species are invasive and can become a threat to natural aquatic ecosystems.

Though invasive species have found niches in some of our wetlands, some management is possible, such as killing any non-native fish you find. Ensuring these species do not spread is crucial to maintain wetland health and biodiversity. Increased management of invasive species will be essential to reduce stress on wetlands in a changing climate (Erwin, 2009).

7.4 Wetlands and Climate Change

As climate change progresses, the role of and impact on wetlands is uncertain. How wetlands respond to climate change will vary depending on factors such as geographic location, hydrology, morphology, vulnerability, and current & future socio-economic effects (Cox & Campbell, 1997). Erwin (2009) suggested that climate change with impact wetlands directly and indirectly in two major ways through the effects of temperature changes, changes in hydrology and land use. There will be an overall decline in the number of functioning wetlands and their functional capacity and shifts in geographic location of wetland types. Wetland habitats will be impacted climate change differently on a regional and watershed level, so it is important to recognize specific management and restoration issues will require examination by habitat (Erwin, 2009).

Based on climate modelling done by Johnson et al. (2005) (see also Mitsch and Hernandez, 2013), the western portion of the PPR (Alberta and Saskatchewan) will likely see a drying trend, whereas the more eastern and southern parts will likely get wetter. This drying, compounded by any continual loss, will reduce both the number and quality of wetlands in the Alberta portion of the PPR. Shorter pond permanence, change in permanence, increase in frost-free days, and the resulting less dynamic vegetation cycles will further reduce productivity in much of Canada’s western PPR wetlands that have may have already showed a decline due to climate change (Johnson et al., 2010; Renton et al., 2015; Werner et al., 2013). These changes will influence biological, biogeochemical, and hydrological functions in wetland ecosystems, as well as the associated socio-economic benefits (Cox & Campbell, 1997).

The climate and wetlands of the PPR should be monitored closely in the future to look for signs of higher evaporative demand and reduced pond permanence to prepare for with less-productive wetlands, especially in western Canada (Millett et al., 2009; Mitsch and Hernandez 2013). More long-term wetland monitoring sites in the PPR that could better detect early signs of warming on water levels and pond permanence would greatly benefit adaptive management efforts (Conley & van der Kamp, 2001).

As wetlands are important areas for net in carbon storage (Badiou et al 2011; Mitsch & Gosselink, 2000), wetland restoration could be a potential climate change mitigation tool (Badiou et al., 2011). Constructed wetlands are higher emitters of carbon dioxide and methane than natural wetlands, so these should to be designed and managed properly (Kayranli et al., 2010).

With their ability to store water, wetlands help manage extremes in water quantity. Wetlands that have been altered by beaver activity by the creation of channels that distribute water far beyond the waterbody's edge, dams that hold water and sediment, and have increased depth and complexity, foster the creation of healthy wetland and riparian areas and are more resistant to disturbance in climate (Hood & Bayley, 2008; Hood & Larson, 2014b). This applies not only to natural cycles of drought, but also to increased climatic variability, loss of hydrostationarity (the previously used water management approaches based on precipitation patterns of the past expected to remain stable into the future), and extreme weather events that are likely to accompany climate change and disruption.

8 Governance and Legislation

Many North American jurisdictions have adopted the hierarchical mitigation direction of 1) avoidance, 2) minimize impacts, and 3) compensation in wetland management (Clare et al., 2011). Complimenting this, the *no net loss* policy has also frequently been used. However, operationally, compensation has become the preferred mechanism in many jurisdictions.

In this section, various policies, legislation, and other governance tools that have been developed are discussed. Though these samples are North American, various European and Asian countries have also developed policies regarding wetland management.

8.1 Federal

Formal federal legislation does not exist in Canada for the protection and conservation of wetlands. Canada does have a national wetland policy. The objective of the *Federal Policy on Wetland Conservation* put out by the Government of Canada (1991) is to "promote the conservation of Canada's wetlands to sustain their ecological and socio-economic functions, now and in the future" (p.5). Wetland conservation is supported throughout the full extent of federal decisions and responsibilities. The *Policy* is not a regulatory document, though the federal Cabinet "directed that it should be applied to all policies, plans, programs, projects, and activities carried out by the federal government" (Lynch-Stewart et al, 1996, p.7).

By working in cooperation with provinces and territories, the Federal Government of Canada strives to achieve the several goals:

- maintenance of the functions and values derived from wetlands throughout Canada;
- no net loss of wetland functions on all federal lands and waters;
- enhancement and rehabilitation of wetlands in areas where the continuing loss or degradation of wetlands or their functions have reached critical levels;
- recognition of wetland functions in resource planning, management and economic decision-making with regard to all federal programs, policies and activities;
- securement of wetlands of significance to Canadians;
- recognition of sound, sustainable management practices in sectors such as forestry and agriculture that make a positive contribution to wetland conservation while also achieving wise use of wetland resources; and
- utilization of wetlands in a manner that enhances prospects for their sustained and productive use by future generations (Government of Canada, 1991, p.5-6).

In conjunction with the *Policy*, the Government of Canada also released an implementation guide (Lynch-Stewart et al., 1996). This guide was designed to "assist federal land managers when making decisions that may affect wetlands", as well as to "assist departmental policy makers in developing "customized" departmental plans and directives for implementing the *Policy*" (Lynch-Stewart et al., 1996, p.7), by providing

- a reference on policy interpretation, explaining the wording and intent of *Policy* statements;
- practical information on the roles and responsibilities of federal land managers and the Canadian Wildlife Service, as well as on the processes and tools for implementing those responsibilities; and,
- references and resources available to assist land managers in carrying out their wetland conservation responsibilities. (Lynch-Stewart et al., 1996, p.7).

There is federal legislation that indirectly addresses wetland conservation and compensation. Under the *Migratory Bird Convention Act*, no disturbance to nests or nesting birds is permitted during breeding and nesting periods (approx. early April to late August in most parts of Canada). Some bird species have more specific legislation requirements under the *Species at Risk Act.* Industrial activities can affect migratory birds by disturbing land (i.e. road construction, clearing trees), sensory disturbance (i.e. noise, light), and through emergencies (i.e. fires, spills) (Alberta Wetland Policy, 2016)

In addition, the *Canadian Environmental Assessment Act*, the *Fisheries Act*, the *Navigable Waters Protection Act*, and the Convention on Biological Diversity (Convention on Biological Diversity Secretariat, n.d.) may have implications for projects that impact wetlands or wetland species in Alberta, and for Alberta wetlands in general. The extent to which these requirements are applied and enforced is a topic of much controversy, and further discussions about collaborative management are needed.

The lands of CFB Wainwright, located within the Battle River watershed, is owned by the Department of Defence. Like other federal ministries, it adheres to the *Federal Policy on Wetland Conservation* (Government of Canada, 1991). Additionally, as a leaseholder of Alberta Public lands, they are also must the objective of Provincial and Federal Acts, policies, and regulations regarding wetlands. CFB Wainwright is developing the strategies to protect wetlands, including use and development of an environmental awareness map, oil & gas management and development, grazing agreements, managing beaver activity, and designated fording sites (CFB/ASU Wainwright – Base Environment, 2013). The aim is to effectively and sustainably manage land use and natural resources while providing realistic military training (CFB/ASU Wainwright – Base Environment, 2013).

8.2 Provincial

Aside from Alberta, several provinces in Canada, including Ontario (Ministry of Natural Resources and Forestry, 2016), British Columbia (Wetland Stewardship Partnership, 2010), Nova Scotia (Nova Scotia Environment, 2011), and P.E.I. (P.E.I. Fisheries, Aquaculture and Environment, 2007), have developed wetland strategies, policies, and other management tools that influence wetland governance. To maintain a regional context for the purpose of this report, this section will focus on the Prairie Provinces, as they are all part of the PPR.

8.2.1 Alberta

8.2.1.1 Provincial-level policy

The *Water Act* is the primary legislation in Alberta that works to protect watercourses and waterbodies on private and public lands, including wetlands. Unlike the *Alberta Wetland Policy* (AESRD, 2013), the *Water Act* protects ephemeral waterbodies. Other pieces of legislation, such as *Municipal Government Act*, *Environmental Protection and Enhancement Act*, and the *Public Lands Act* all contain different aspects of wetland management. For a summary of how these acts are involved, please refer to the Alberta Water Council's *Recommendations for a New Alberta Wetland Policy* (Alberta Water Council, 2008a).

The *Water Act* is the primary legislation in Alberta that enables management and protection of water and waterbodies on private and public lands. The *Water Act* is the enabling legislation for the *Alberta Wetland Policy* (AESRD, 2013), as wetlands are considered waterbodies under the act. Other pieces of legislation, such as *Municipal Government Act*, *Environmental Protection and Enhancement Act*, and the *Public Lands Act* are also relevant for wetland management.

Alberta's Wetland Management in the Settled Area of Alberta: An Interim Policy (Alberta Water Resources Commission, 1993b) was developed in response to increased public awareness about wetland values and the need for wetland management in the White Area of Alberta. This policy, along with *Beyond Prairie Potholes* (Alberta Water Resources Commission, 1993a), were created in response to increased public awareness about wetland values and the need for wetland management. The stated goal of the interim policy was to "sustain the social, economic and environmental benefits that functioning wetlands provide, now and in the future" (Alberta Water Resources Commission, 1993b, p.1). It was in this document that the mitigation hierarchy was introduced with preference given to conserving sloughs/marshes in their natural state, then mitigating degradation or loss at or near the site of disturbance, then lastly enhancing, restoring, or creating sloughs/marshes in other areas where wetlands have been lost or degraded (Alberta Water Resources Commission, 1993b).

In 2013, the *Alberta Wetland Policy* (AESRD, 2013) replaced the interim policy, with full implementation in both the Green and White areas of Alberta in 2016, and provides policy, direction, and tools to support wetland management in the province. Wetlands are a key component of watershed health in and the *Alberta Wetland Policy* is integral to the achievement of all three goals of *Water for Life*. The *Alberta Wetland Policy* "provides the strategic direction and tools required to make informed management decisions in the long-term interest of Albertans" (AESRD, 2013, p.2), with the goal of conserving, restoring, protecting, and managing Alberta's wetlands "to sustain the benefits they provide to the environment, society, and economy" (AESRD, 2013, p.2). The *Alberta Wetland Policy* is supported by a number of tools and directives, including the *Wetland Identification and Delineation Directive*, the *Wetland Assessment and Impact Report Directive*, the *Wetland Mitigation Directive*, the *Alberta Wetland Restoration Directive*, the *Guide for Assessing Permanence of Wetland Basins*, the *Alberta Merged Wetland Inventory (AMWI)*, the *Alberta Wetland Classification System*, and the *Alberta Wetland Rapid Evaluation Tool (ABWRET)*.

The *Alberta Wetland Policy* addresses wetland values and functions by using a relative wetland value based on the following functions: biodiversity and ecological health, water quality improvement, hydrologic function, and human uses. Value categories of A to D are based on criteria related to these functions, as well as in consideration of the relative abundance wetlands in a given region of the province. The value categories are used to determine replacement values, in the case that wetland impacts are unavoidable. The Alberta Wetland Mitigation Directive (Government of Alberta, 2015b) is a key component of the Alberta Wetland Policy. The stated goal of the directive is to "inform decision making to avoid and minimize negative impacts to wetlands and, where necessary, replace lost wetland area and value". The Alberta Wetland Restoration Directive guides the process for replacement of wetlands and wetland values.

If there is a proposed direct or indirect impact to a wetland, an application for an approval under the *Water Act* must be submitted; the requirements in the Alberta Wetland Policy directives are administered through the approvals process. Submission of regulatory documents in support of an application to cause impacts to a wetland must be authenticated by a qualified individual. Alberta Environment and Parks has collaborated with ten professional organizations in the province to develop the Practice Standard for Wetland Science, Design, and Engineering. In addition to holding a designation with a professional organization, a practitioner must meet specific competency and professional experience requirements in order to authenticate regulatory documents. Under this system, the professional organization evaluates their members for competency and scope of practice in the fields of wetland science, design and engineering.

The applicant must demonstrate sufficient consideration of the mitigation hierarchy **avoid, minimize**, and in the case of unavoidable impacts, meet the requirements for **replacement.**

The priority is to replace wetlands near the point of original wetland loss. Wetland restoration on private land is voluntary. As defined in the Wetland Restoration Directive, there are three options for restorative replacement: payment to the in-lieu fee program allocated to restorative replacement with wetland restoration completed by a Wetland Replacement Agent, purchase of credits from a third-party wetland bank, or permitee-responsible replacement. It is anticipated that municipalities, environmental non-governmental organizations, consultants, and other organizations will be able to deliver wetland replacement services.

\Wetland conservation and restoration goals are supported by various tools enabled under the Policy but stewardship is also recognized in the Policy as an important component of effective wetland management. Stewardship will be advanced through education and awareness, voluntary programs, and/or incentives to encourage wetland conservation, restoration, and protection. Alberta Environment and Parks is currently working with stakeholders to explore opportunities for enhanced wetland stewardship, including the creation of a wetland banking program.

Several grants are currently available for creating and restoring wetlands. For example, Watershed Resiliency and Restoration Program (WRRP), through Alberta Environment and Parks (AEP), and the Growing Forward 2 program, though Alberta Agriculture and Forestry (AAF), provide financial assistance for restoration or creation of wetlands. Replacement agents like DUC may also pay landowners for voluntary restoration (T. Scott, personal communication, October 17, 2016).

Another joint program through Growing Forward 2 and Government of Alberta is the Agricultural Watershed Enhancement (AWE) Program. AWE aims to promote wetland restoration and riparian health BMPs by producers within the agricultural sectors (AESRD, 2014a).

Accompanying the new wetland policy are several directives. The *Alberta Wetland Identification and Delineation Directive* (Government of Alberta, 2015a) is to improves both the accuracy and consistency of delineating wetlands using standardized identification and delineation methods. The directive can also be used for other related initiatives such as creating wetland inventories, land use planning, and establishing setbacks (Government of Alberta, 2015a). The *Alberta Wetland Mitigation Directive* (Government of Alberta, 2015b) informs "decision making to avoid and minimize negative impacts to wetlands and, where necessary, replace lost wetland area and value" (p.2). This directive lays out how proponents should proceed in avoiding and minimizing impacts, as well as what must be included in a Wetland Minimization Proposal, and how they plan to address reclamation where needed. The Wetland Replacement Matrix, replacements proposals and conditions, and replacement fees are also discussed.

In 2016, the Canadian Institute of Resources Law, with Alberta NAWMP Partnership, released the revised *Alberta Wetlands: A Law and Policy Guide* (Kwasniak, 2016) developed a document outlining the legal and policy status of wetlands in Alberta. This document outlining the legal and policy status of wetlands in Alberta, and provides an in-depth look at wetland and riparian areas within the international, federal, and Alberta legal framework.

8.2.1.2 Regional

Within Alberta, several regional approaches influence the management of wetlands within the Battle River and Sounding Creek watersheds. Some pertain specifically to the Battle River and Sounding Creek watersheds, and some are regional initiatives or organizations that operate within the watersheds.

The *Approved Water Management Plan for the Battle River Basin (Alberta)* (AESRD, 2014b) outlines that maintenance and restoration of wetlands is preferred to drainage. It also stipulates that wetland compensation for drainage within the basin must be applied within the Battle River Basin, and be located as near as is practical to the wetland where impact occurred. Other guidelines with respect to expansion of drainage infrastructure are included.

Though they do not cover all of the Battle River and Sounding Creek watersheds, the drainage districts also play an important role in managing wetlands. The *Drainage District Act* allows the district to enforce the closure or removal of any unauthorised works including existing ditch modification, culvert installation or new construction. Though previously involved in wetland drainage, drainage districts could provide a mechanism and opportunity to control wetland modification, especially in coordination with the new *Alberta Wetland Policy*. Districts have been able to enforce the reduction of wetland removal by refusal to improve ditches that would allow work, and by restricting outflow with smaller diameter culverts. If the districts are able to modify their assessment format in the future, there could be opportunities to directly fund wetland retention or increase assessments for wetland removal (A. Corbett, personal communication, November 19, 2016).

Work has also begun by North American Waterfowl Management Plan (NAWMP) in collaboration with other regional planning bodies (Land Use Framework, Alberta Environment and Parks, WPACs, and municipalities) to develop regional wetland management objectives. Though this work is still in the preliminary stages, setting regional wetland objectives would support the work of the Wetland Policy by setting recommendations for how the wetland policy outcomes could be accomplished in a given region. This approach would take regional context and values into account, and ensure wetland planning occurs across the province at appropriate scales. As a tool to ensure key wetlands and wetland habitats are conserved, it would also help ensure all stakeholders are involved to help make trade-off decisions as needed in regards to wetland restoration, conservation, and disturbance.

8.2.1.3 Municipal

The 2013 *Municipal Water Policy on Wetlands* by AUMA (2013) developed to provide a municipal perspective on the implementation the new Alberta wetland policy laid out several policy direction statements suggesting how municipalities and their partners can work towards conserving and restoring wetlands. The implementation of this policy will be ongoing as the provincial partners roll out the wetland policy.

Municipalities also have some control through the *Municipal Government Act* over waterbodies and land use in their jurisdiction. Land use bylaws and municipal develops plans are a couple of these tools that can be used to manage upland land use, buffers/setbacks, associated riparian areas, and other land management aspects of wetland management. Several municipalities within the Battle River Watershed suggest setbacks from wetlands and other environmentally sensitive/significant areas within their land use bylaws, area structure plans, and municipal development plans (i.e. County of Wetaskiwin, Leduc County, City of Camrose & Camrose County).

Other municipalities have developed stand-alone wetland policies/plans regarding the management and conservation of wetlands. The Town of Strathmore's *Wetland Conservation Plan* was created primarily to "identify, map, and classify all of the wetlands located within the current boundaries of the Town of Strathmore and within the proposed expansion area" (Sadler, 2005, p.3), including those of environmental significance. Strathmore's *Wetland Conservation Policy* (Town of Strathmore, 2007) outlines principles and strategies for a Wetland Policy Implementation Plan, including setbacks, development directions, and staff resources.

The purpose of the Rocky View County's *Wetland Conservation and Management Policy* is to provide polices and procedures to help Rocky View County conserve and manage wetlands while adopting or amending other municipal bylaws and operating polices and plans. This policy will also provide the County, the development industry, and all other stakeholders "with clear direction for the use and development of all municipal and private lands in proximity to wetlands" (Rocky View County, 2010, p. 1).

The role of Calgary's *Wetland Conservation Plan* is to "provide policies and procedures for the conservation of wetlands within the city of Calgary (City of Calgary, 2004, p.30), and to help Calgarians gain an awareness, understanding, and appreciation of the benefits of wetlands.

Edmonton's *Wetland Strategy* was created to unite "efforts to conserve wetlands into a single document, in order to strengthen and coordinate the City's wetland conservation approach, raise the profile of the City's work in this area, and help to identify areas for improvement in current wetland conservation efforts" (City of Edmonton, 2012, p.1). Its major goals include "secure Edmonton's wetlands as part of the city's ecological network, manage Edmonton's wetlands to maximize their ecological function, and engage Edmontonians to support wetland conservation" (City of Edmonton, 2012, p.1).

8.2.2 Saskatchewan

Currently, no provincial wetland policy or legislation has been approved in Saskatchewan, though new regulations regarding agricultural drainage were recently updated. The Agricultural Water Management Strategy (Water Security Agency, 2015) considers the protection and retention of wetlands when granting approvals, with the possibility of need for compensation or complete retention of the wetland.

Some sources have suggested the development and implementation of individual wetland management plans by landowners (Huel et al., 2000). This idea could be more easily implemented when combined with potential support from the provincial Farm Stewardship Program (FSP) that could provide Saskatchewan producers with financial assistance to implement BMPs to "help maintain or improve the quality of soil, water, air, or biodiversity resources" (Government of Saskatchewan, n.d., para. 1).

The City of Saskatoon developed a wetland policy (City of Saskatoon, 2013b) to support stated wetland conservation and management objectives (City of Saskatoon, 2013a). These objectives include the responsible stewardship of wetland resources as part of a holistic approach to urban development, and "to ensure that natural and constructed wetland resources are integrated into the urban environment, and to conserve the biodiversity and function of significant wetland resources prior to, during, and after land development" (City of Saskatoon, 2013a, section 9.5.1).

8.2.3 Manitoba

Currently, no provincial wetland policy or legislation has been approved in Manitoba, though a policy framework for wetlands has been proposed (R. McDougal, personal communication, April 8, 2016). Under the proposed policy framework, larger class 3, 4, and 5 wetlands (as classified by Stewart & Kantrud, 1971) would be protected from drainage by regulation. This framework will also utilize the *no net loss* approach with the mitigation hierarchy of avoidance, minimization, and compensation (R. McDougal, personal communication, April 8, 2016).

Under The Water Rights Act, there is a draft concept of the Drainage, Retention, and Water Control Works Regulation. The goal is to create a regulatory approach to manage surface water, drainage, and water retention to "reduce the risks to property from excess water, safeguard human health, conserve and protect wetlands and other sensitive habitat, provide resilience to droughts, reduce the risk of flooding by retaining water within the watershed, and minimize the loss of nutrients from the landscape and provide a mitigation framework for appropriate compensation for unavoidable wetland drainage" (Government of Manitoba, 2014a, p.12). Ideally, this will be achieved by implementing a watershed-based planning framework that incorporates the concept of 'no net increase in water export', a concept that suggests that the current total volume of water leaving the watershed will not increase as a result of human activities such as drainage (Government of Manitoba, 2014b)

One aspect of this new approach is to regulate the protection of wetlands from on-going losses with the goal of no-net loss of wetland benefits. This would include protection for all Class III, IV, and V wetlands (as defined by Stewart and Kantrud (1971)) and requiring licences for all works impacting these wetlands, and cost and tools for compensation including direct restoration or purchase of wetland credits (Government of Manitoba, 2014b).

Winnipeg itself manages wetlands within the context of ecologically significant natural lands (City of Winnipeg, 2007). Theses are sensitive lands and natural heritage sites, which the City of Winnipeg has identified as being important to create a vibrant and healthy city that prioritizes a high quality of life for all its citizens (City of Winnipeg, 2007). The City of Winnipeg aims to be a city "which has protected important pockets of natural flora and fauna representative of the original natural ecosystems and lands susceptible to damage from flooding or erosion for the enrichment of the quality of life of the citizens of Winnipeg" (City of Winnipeg, 2007, p.4).

8.3 International

Many other nations experience challenges when dealing with wetland management, especially in growing agricultural nations. To maintain a regional context, focus will be given to our neighbouring nations in North America.

8.3.1 North American Waterfowl Management Plan (NAWMP)

The North American Waterfowl Management Plan (NAWMP) is an international partnership between Canada, the United States, and Mexico created in 1986 that focuses on habitat conservation to sustain waterfowl and other water and shore bird populations (Alberta NAWMP Partnership, 2015). The NAWMP also aims to provide a strategy for the long-term protection of wetlands and associated uplands habitats needed by waterfowl and other migratory birds in North America (FWS, 2016b). They work with local regional joint ventures to facilitate local actions.

NAWMP, in conjunction with the Prairie Habitat Joint Venture, works to facilitate educational opportunities and stewardship actions throughout the Canadian Prairies, as well as assisting in the role-out of the new *Alberta Wetland Policy* implementation (Prairie Habitat Joint Venture, 2014). In the U.S., the Prairie Pothole Joint Venture includes all the U.S. states part of the PPR.

8.3.2 United States

As a neighbour and a NAWMP partner, understanding the legislation and policies that the United States have in place is important, especially in terms of future collaboration. Many states have experienced significant wetland loss post-European settlement. Some have worked to protect remaining wetlands, and worked to restore some of what was lost.

Like Canada, the U.S. has adopted the *no net los*s policy (Clare et al., 2011, Hough & Robertson, 2009). In the United States, five federal agencies share the responsibility for protecting and managing wetlands. These include the U.S. Army Corps of Engineers (Corps), U.S. Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (FWS), National Oceanic and Atmospheric Administration (NOAA) (primarily coastal wetlands), and Natural Resources Conservation Service (NRCS). Additionally, Department of Commerce, Department of Agriculture, the Department of Defense, and the Department of the Interior also have some responsibility, along with state governments, in managing wetlands.

Clean Water Act

The primary legislation concerning the management of wetlands in the U.S. is the *Federal Water Pollution Control Act* (more commonly known as the *Clean Water Act*)

(Environmental Protection Agency [EPA] 2015b). The *Clean Water Act* (CWA) regulates discharges of pollutants into the waters of the United States, and water quality standards for all contaminants in surface water (EPA, 2015b), and specifically, Section 404 was intended to "restore and maintain the chemical, physical and biological integrity of the Nation's waters, including wetlands" (EPA, 2016b, para.1).

Within the *Clean Water Act* is the Clean Water Rule. Broadly, the "Clean Water Rule ensures that waters protected under the Clean Water Act are more precisely defined, more predictably determined, and easier for businesses and industry to understand" (EPA, 2015c, para.1). The Environmental Protection Agency (EPA) and the Army Corps of Engineers administers and enforces the Clean Water Rule. The "Clean Water Rule protects streams and wetlands that are scientifically shown to have the greatest impact on downstream water quality and form the foundation of our nation's water resources" (EPA, 2015a, p.1). Activities such as planting, harvesting, and moving livestock are exempt from Clean Water Act regulation, therefore Clean Water Rule does not apply to those areas. Only waters that were historically covered by the Clean Water Act are protected. However, "[I]t does not interfere with or change private property rights, or address land use" (EPA, 2015a, p.1).

The *North American Wetlands Conservation Act* (NAWCA) was passed in 1989 by the United States Congress to conserve North American wetland ecosystems and waterfowl and the other migratory birds and other fish and wildlife that depend on these habitats (North American Wetlands Conservation Council (Canada), n.d.). The NAWCA grant program provides funding grants to wetlands conservation projects in the United States, Canada, and Mexico through (FWS, 2016b). Projects are approved through Migratory Bird Conservation Commission (established under the *Migratory Bird Conservation Act*), all aimed at carrying out the NAWMP objectives (FWS, 2016a).

The *Farm Bill*, introduced in 1985 (amended in 1990, 1996, and 2002), contains the Highly Erodible Land Conservation and Wetland Conservation Compliance provisions (also known as Swampbuster). These provisions were put in place to "remove certain incentives to produce agricultural commodities on converted wetlands or highly erodible land" (United States Department of Agriculture [USDA], n.d.d, para.1).

Like in Canada, other legislation may also affect wetland management such as *Endangered Species Act*, *National Environmental Policy Act*, *North American Wetlands Conservation Act*, and other legislation that impacts land use, water, sensitive areas, and wildlife. There also many other regulations and executive orders that impact wetland management on a federal level.

There are also several federal programs to aid agricultural landowners and managers with sensitive lands and wetland management. The Conservation Reserve Program creates an agreement to pay farmers to take environmentally sensitive land out of agricultural production and plant species that will improve environmental health and quality (USDA, n.d.b). Under the CRP, the Farmable Wetland Program (FWP) aims to restore previously farmed wetlands and wetland buffers. The FWP is a voluntary program, and participants must agree to restore the wetlands, establish plant cover, and not use the land enrolled in the program for commercial purposes (USDA, n.d.c).

The Agricultural Conservation Easement Program provides financial and technical assistance to aid in the conservation of agricultural lands, wetlands, and their related benefits and functions (USDA, n.d.a). Under the Agricultural Land Easements component of this program, Natural Resource Conservation Service (NRCS) helps First Nations, state and local governments, and non-governmental organizations protect agricultural lands in production and limit non-agricultural uses of the land. Under the Wetlands Reserve Easements component, NRCS works to restore, protect and enhance wetlands enrolled in the program (USDA, n.d.a).

The *National Wetland Condition Assessment* (NWCA) (EPA, 2016a) was done to answer questions about how well wetlands in the U.S. support healthy ecological conditions, and to document the prevalence of key stressors at the national and regional scale. With ongoing status and trend reports every 5 years, this program aims to (EPA, 2016a; Hoeven & Dwelle, 2014):

- Collaborate with states and tribes to develop and build capacity for complementary monitoring and assessment tools, analytical approaches, and data management technology to aid wetland protection and restoration programs;
- Create a robust, statistically-valid set of wetland data; and
- Develop baseline information to evaluate progress made with wetland protection and restoration programs.

Some states have wetland monitoring programs that support and participate in the NWCA, including some mentioned in the next section, many of which have experienced substantial wetland losses over their history post-European settlement.

8.3.2.1 State-level policy

Several states in the U.S. are also part of the PPR. These include Montana, North Dakota, South Dakota, Minnesota, and Iowa (and a very small piece in Nebraska). Understanding what state-specific policies and legislation exist in these states is valuable in understanding how we might work in tandem to address issues specific to this region.

Since 2012, Ducks Unlimited (and Ducks Unlimited Canada) have been working on a cross-border initiative *Preserving Our Prairies*. The aim of the initiative is to protect and restore grasslands and wetlands in the Prairie Pothole Region by working with landowners and managers to protect wetlands and grasslands, and encouraging them to plant waterfowl-friendly crops such as winter wheat (Ducks Unlimited, n.d.). This initiative in focused on habitat throughout North Dakota, South Dakota, Montana, Wyoming, Manitoba, Saskatchewan, and Alberta. Though Wyoming is not part of the PPR, it spans the area between Montana and the Dakotas.

Each state also has one or more Wetland Management Districts (WMDs) (Figure 16). In most states, these WMDs cover the majority of the PPR within that state, except Nebraska. WMDs are units by which the National Wildlife Refuge System acquires wetlands and grasslands to manage as Waterfowl Production Areas (FWS, 2014). Most WMDs have completed comprehensive conservation plans. These 15-year plans provide long-term guidance for management decisions for wetlands, set goals, objectives, and strategies to accomplish refuge purposes, and identify future needs of the area. Within these districts, land management tools and methods are utilized to manage wetlands.

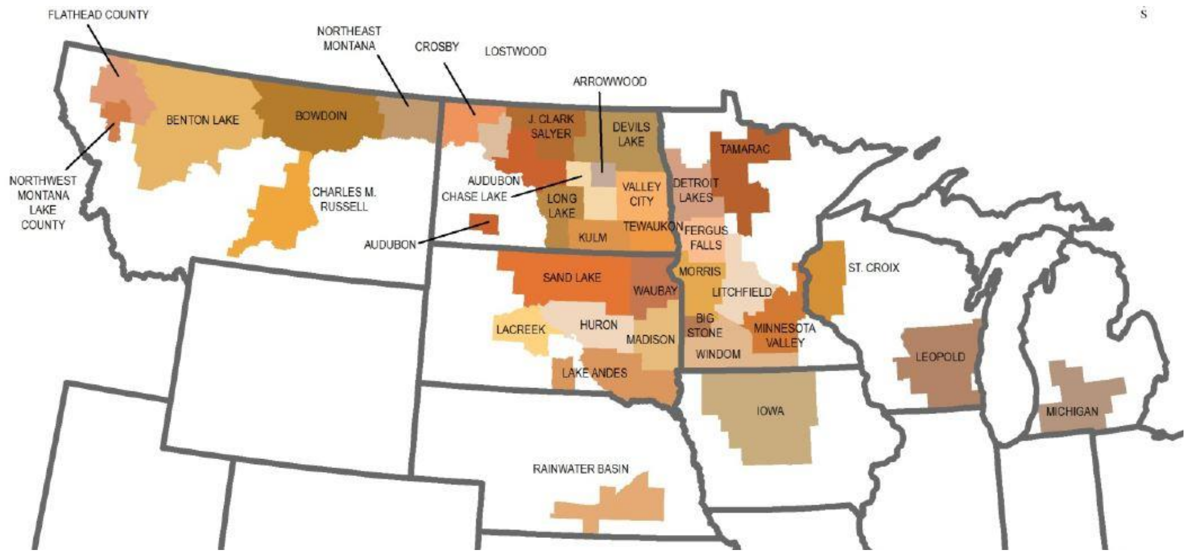


***Figure 16*. Wetland Management Districts of states in the PPR (from FWS, 2014).**

8.3.2.1.1 Montana

As our closest American neighbour Montana should be considered an important partner in wetland management. Extensive work has been done in Montana evaluating impacts of hydrologic changes on different species (Vance et al., 2013) and developing recommended limits to the amount of hydrologic alteration to reduce negative impacts on the dependent biology and associated management actions (Phelan, et al., 2013).

Montana's overarching wetland goal is no net loss of the state's remaining wetland resource base, and facilitate an increase in the quality and quantity of wetlands in Montana. The Montana Department of Environmental Quality (DEQ) coordinates and provides state direction to protect wetlands and riparian areas for their water quality, water quantity, habitat, and flood control functions. The DEQ and the Montana Wetland Council (MWC) developed, and implements, the state's wetland and riparian plan (Montana Wetland Council, 2013). The strategic framework list several strategic directions, including (Montana Wetland Council, 2013, p. v-vi)

- support and participate in on-the-ground projects and practices that foster wetland and riparian restoration, protection, and management and net gain of wetlands;
- support the completion, maintenance, and dissemination of statewide digital wetland and riparian mapping information, and provide training and support to use the data in planning, protection, and restoration decision-making;
- collection, integration, and use of monitoring and assessment data to inform local planning, protection, restoration, and landscape-level decision-making;
- help local, state, tribal, and federal governments to plan, implement, and manage information, resources, and tools needed to protect wetland and riparian areas for their water quality, water quantity, habitat, and flood control benefits;
- contribute understanding and knowledge regarding the impacts of energy development, climate change, limited water resources, and invasive aquatic species on wetlands and riparian resources, and promote approaches to minimize harmful impacts; and
- foster public awareness and understanding of the valuable ecologic, economic, and public safety functions of wetlands and riparian, and encourage and support public and private actions.

The Montana Natural Heritage Program (MTNHP) is the primary public source for wetland and riparian mapping, and monitoring and assessment tools in Montana. Science-based information on the distribution, extent, condition and biodiversity significance of the state's wetlands and riparian areas is all publically available (Vance & Chutz, 2016). The MTNHP collaborate with the Wetland Program at Montana DEQ on research projects and development of database tools, designing workshop and course content for training, and teaching wetland plant identification workshops provided. The strategic actions outlined in the *Wetland Program Plan* (Vance & Chutz, 2016) address all seven of the current Five-Year Strategic Directions set out in the Montana Wetland Council's (2013) strategic framework.

8.3.2.1.2 North Dakota

North Dakota does not have any current wetland regulations, policies, or legislation for a wetland mitigation or conservation plan. At one time the state had adopted an overall no net loss goal, but it was repealed in 1997 (Association of State Wetland Managers, 2015). Aside from the federal legislation, wetlands are managed (to a certain degree) under *North Dakota's Water Quality Monitoring Strategy* (Hoeven & Dwelle, 2014). As a part of this strategy, the Wetland Monitoring and Assessment Program develops biological indicators and assessment methodologies for wetlands and use these indicators and methods to monitor and assess wetland condition at varying spatial scales. The program also develops spatial analysis methods and tools to identify potential sites for wetland restoration and creation, and apply these methods in a watershed planning and restoration context (Hoeven & Dwelle, 2014). The North Dakota Department of Health participated in the NWCA as part of the wetland monitoring program.

8.3.2.1.3 South Dakota

South Dakota does not have any wetland regulations, policies, or legislation for a wetland mitigation or conservation plan. Though out of date, the work done by the South Dakota Interagency Wetlands Working Group (2001) examined wetland conservation and management guidelines for state agencies in South Dakota. These guidelines were designed to provide state natural resource agencies with an overall view of wetland issues for their use and a summary of programs available to encourage wetland conservation and management. The hope was these programs would provide voluntary, incentive-based options for landowners to maintain the multiple benefits wetlands provide to all South Dakota residents. As well, the programs would encourage state government agencies involved with projects involving wetlands to consider wetland impacts in their policy and project development.

8.3.2.1.4 Minnesota

Wetlands in Minnesota are regulated under the Wetland Conservation Act (WCA) of 1991 to protect wetlands not protected under Department of Natural Resources' public waters permit program, and provide no net loss of Minnesota's remaining wetlands. Under the WCA, wetlands "must not be drained or filled, wholly or partially, unless replaced by restoring or creating wetland areas of at least equal public value under an approved replacement plan" (Minnesota Board of Water and Soil Resources, 2003, p.11). WCA does not apply to public waters wetlands, which are regulated by the Minnesota Department of Natural Resources (Minnesota Board of Water and Soil Resources, 2004). Public waters wetlands are all 3, 4, and 5-type wetlands [as defined by United States Fish and Wildlife Service (FWS)] not included within the definition of public waters, that are ten (10) or more acres in size in unincorporated areas or 2.5 acres or more in incorporated areas (Minnesota Department of Natural Resources, 2016).

In Minnesota, wetlands are regulated under several agencies. The WCA does not supersede other regulations by other agencies, such as the U.S. Army Corps of Engineers, U.S. Department of Agriculture, Minnesota Pollution Control Agency, watershed districts, and local governments (Minnesota Board of Water and Soil Resources 2004). The local government unit (LGU) is the primary agency responsible for administering WCA. The LGU is generally the city or county, but may be another entity such as a watershed district or soil and water conservation district (Minnesota Board of Water and

Soil Resources 2004). A LGU may develop a comprehensive wetland protection and management plan. The purpose of this kind of plan is to provide for alternative standards for management of wetland resources, based on the needs and priorities of the LGU. While local plans can adopt alternative standards for greater flexibility, there is also the opportunity within these plans for the LGU to create additional requirements that are more restrictive than WCA (Minnesota Board of Water and Soil Resources 2004).

The State of Minnesota developed a wetlands restoration strategy to provide a statewide perspective and approach for restoration of wetlands. This framework encourages state and federal agencies, local government units, and non-governmental organizations to combine and coordinate efforts to achieve the shared goal of net gains in wetland functional benefits (Minnesota Board of Water and Soil Resources 2009). The vision is that "Minnesotans will enjoy significant improvements in habitat, water quality, surface water flows, and ground water interactions that are attributable to wetlands restoration" (Minnesota Board of Water and Soil Resources 2009, p.1).

8.3.2.1.5 Iowa

As with several of the states examined in this report, Iowa has no state wetland policy, act, or related legislation, aside from federal regulations. Unlike other states, the Iowa Wetland Management District (WMD) encompasses the full extent of the PPR in Iowa. The Iowa WMD was developed in partnership with the Iowa Department of Natural Resources. The Iowa WMD aims to conserve, restore, and expand grassland and wetland habitat to manage a natural biodiversity of native flora and abundance of waterfowl, migratory birds, and other native fauna, as well as promote understanding, appreciation, and support for the Iowa WMD. Stewardship and understanding of the southern PPR and its native ecosystems to visitors and local residents is also involved (FWS, 2014).

8.3.3 Ramsar Convention

The Convention on Wetlands of International Importance, commonly referred to as the Ramsar Convention, of February 2, 1971 is an international treaty with 163 member nations (as of 2013). The mission of the Ramsar Convention "is the conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world" (Ramsar Convention Secretariat, 2013, p.2). There are six Ramsar sites within the PPR, with only one in the U.S., and one in Alberta (Beaverhill Lake). Though no Ramsar sites are present in the Battle River and Sounding Creek watersheds, it is an important international agreement to recognize in terms of wetland conservation. February 2nd has also become World Wetlands Day, a day we can celebrate and help raise public awareness about the importance and value of wetlands. Each year since 1997, the Ramsar

Secretariat provides materials for those interested in hosting activities and providing educational material on World Wetlands Day.

9 Conservation and Restoration

Wetland conservation is always preferred over replacement or restoration. Conservation and restoration of wetlands and surrounding uplands is a crucial part of wetland management (Whited et al., 2000). A number of organizations have developed programs and initiatives to help with both of these important aspects of wetland management across Alberta and within the Battle River and Sounding Creek watersheds.

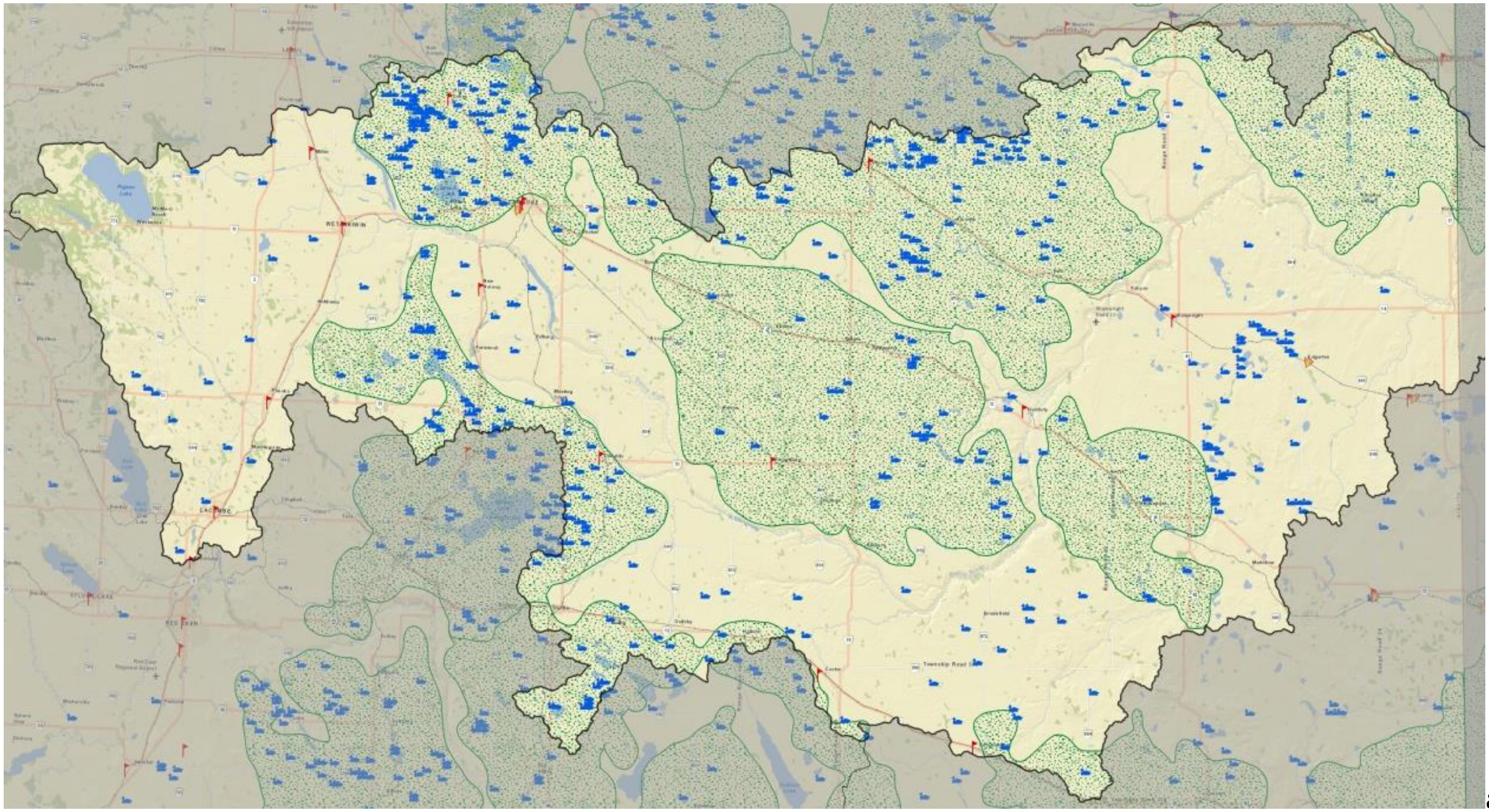
9.1 Wetland Restoration in Battle River and Sound Creek Watersheds

Many programs exist that can be used individually and in concert to help conserve and restore wetlands within the Battle River and Sounding Creek watersheds, such as ALUS and DUC programs. There are also some opportunities in the new economy that could provide incentive for landowners and managers.

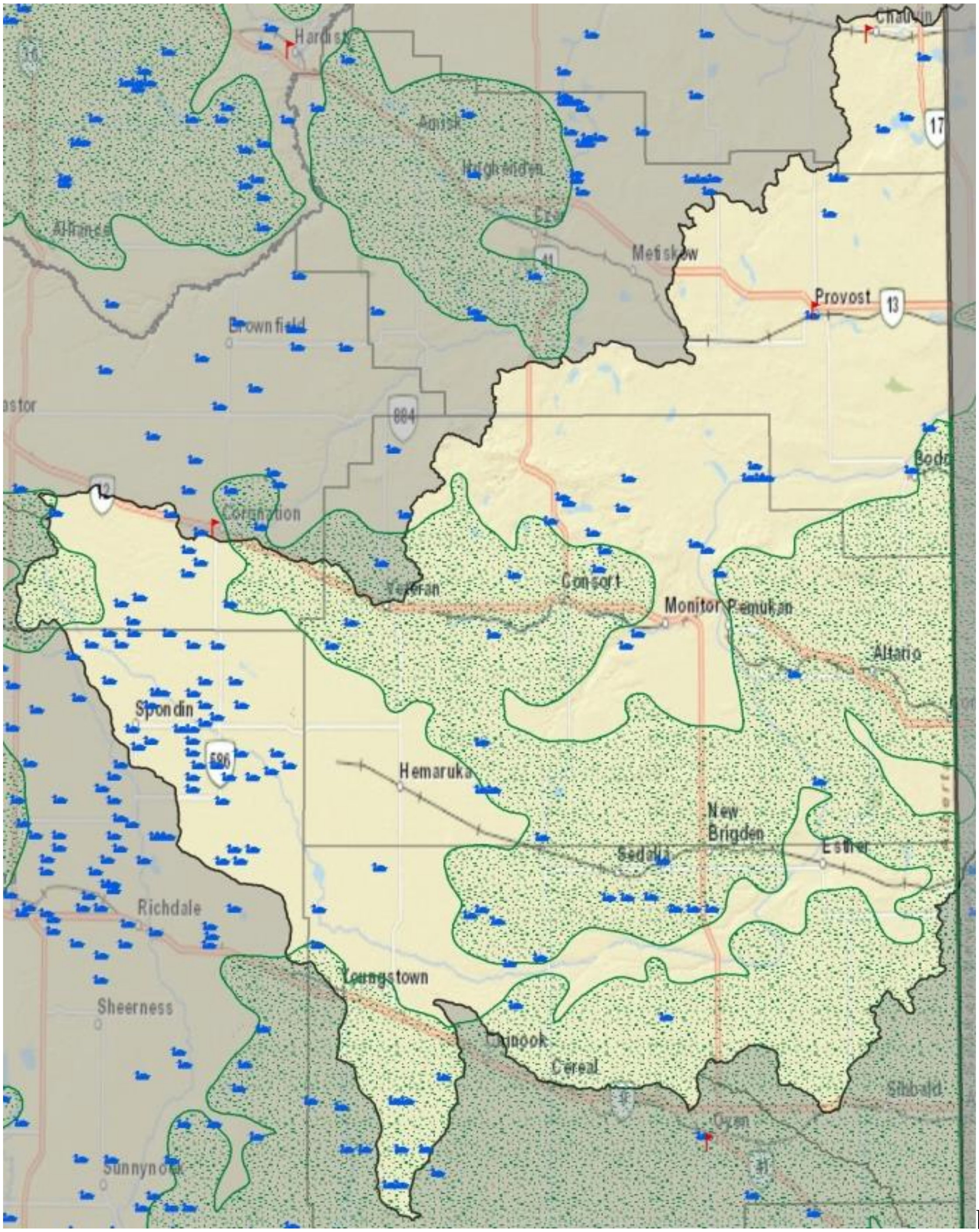
Over 100 licensed wetland projects were licensed in the Battle River Basin in 2011, including 27 structures in the Ribstone Creek subwatershed. Varieties of structures, such as ditch plugs, were used to restore wetlands, and flood hay meadows for agriculture and habitat improvement. These wetland projects will also aid groundwater recharge, and river and creek flow augmentation during low flow (AESRD, 2014b).

A few agencies that facilitate wetland (and upland) restoration and conservation projects within Alberta. Ducks Unlimited Canada, as a wetland restoration agent (WRA), delivers wetland restoration opportunities and several incentive programs to landowners in the Battle River and Sounding Creek watersheds. They have been active very in the Battle River and Sounding Creek watersheds for many years, and have done many projects throughout each of the watersheds (Figure 17a and b).

Within the Battle River watershed, Ducks Unlimited Canada has undertaken 452 projects, securing over 137, 300 acres (including wetlands, surrounding upland, and other upland habitat) (M. Simikian, personal communication, January 15, 2016). In Sounding Creek watershed, 111 projects have been done, securing almost 34,000 acres (M. Simikian, personal communication, January 19, 2016).



a)



b)

*Figure 17***. Ducks Unlimited Canada projects in the a) Battle River and b) Sounding Creek watersheds. Blue ducks represent DUC habitat projects, Red flags represent DUC funding events, and Orange duck feet represent education programs. The green stippled areas are DUC/NAWMP priority areas. Maps provided by Ducks Unlimited Canada, 2016.**

DUC works with landowners to restore or conserve wetland and upland habitat through several other programs. In addition to the Western Winter Wheat Initiative and Forage Program, DUC offers several programs for landowners, including conservation agreements, Wetland Restoration Lease program, and the Revolving Land Purchase program. With the Wetland Restoration Lease program, DUC compensates landowners for restored wetland areas under a 10-year lease based on current fair market value. As part of DUC's program, the restored wetland areas stay under the management of the landowner, where these areas can be hayed or grazed but cannot be drained, altered or tilled during the term of the agreement. Through the Revolving Land Purchase program, DUC purchases a piece of land, restores its wetlands and grasslands, and then makes it available to potential land buyers on the real estate market after placing a conservation easement (CE) on the title. The RLP program often works well with livestock producers. As well, the Forage Program helps create critical habitat while converting cultivated acres to perennial cover.

County of Vermillion River also a designated wetland restoration agent, and has facilitated several wetland projects within the Battle River watershed with their relationship with ALUS. In their part of the watershed, they have restored over 7 acres of wetland, 202 acres of upland, and conserved 228 acres of wetland (C. Elder, personal communication, April 12, 2016). Additional counties and organization within the Battle River and Sounding Creek watersheds have the potential to become wetland restoration agents, as well as continue the possibilities of wetland conservation and restoration throughout the watershed.

9.2 Reverse Auctions

Most program options for restoring wetlands include conservation easements, land trusts, enhanced forage conversion programs, and land purchases or donations. Though not currently widely used in Canada, reverse auctions, or conservation auctions, have been successfully used in Australia, Europe, and the United States for habitat conservation (Latacz-Lohmann & Hodge 2003; Reichelderfer & Boggess, 1988; Selman et al 2008; Stoneham et al 2003; White & Burton 2005). A couple pilot programs have been done, or are being done, in Canada, notably in Saskatchewan (Hill et al., 2011) and Alberta (Alberta Land Institute, 2015) to determine the best approach in using this tool specifically for wetland restoration in the Canadian Prairies.

9.3 Prioritising Wetlands and Regional Wetland Objectives

Each type of wetland has different hydrological and ecological functions (Stewart & Kantrud, 1971). As such, "ecological integrity of the prairie landscape needs to be understood in the context of a wetland complex, rather than individual wetlands (Winter, 1989; Euliss et al., 2004)" (Hayashi et al., 2016, p. 8). Maintaining this regional perspective will not only help conserve a diversity of wetlands and habitats, but also hydrological and ecological connectivity (Amezaga et al., 2002).

As development continues, an important element of wetland management is development of proactive regional and watershed-based wetland management objectives, and determining which wetlands are vital to meet those objectives. These objectives would help inform protection, conservation, and restoration activities based on a combination of acreage and ecosystem function and services that address ecological, social and economic values (Alberta Water Council, 2008b). Regional wetland objectives should provide "steps toward identifying and acting on opportunities to protect wetlands of exceptional value; identifying areas suitable for wetland restoration, construction, or enhancement; and managing impacts to existing wetlands" (Alberta Water Council, 2008b, p.13) and be integrated into watershed and land use planning, policy, and management processes. In agricultural watersheds, such as the Battle River and Sounding Creek watersheds, identifying wetlands or restoration sites to address certain functions on a sub-watershed scale may be a valuable approach (Zedler, 2003).

As mentioned in Section 8.2.1.2, NAWMP has begun work in Alberta to develop regional wetland management objectives, though how regions are to be delineated is still to be decided. As a leader in wetland education, science, and management across North America, NAWMP is well positioned to start addressing inter-provincial and international regional wetland objectives. WPACs, municipalities, academia, utility companies, transportation and infrastructure representatives, and tourism representatives should all be involved in the development of any wetland objectives to ensure ecological, social, and economic viability of goals.

Recently, the EPA has developed a tool for decision-makers in the United States using the Rapid Benefits Indicators (RBI) approach. This is a process for assessing wetland restoration using non-monetary/social benefits indicators of ecosystem restoration (Mazzotta et al., 2016). This approach, among other uses, helps to prioritize restoration projects and sites, especially in urban areas.

9.4 Wetland Mapping

Some mapping of wetlands has been completed for the Battle River and Sounding Creek basins, but it is not complete. As the basis on much wetland management planning, having accurate and current data and maps is crucial. However, these are often hard to obtain due to financial and time constraints. Though ground-truthing is an essential aspect of all wetland research and fundamental in wetland management, this method is time and labour intensive. Studies suggest that the use of small, unmanned aerial vehicles (UAVs) may be effective tools to gather data and map wetlands (O'Brien, 2016). Using UAVs with near infrared light remote sensing, this approach can advance landscape understanding, and could provide a precise, accessible, and affordable wetland data collection method (O'Brien, 2016). Additional application of this technique at a more local level should be considered as a part of wetland management moving forward.

9.5 Carbon offset credits

New market-based tools are increasingly used to integrate costs associated with decreases in ecosystem services into decision-making and influencing behaviour of citizens (The Economics of Ecosystems and Biodiversity [TEEB], 2011), and many have been discusses in this report. There is work being done regarding carbon-offset credits for wetland conservation and restoration. Since wetlands are generally considered carbon sinks (see section 5.5), carbon offsetting schemes represent an interesting option to find additional financing for wetland conservation or enhancement (Russi et al., 2013).

Most existing research and methodology for carbon offsets and wetlands is focused on creation (Hansen, 2009) or restoration (Gardner & Fox, 2013; Louisiana Coastal Protection and Restoration Authority, 2014; Tierra Resources, 2013; UNEP & CIFOR, 2014) of wetlands, and do not include conservation. All resources focused on coastal wetlands and estuaries. Since it is difficult to quantify carbon sequestration services for restored wetlands, as this function develops over time, carbon credits for wetland conservation may be more feasible in the near future.

10 Conclusion

With the development of the *Alberta Wetland Policy* implementation and work done through NAWMP, municipalities, and other wetland partners, new strategies for managing wetlands in the Battle River and Sounding Creek watersheds are forthcoming. All watershed stakeholders need to be involved to ensure the sustainable wetland management now and for the future.

10.1 Data Gaps and Future Directions

10.1.1 Wetland Inventories

Without accurate inventory data, the wetland component of watershed planning is hindered, and the setting of wetland objectives, targets and thresholds more difficult. Wetlands inventories should be completed for all areas of the Battle River and Sounding Creek watersheds. In Alberta's White Zone, high resolution, historic and current aerial photography is typically used to determine the change in wetland area over time. Commonly referred to as the "Comprehensive" or "Drained" wetland inventory, this product differs from previous inventory methods in that it can accurately capture drained and altered wetlands, thereby accurately measuring wetland loss. This method does not typically classify wetlands remotely, but classification data can be added through inclusion of field observations.

As an example of this inventory methodology and its application, the Iron Creek sub-watershed was inventoried in 2005. The resulting data was utilized to develop a cartographic representation of wetland impacts and a wetland impact model as a product of the broader Water for Life Inventory. The model incorporated baseline wetland inventory collected for the entire sub-watershed based on 1963 photography, and the process repeated for current conditions using 2005 photography. With representations of the abundance and distribution of wetland features from the two time periods, a geoprocessing model was developed that would assign impact categories to each wetland basin. The model output characterizes the current state of wetland resources and the distribution of wetland impacts across the entire sub-watershed. These data provide a valuable resource for targeting wetland conservation and restoration initiatives, and support further research into the hydrologic and ecological consequences of the impacts.

This level of wetland inventory and mapping is fundamental to planning, decision-making, objective setting, and implementation in watershed and land use planning initiatives. Setting appropriate wetland retention and restoration objectives depend on development of these high-resolution inventories.

The Alberta Water Research Institute (AWRI) Wetland Health team was developing wetland condition/ health assessment methods and tools in the Beaver Hills watershed, within the NSRP area. Wetlands along a disturbance gradient (including pristine wetlands, natural wetlands in agriculture and other human affected landscapes, restored wetlands, stormwater treatment ponds) were surveyed. Work is being done on scaling this information to the regional level using GIS that could be used to inform wetland assessment methods in the NSRP, including the Battle River watershed (Barr, 2011).

10.1.2 Land Use Planning

A no-net-loss objective for the basin should be adopted as a sustainable approach. This should be incorporated into all planning initiatives including municipal plans and the North Saskatchewan Regional Plan (and the forthcoming Red Deer Regional Plan) to be developed under the Land Use Framework.

Regardless of the level land use planning occurs at, ensuring land use planning safeguards the ecological, societal, and economic value and function of wetlands and is considerate of the key functions and strategically important location of wetlands is imperative.

10.1.3 Restoration and Conservation

In regards to overall for restoration, conservation, and compensation, there are some overall BMPs that should be considered in all projects, and in wetland alteration approvals:

- Due to the cost impact and social expectations of farmers regarding wetlands, agricultural crop producers would like more discussion pertaining to compensation for retaining and replacing wetlands and subsequent reduced land values (Graymore & McBride, 2013)
- Stronger and less lenient wetland alteration approvals at the provincial government level (Clare et al., 2011)
- Stricter enforcement of rural impacts to wetlands.
- Systematic and systemic planning for wetland conservation in advance of development
- Avoid or minimize impacts on ephemeral and temporary wetlands so as to maintain the important functions they provide, in particular those relating to wildlife habitat (Hayashi et al., 2003)
- Restoration and conservation actions need to capture the full range of wetland types, areas, pond permanence, and other wetland values that occurred historically within the watershed. Maintaining hydrodiversity also maintains biodiversity (van der Kamp & Hayashi, 2009).

- Future compensation for wetland impacts accrued within the watershed should be applied within the basin (preference given to biogeographically similar areas) and be located as near as is practical to the wetland where impact occurred.
- Compensation criteria should be based on the landowners' ability to recoup costs.
- Emphasis on conservation and avoidance over minimizing impact or replacement.
- Encourage conservation of existing wetland complexes including associated upland areas and ephemeral wetlands are kept intact or restored, ecologically functional, appreciated, and valued (Amezaga et al., 2002; Whited et al., 2000).
- Additional restoration agents should be created throughout the province.

Other policy advice and management guidelines are discussed in the accompanying documents *Wetlands Management: Policy Advice*, and *Wetland Management: Implementation Guidelines*.

10.2 Summary

Over the next century, wetlands and their riparian and upland ecosystems will play crucial roles in determining the vulnerability and resilience of natural and human systems to climate change, as well as capacity of these systems to adapt. Additionally, wetland ecosystems themselves are likely to become more vulnerable to climate change and land use impacts. However, given the critical role of wetland ecosystem functions on the landscape, as well as the strong links between wetland ecosystems and human well-being, change in how we view and live with wetlands is needed. The need for planned adaptation and management of and for wetlands in the landscape mosaic will be strengthened as the importance of many wetland ecosystem functions, goods and services grows in social values, and with a changing climate. Consequently, wetland ecosystems have become the focus of significant adaptation worldwide.

It is in the best interest of all watershed stakeholders to be proactive in managing the use of and impacts to our wetlands. Dialogue about challenges, mitigation, and adaptation must be undertaken to ensure wetlands are able to maintain their function and value for generations to come.

Literature Cited

Adams, G., Buteau, P., Dignard, N., Grondin, P., Jeglum, J., Keys, D., Mills, G., Price, J., Rothwell, R., Rubec, C., Selby, C., Veldhuis, H., Warner, B., Wells, D., and Zoltai, S. (1997). *The Canadian Wetland Classification System, 2nd edition. Edited by* B.G. Warner and C.D.A. Rubec. National Wetlands Working Group, Canadian Wildlife Service, Environment Canada, Ottawa, Ontario. Retrieved from http://nawcc.wetlandnetwork.ca/Wetland%20Classification%201997.pdf

Adamus, P.R. 2011. Manual for the Wetland Ecosystem Services Protocol for the United States (WESPUS). Retrieved from https://www.novascotia.ca/nse/wetland/docs/Manual_WESPUS.pdf

Adamus, P.R. 2013. Wetland Ecosystem Services Protocol for Southern Alberta (WESPAB). Prepared for Alberta Environment and Sustainable Resource Development, Government of Alberta, Edmonton, AB. Retrieved from http://people.oregonstate.edu/~adamusp/Alberta_PrairieWetlands_Assessment_Method/WESPAB_Manual_31July2013.pdf

Alberta Conservation Association. (2011). *Amphibians on my land*. Retrieved from http://www.ab-conservation.com/downloads/avamp/aca_amphibians_on_my_land.pdf

Alberta Energy Regulator (AER). (2011). *Directive 056: Energy development applications and schedules*. Retrieved from http://www.aer.ca/rules-and-regulations/directives/directive-056

Alberta Energy Regulator. (2013). *Integrated standard and guidelines – Enhanced Approval Process (EAP)*. Retrieved from http://aep.alberta.ca/forms-maps-services/enhanced-approval-process/eap-manuals-guides/default.aspx

Alberta Environment. (2003). *Focus on wetlands*. Edmonton, Alberta: Alberta Environment. Retrieved from http://www.brocku.ca/virtualmuseum/riveroflife/wetlands.pdf

Alberta Environment. (2004). *A guide to the code of practice for pits*. Edmonton, Alberta: Queens Printer. Retrieved from http://aep.alberta.ca/lands-forests/land-industrial/legislation-guidelines.aspx

Alberta Environment and Parks. (2014). *Guide to assessing permanence of wetland basins*. Land Policy Branch, Policy and Planning Division. 28 pp. Retrieved from http://aep.alberta.ca/water/programs-and-services/wetlands/default.aspx

Alberta Environment and Parks. (2015). *Watershed resiliency and restoration program*. Retrieved from http://aep.alberta.ca/water/programs-and-services/watershed-resiliency-and-restoration-program/default.aspx

Alberta Environment and Parks. (2016a). *Don't let it loose*. Retrieved from http://aep.alberta.ca/fish-wildlife/invasive-species/aquatic-invasive-species/dont-let-it-loose.aspx

Alberta Environment and Parks. (2016b). *Motorized.* Retrieved from http://aep.alberta.ca/recreation-public-use/recreation-on-public-land/motorized.aspx

Alberta Environment and Parks. (2016c). *Wetlands*. Retrieved from http://aep.alberta.ca/lands-forests/shorelands/wetlands.aspx

Alberta Environment and Sustainable Resource Development (AESRD). (2009). *South Saskatchewan Region – wetlands: Facts at your fingertips*. Retrieved from http://wsow.brbc.ab.ca/reports/SSRP-Wetlands.pdf

Alberta Environment and Sustainable Resource Development. (2012a). *Alberta Northern Leopard Frog Recovery Plan, 2010-2015*. Alberta Environment and Sustainable Resource Development, Alberta Species at Risk Recovery Plan No.22. Edmonton, AB. 34 pp. Retrieved from http://aep.alberta.ca/fish-wildlife/species-at-risk/species-at-risk-publications-web-resources/amphibians/

Alberta Environment and Sustainable Resource Development. (2012b). *Stepping back from the water: A beneficial management practices guide for new development near water bodies in Alberta's settled region*. Calgary, Alberta: Government of Alberta. Available at http://environment.alberta.ca/04100.html

Alberta Environment and Sustainable Resource Development. (2013). *Alberta wetland policy*. Water Policy Branch, Policy and Planning Division, Edmonton, AB. Retrieved from http://aep.alberta.ca/water/programs-and-services/wetlands/alberta-wetland-policy.aspx

Alberta Environment and Sustainable Resource Development. (2014a). *Agriculture watershed enhancement program & watershed resiliency and restoration program*. Retrieved from http://aep.alberta.ca/water/programs-and-services/watershed-resiliency-and-restoration-program/

Alberta Environment and Sustainable Resource Development. (2014). *Approved water management plan for the Battle River basin (Alberta)*. Alberta Environment and Sustainable Resource Development Planning Report. Retrieved from http://www.qp.alberta.ca/documents/orders/orders_in_council/2014/714/2014_299.html

Alberta Environment and Sustainable Resource Development. (2015). *Alberta wetland classification system*. Water Policy Branch, Policy and Planning Division, Edmonton, AB. Retrieved from http://www.waterforlife.alberta.ca/documents/ClassificationSystem-Jun01-2015.pdf

Alberta Environmental Protection. (1999). *Stormwater management guidelines for the Province of Alberta*. Municipal Program Development Branch, Environmental Sciences Division, Edmonton, AB. Retrieved from http://aep.alberta.ca/water/programs-and-services/municipal-wastewater-and-storm-water-management-program/documents/StormwaterManagementGuidelines-1999.pdf

Alberta Invasive Plants Council. (2012). *Water invaders: Plants that can change Alberta`s waters and wetlands*. Retrieved from http://www.invasiveplants.ab.ca/

Alberta Land Institute. (2015). *How can we restore your wetland?* Retrieved from http://www.albertalandinstitute.ca/research/research-projects/project/wetlands

Alberta NAWMP Partnership. (2015). *Alberta NAWMP Partnership 2014-2015 Progress Review: April 2014 to March 2015*. Ducks Unlimited Canada, Edmonton, AB. Alberta NAWMP-066. 20 pp. Retrieved from http://www.abnawmp.ca/news/2016/feb/22/our-2014-2015-progress-review-now-available/

Alberta Sand & Gravel Association (ASGA). (2015). *Regulation*. Retrieved from http://www.asga.ab.ca/resources-regulation.asp

Alberta Transportation. (2010). *Rules & regulations applying to small vehicles*. Retrieved from http://www.transportation.alberta.ca/Content/docType41/Production/small_vehicle_booklet_final.pdf

Alberta Urban Municipalities Association. (2013). *2013 Municipal water policy on wetlands*. AUMA Policy Paper 2013.A1. Retrieved from https://auma.ca/advocacy-services/programs-initiatives/water-management/watershed-management/wetlands

Alberta Water Council. (2008a). *Recommendations for a new Alberta wetland policy*. Edmonton, Alberta. Retrieved from http://www.awchome.ca/Projects/WetlandPolicy/tabid/103/Default.aspx

Alberta Water Council. (2008b). *Recommendations for a new Alberta wetland policy implementation plan*. Edmonton, Alberta. Retrieved from http://www.awchome.ca/Projects/WetlandPolicy/tabid/103/Default.aspx

Alberta Water Resources Commission. (1993a). *Beyond prairie potholes: A draft policy for managing Alberta's peatlands and non-settled area wetlands.* Retrieved from http://www.biodiversitylibrary.org/bibliography/104078#/summary

Alberta Water Resources Commission. (1993b). *Wetland management in the settled area of Alberta: An interim policy*. Retrieved from http://www.environment.gov.ab.ca/info/library/6169.pdf

Alberta Wetland Policy. (2016). *Migratory Birds Convention Act (1994)*. Retrieved from http://www.wetlandpolicy.ca/migratory-birds-convention-act-1994/

Amezaga, J.M., Santamaría, L., & Green, A.J. (2002). Biotic wetland connectivity – supporting a new approach for wetland policy. *Acta Oecologica, 23,* 213–222. doi: 10.1016/S1146-609X(02)01152-9

Ambrose, N. 2010. Riparian Health Summary, Final Report, Cooking Lake – Blackfoot Grazing, Wildlife and Provincial Recreation Area. Alberta Riparian Habitat Management Society (Cows and Fish). Retrieved from https://www.albertaparks.ca/media/3194168/Cooking%20Lake%20-%20Blackfoot%20Comm%20Report%202010%20FINAL.pdf

Ambrose, N., Ehlert, G., & Spicer-Rawe, K. (2009). *Riparian health assessment for lakes, sloughs, and wetlands - Field Workbook Second Edition*. Modified from Fitch, L., B. W. Adams, and G. Hale, 2001. Riparian Health Assessment for Streams and Small Rivers - Field Workbook. Cows and Fish program. Graphcom Printers Ltd: Lethbridge, Alberta. Available from http://cowsandfish.org/publications/assessment.html

Anderson, H.L. (2013). *Habitat use by the wood frog (Lithobates sylvaticus (LeConte, 1825)) within pothole wetlands modified by beaver (Castor canadensis Kuhl, 1820) in east-central Alberta* (Master's thesis). University of Alberta, Edmonton, Alberta. Retrieved from https://era.library.ualberta.ca/files/cf95jc42f#.WEBkxH3eNQM

Anderson, J.C., Carlson, J.C., Low, J.E. Challis, J.K., Wong, C.S., Knapp, C.W., & Hanson, M.L. (2013). Performance of a constructed wetland in Grand Marais, Manitoba, Canada: Removal of nutrients, pharmaceuticals, and antibiotic resistance genes from municipal wastewater. *Chemistry Central Journal, 7,* 1-15. doi: 10.1186/1752-153X-7-54

Anderson, N.L., Paszkowski, C.A., & Hood, G.A. (2014). Linking aquatic and terrestrial environments: can beaver canals serve as movement corridors for pond-breeding amphibians? *Animal Conservation, 18*, 287–294. doi: 10.1111/acv.12170

Association of State Wetland Managers. (2015). *North Dakota state wetland program summary*. Retrieved from http://www.aswm.org/pdf_lib/state_summaries/north_dakota_state_wetland_program_summary_083115.pdf

Atkinson, M. M. & Coleman, W.D. (1992). Policy networks, policy communities and the problems of governance. *Governance*, 5(2), 154-180. doi: 10.1111/j.1468-0491.1992.tb00034.x

Badiou, P., McDougal, R., Pennock, D., & Clark, B. (2011). Greenhouse gas emissions and carbon sequestration potential in restored wetlands of the Canadian prairie pothole region. *Wetlands Ecology and Management, 19,* 237–256. doi: 10.1007/s11273-011-9214-6

Baldwin, R.F., Calhoun, A.J.K., & DeMaynadier, P.G. (2006). Conservation planning for amphibian species with complex habitat requirements: A case study using movements and habitat selection of the wood frog *Rana sylvatica*. *Journal of Herpetology*, *40*, 443–454. doi: 10.1670/0022-1511(2006)40[442:CPFASW]2.0.CO;2

Barr, M. (2011). *State of wetlands (North Saskatchewan Region).* Retrieved from http://www.abnawmp.ca/media/protected/dfd1cd1e-90b6-4f2f-87e1-5015c18c8c04.pdf

Batt, B.D.J., Anderson, M.G., Anderson, C.D., and Caswell, F.D. (1989). The use of prairie potholes by North American ducks. In: van der Valk, A.G. (Ed.) *Northern prairie wetlands* (pp. 204-227). Ames, Iowa, USA: Iowa State University Press.

Battle River Watershed Alliance (BRWA). (2011). *Our battle: State of the Battle River and Sounding Creek watersheds report 2011*. Camrose Alberta: Battle River Watershed Alliance. Retrieved from http://www.battleriverwatershed.ca/publications

Battle River Watershed Alliance (BRWA). (2012). *Battle River watershed management planning process: Phase two terms of reference February 2012*. Camrose Alberta: Battle River Watershed Alliance. Retrieved from http://www.battleriverwatershed.ca/publications

Bedford, B.L. (1999). Cumulative effects on wetland landscapes: Links to wetland restoration in the United States and southern Canada. *Wetlands, 19,* 775-788.

Bedford, B.L., & Preston, E.M. (1988). Developing the scientific basis for assessing cumulative effects of wetland loss and degradation on landscape functions: Status, perspectives, and prospects. *Environmental Management, 12,* 751-771.

Bergström, J.C., Stoll, J.R., Titre, J.P., & Wright, V.L. (1990). Economic value of wetland-based recreation. *Ecological Economics, 2,* 129-147.

Boyer, T., & Polasky, S. (2004). Valuing urban wetlands: A review of non-market valuation studies. *Wetlands,* 24, 744–755.

Brakhage, D. (n.d.). *The positive effects of drought*. Retrieved from http://www.ducks.org/Conservation/National/The-Positive-Effects-of-Drought

Brander, L., Brouwer, R., and Wagtendonk, A. (2013). Economic valuation of regulating services provided by wetlands in agricultural landscapes: A meta-analysis *Ecological Engineering, 56*, 89– 96. doi: 10.1016/j.ecoleng.2012.12.104

Bridgham, S.D., Megonigal, J.P., Keller, J.K., Bliss, N.B., & Trettin, C. (2006). The carbon balance of North American wetlands. *Wetlands, 26(4)*, 889-916. doi: 10.1672/0277-5212(2006)26[889:TCBONA]2.0.CO;2

Bromley, C.K., & Hood, G.A. (2013). Beavers (*Castor canadensis*) facilitate early access by Canada geese (*Branta canadensis*) to nesting habitat and areas of open water in Canada's boreal wetlands. *Mammalian Biology, 78*, 73–77. doi: 10.1016/j.mambio.2012.02.009

Bruneau, S. (2015a). *BRWA's approach to policy research and development*. Retrieved from http://www.battleriverwatershed.ca/publications

Bruneau, S. (2015b). *Understanding the policy context for riparian areas of the Battle River and Sounding Creek watersheds.* BRWA WMP Report. Camrose, Alberta: Battle River Watershed Alliance. Retrieved from http://www.battleriverwatershed.ca/publications

Brunet, N.N. (2011). *Prairie pothole drainage and water quality*. (Master's thesis). University of Saskatchewan, Saskatoon, Saskatchewan. Retrieved from https://ecommons.usask.ca/handle/10388/etd-04112011-140210

Brunet, N.N., & Westbrook, C.J. (2012). Wetland drainage in the Canadian prairies: Nutrient, salt and bacteria characteristics. *Agriculture, Ecosystems & Environment, 146,* 1-12. doi: 10.1016/j.agee.2011.09.010

Butts, W.L. (2001). Beaver ponds in upstate New York as a source of anthropophilic mosquitoes. *Journal of the American Mosquito Control Association, 17*, 85–86.

Butts, W.L. (2004). Changes in distribution and abundance of mosquito populations in an ecological research tract over a 35-year history. *Journal of the American Mosquito Control Association, 20*, 319–320.

Camrose County, *By-law No 1142 Land Use Bylaw*. August 26, 2014. Retrieved from http://www.county.camrose.ab.ca/content/2015-mdp-lub-review-0

CFB/ASU Wainwright – Base Environment. (2013). *CFB/ASU Wainwright wetlands & riparian areas management plan*.

Chan, K.M.A., Satterfield, T., & Goldstein, J. (2012). Rethinking ecosystem services to better address and navigate cultural values. *Ecological Economics*, *74*, 8–18. doi: 10.1016/j.ecolecon.2011.11.011

Chase, J.M., & Shulman, R.S. (2009). Wetland isolation facilitates larval mosquito density through the reduction of predators. *Ecological Entomology*, *34*, 741–747. doi: 10.1111/j.1365-2311.2009.01128.x

Cai, Y.-B., Zhang, H., Pan, W.-B., Chen, Y.-H., & Wang, X.-R. (2013). Land use pattern, socio-economic development, and assessment of their impacts on ecosystem service value: study on natural wetlands distribution area (NWDA) in Fuzhou city, southeastern China. *Environmental Monitoring and Assessment*, *185*, 5111–5123. doi: 10.1007/s10661-012-2929-x

City of Camrose & Camrose County. (2016). *Camrose source water protection plan*. Retrieved from http://www.county.camrose.ab.ca/content/bylaws

City of Edmonton. (2012). *City of Edmonton wetland strategy*. Retrieved from https://www.edmonton.ca/city_government/documents/FINAL_Wetland_Strategy_low_res.pdf

City of Calgary. (2004). *Calgary wetland conservation plan*. Retrieved from http://www.calgary.ca/CSPS/Parks/Pages/Planning-and-Operations/Protecting-Calgarys-wetlands.aspx

City of Saskatoon. (2013a). *Official Community Plan Bylaw No. 8769*. Revised. November 4, 2013. Retrieved from https://www.saskatoon.ca/sites/default/files/8769.pdf

City of Saskatoon. (2013b). *Wetland Policy C09-041*. Final Approved. November 4, 2013. Retrieved from https://www.saskatoon.ca/sites/default/files/documents/city-clerk/civic-policies/C09-041.pdf

City of Winnipeg. (2007). *Ecologically significant natural lands strategy & policy*. Retrieved from http://winnipeg.ca/publicworks/parksOpenSpace/NaturalistServices/PDF/ESNL.pdf

Clare, S., Krogman, N., & Lemphers, N. (2011). Where is the avoidance in the implementation of wetland law and policy? *Wetlands Ecological Management*, *19*, 165-182. doi: 10.1007/s11273-011-9209-3

Coleman, W. D. & Skogstad, G. (Eds.). (1990). *Policy communities and public policy in Canada*. Toronto: Copp Clark Pitman.

Conley, F.M., van der Kamp, G. (2001). Monitoring the hydrology of Canadian prairie wetlands to detect the effects of climate change and land use changes. *Environmental Monitoring and Assessment, 67,* 195–215. doi: 10.1023/A:1006486607040

Convention on Biological Diversity Secretariat. (n.d.). *The convention on biological diversity*. Retrieved from https://www.cbd.int/

Cortus, B., Jeffrey, S., Unterschultz, J.R., & Boxall, P.C. (2010). The economics of wetland drainage and retention in Saskatchewan. *Canadian Journal of Agricultural Economics, 59,* 109–126. doi: 10.1111/j.1744-7976.2010.01193.x

Cows and Fish. (2013). *An overview of beaver management for agricultural producers*. Alberta Riparian Habitat Management Society: Lethbridge, Alberta. http://www.cowsandfish.org/pdfs/Beaver-Matrix-FINAL.pdf

Cox, K.W., & Campbell, L. (1997). *Global climate change and wetlands: Issues and awareness*. Environmental Protection Service, Environment Canada. Retrieved from http://nawcc.wetlandnetwork.ca/Global%20Climate%20Change.pdf

Dahl, T.E. 2014. Status and trends of prairie wetlands in the United States 1997 to 2009.U.S. Department of the Interior; Fish and Wildlife Service, Ecological Services, Washington, D.C. (67 pages). Retrieved from www.fws.gov/wetlands

DeBeer, C.M., Wheater, H.S., Carey, S.K., & Chun, K.P. (2016). Recent climatic, cryospheric, and hydrological changes over the interior of western Canada: a review and synthesis. *Hydrology Earth System Science, 20*, 1573–1598. doi: 10.5194/hess-20-1573-2016

Ducks Unlimited. (n.d.). *Preserve our prairies initiative*. Retrieved from http://www.ducks.org/Conservation/DU-Conservation-Initiatives/Preserve-Our-Prairies-Initiative

Ducks Unlimited Canada. (2006). *Natural values: Linking the environment to the economy: Biodiversity* (Report No. 5). Retrieved from http://www.aipa.ca/wp-content/uploads/2013/11/nv5_bio.pdf

Ducks Unlimited Canada, Louisiana-Pacific Canada Ltd., FPInnovations, Weyerhaeuser Company, Spruce Products Ltd. (2014). *Operational guide for forest road wetland crossings*. Version 1.0. 44p. Retrieved from http://www.ducks.ca/resources/industry/operational-guide-for-forest-road-wetland-crossings/

Environment Canada. (2013a). *How much habitat is enough*? 3rd ed. Environment Canada, Toronto, Ontario. Retrieved from http://ec.gc.ca/Publications/default.asp?lang=En&xml=1B5F659B-B931-4F37-A988-3DD73DF656B7

Environment Canada. (2013b). *Management plan for the Northern Leopard Frog (Lithobates pipiens), Western Boreal/Prairie Populations, in Canada*. *Species at Risk Act* Management Plan Series. Environment Canada, Ottawa. iii + 28 pp. Retrieved from http://www.registrelep-sararegistry.gc.ca/document/default_e.cfm?documentID=1929

Environmental Law Institute. (2008). *Planner's guide to wetland buffers for local governments*. Retrieved from http://www.eaaflyway.net/documents/resources/ELC-Pl-Guide_Wetland-buf.pdf

Erwin, K.L. (2009). Wetlands and global climate change: the role of wetland restoration in a changing world. *Wetlands Ecology and Management, 17*, 71–84 doi: 10.1007/s11273-008-9119-1

European Commission. (2013). *Commission Implementing Regulation* (EU) No. 485/2013. Retrieved from http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:32013R0485

Fang, X. & Pomeroy, J.W. (2008). Drought impacts on Canadian prairie wetland snow hydrology. *Hydrological Processes 22*, 2858-2873. doi: 10.1002/hyp.7074

Fang, X., Pomeroy, J.W., Westbrook, C., Guo, X., Minke, A., & Brown, T. (2010). Prediction of snowmelt derived streamflow in a wetland dominated prairie basin. *Hydrology and Earth System Sciences 14*, 991–1006. doi: 10.5194/hess-14-991-2010

Fisheries (Alberta) Act, RSA 2000, c. F-16). Edmonton: Alberta Queen's Printer. Retrieved from www.qp.alberta.ca/documents/Acts/F16.pdf

Fitch, L., Adams, B., & O'Shaughnessy, K. (2003). *Caring for the green zone: Riparian areas and grazing management – Third Edition*. Cows and Fish. Graphcom Printers Ltd.: Lethbridge, AB. Available from http://www.cowsandfish.org/publications/management.html

Forcey, G.M., Linz, G.M., Thogmartin, W.E., & Bleier, W.J. (2007). Influence of land use and climate on wetland breeding birds in the Prairie Pothole region of Canada. *Canadian Journal of Zoology, 85,* 421-436. doi: 10.1 139lZ07-005

Forrest, A.S.M. (2010). *Created stormwater wetlands as wetland compensation and a floristic quality approach to wetland condition assessment in central Alberta.* (Master's thesis). University of Alberta, Edmonton, Alberta. Retrieved from https://era.library.ualberta.ca/

Fritzell, E.K. (1989). Mammals in prairie wetland. In: A.G. van der Valk, (Ed.), *Northern prairie wetlands* (pp. 268-301), Ames, Iowa: Iowa State University Press.

Gabor, T.S., North, A.K., Ross, L.C.M., Murkin, H.R., Anderson, J.S., & Raven, M. (2004). *Natural values-The importance of wetlands and upland conservation practices in watershed management: Functions and values for water quality and quantity*. Ducks Unlimited Canada. Available from http://www.wetlandnetwork.ca/pg_ResourceDetails.php?int_ResourceId=1309

Gardner, R.C., & Fox, J. (2013). The legal status of environmental credit stacking. *Ecology Law Quarterly, 40,* 713-757. doi: 10.15779/Z38DZ83 Available at: http://scholarship.law.berkeley.edu/elq/vol40/iss4/1

Gascoigne, W.R., Hoag, D., Koontz, L., Tangen, B.A., Shaffer, T.L., & Gleason, R.A. (2011). Valuing ecosystem and economic services across land-use scenarios in the Prairie Pothole Region of the Dakotas, USA. *Ecological Economics, 70,* 1715-1725. doi: 10.1016/j.ecolecon.2011.04.010

Gleason, R.A., Laubhan, M.K., and Euliss, N.H., Jr., eds., 2008, Ecosystem services derived from wetland conservation practices in the United States Prairie Pothole Region with an emphasis on the U.S. Department of Agriculture Conservation Reserve and Wetlands Reserve Programs: U.S. Geological Professional Paper 1745, 58 p. Retrieved from http://pubs.usgs.gov/pp/1745/

Government of Alberta. (2003). *Water for Life: Alberta's Strategy for Sustainability*. Government of Alberta. (Publication No. 1/955). Edmonton, Alberta: Alberta Environment. Retrieved from http://www.waterforlife.alberta.ca/01548.html

Government of Alberta. (2011a). *Ecosystem services approach pilot on wetlands: An exploration of approaches to understand cultural services and benefits to ecosystem service assessments.* Edmonton, Alberta: Government of Alberta. Retrieved from http://environment.gov.ab.ca/info/listing.asp?page=1&searchtype=asset&txtsearch=ecosystem%20services

Government of Alberta. (2011b). *Ecosystem services approach pilot on wetlands: Integrated assessment report*. Edmonton, Alberta: Government of Alberta. Retrieved from http://www.environment.gov.ab.ca/info/library/8493.pdf

Government of Alberta. (2011c). *Recommended land use guidelines for protection of selected wildlife species and habitat within grassland and parkland natural regions of Alberta*. Available at http://esrd.alberta.ca/fish-wildlife/wildlife-land-use-guidelines/default.aspx

Government of Alberta. (2012). *Lower Athabasca regional plan 2012-2022*. Retrieved from https://landuse.alberta.ca/RegionalPlans/LowerAthabascaRegion/Pages/default.aspx

Government of Alberta. (2014). *South Saskatchewan regional plan 2014-2024*. Retrieved from https://landuse.alberta.ca/RegionalPlans/SouthSaskatchewanRegion/Pages/default.aspx

Government of Alberta. (2015a). *Alberta wetland identification and delineation directive*. Water Policy Branch, Alberta Environment and Parks. Edmonton, Alberta. Retrieved from http://aep.alberta.ca/water/programs-and-services/wetlands/documents/IdentificationDelineationDirectiveJun2015.pdf

Government of Alberta. (2015b). *Alberta wetland mitigation directive*. Water Policy Branch, Alberta Environment and Parks. Edmonton, Alberta. Retrieved from http://aep.alberta.ca/water/programs-and-services/wetlands/alberta-wetland-policy-implementation.aspx

Government of Alberta. (2015c). *Alberta wetland policy implementation in the white area – agriculture factsheet*. Retrieved from http://www.aaaf.ab.ca/uploads/pdf/AB_Wetland_Policy_Implement_fact_sheet_2015_FINAL_2.pdf

Government of Alberta. (2015d). *Alberta Wetland Rapid Evaluation Tool –Actual (ABWRET- A) Manual.* Water Policy Branch, Alberta Environment and Parks. Edmonton, Alberta. Retrieved from http://aep.alberta.ca/water/programs-and-services/wetlands/documents/WetlandRapidEvaluationTool-Jun2015.pdf

Government of Canada. (1991). *The federal policy on wetland conservation.* Ottawa, Ontario: Environment Canada. Canadian Wildlife Service. Retrieved from http://publications.gc.ca/collections/Collection/CW66-116-1991E.pdf

Government of Manitoba. (2014a). *Manitoba's surface water management strategy.* Retrieved from http://gov.mb.ca/waterstewardship/questionnaires/surface_water_management/index.html

Government of Manitoba. (2014b). *Towards sustainable drainage: A proposed new regulatory approach.* Retrieved from http://www.gov.mb.ca/conservation/waterstewardship/licensing/drainage/index.html

Government of Saskatchewan. (n.d.). *Farm stewardship program*. Retrieved from https://www.saskatchewan.ca/business/agriculture-natural-resources-and-industry/agribusiness-farmers-and-ranchers/growing-forward-2/environment-programs/farm-stewardship-program

Gray, M.J., Smith, L.M., & Brenes, R. (2004). Effects of agricultural cultivation on demographics of southern high plains amphibians. *Conservation Biology, 18*, 1368-1377. doi: 10.1111/j.1523-1739.2004.00089.x

Graymore, M.LM., & McBride, D. (2013). Socio-ecological value of wetlands: the dilemma of balancing human and ecological water needs. *Australasian Journal of Environmental Management, 20*, 225-241. doi: 10.1080/14486563.2013.816252

Greenway, M. (2005). The role of constructed wetlands in secondary effluent treatment and water reuse in subtropical and arid Australia. *Ecological Engineering*, 25, 501–509. doi: 10.1016/j.ecoleng.2005.07.008

Gren, I.-M., Folke, C., Turner, K., & Batemen, I. (1994). Primary and secondary values of wetland ecosystems. *Environmental and Resource Economics, 4,* 55-74.

Grygoruk, M., Mirosław-Świątek, D., Chrzanowska, W., & Ignar, S. (2013). How much for water? Economic assessment and mapping of floodplain water storage as a catchment-scale ecosystem service of wetlands. *Water, 5*, 1760-1779. doi: 10.3390/w5041760

Gundserson, L.H., Carpenter, S.R., Folke, C., Olsson, P., & Peterson, G. (2006). Water RATs (resilience, adaptability, and transformability) in lake and wetland social-ecological systems. *Ecology and Society, 11,* 1-9. doi: 10.5751/ES-01556-110116

Haak, D. (2015). *Sustainable agricultural land management around wetlands on the Canadian Prairies*. Retrieved from http://www.agr.gc.ca/eng/science-and-innovation/agricultural-practices/soil-and-land/riparian-areas/sustainable-agricultural-land-management-around-wetlands-on-the-canadian-prairies/?id=1231514224747

Haddock, R. (2015). *Beaver restoration across boundaries*. Miistakis Institute: Calgary, Alberta. Retrieved from http://rockies.ca/project_info2.php?id=93

Hannon, S.J., Paszkowski, C.A., Boutin, S., DeGroot, J., Macdonald, S.E., Wheatley, M., & Eaton, B.R. (2002). Abundance and species composition of amphibians, small mammals, and songbirds in riparian forest buffer strips of varying widths in the boreal mixedwood of Alberta. *Canadian Journal of Forest Research, 32*, 1784-1800. doi: 10.1139/X02-092

Hansen, L.T. (2009). The viability of creating wetlands for the sale of carbon offsets. *Journal of Agricultural and Resource Economics, 34,* 350–365.

Hayashi, M., & Rosenberry, D.O. (2002). Effects of ground water exchange on the hydrology and ecology of surface water. *Groundwater 40,* 309-316. doi: 10.1111/j.1745-6584.2002.tb02659.x

Hayashi, M., & van der Kamp, G. (2000). Simple equations to represent the volume–area–depth relations of shallow wetlands in small topographic depressions. *Journal of Hydrology, 237,* 74-85. doi: 10.1016/S0022-1694(00)00300-0

Hayashi, M., van der Kamp, G., & Rosenberry, D.O. (2016). Hydrology of prairie wetlands: Understanding the integrated surface-water and groundwater processes. *Wetlands, 36(Suppl 2)*, 237- 254. doi: 10.1007/s13157-016-0797-9

Hayashi, M., van der Kamp, G., & Rudolph, D.L. (1998a). Water and solute transfer between a prairie wetland and adjacent uplands: 1. Water balance. *Journal of Hydrology*, *207,* 42-55.

Hayashi, M., van der Kamp, G., & Rudolph, D.L. (1998b). Water and solute transfer between a prairie wetland and adjacent uplands, 2. Chloride cycle. *Journal of Hydrology 207*, 56–67.

Hayashi, M., van der Kamp, G., & Schmidt, R. (2003). Focused infiltration of snowmelt water in partially frozen soil under small depressions. *Journal of Hydrology, 270,* 214–229. doi: 10.1016/S0022-1694(02)00287-1

Heimlich, R.E., Wiebe, K.D., Claassen, R., Gadsby, D., & House, R.M. (1998). Wetlands and agriculture: private interests and public benefits. Resource Economics Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 765. Retrieved from https://www.researchgate.net/publication/43284826_Wetlands_and_agriculture_private_interests_and_public_benefits

Hein, L., van Koppen, K., de Groot, R.S., & van Ierland, E.C. (2006). Spatial scales, stakeholders and the valuation of ecosystem services. *Ecological Economics*, *57,* 209– 228. doi: 10.1016/j.ecolecon.2005.04.005

Higginbotham, N., Connor, L., Albrecht, G., Freeman, S., & Agho, K. (2007). Validation of an environmental distress scale. *EcoHealth, 3,* 245-254. doi: 10.1007/s10393-006-0069-x

Hill, M.R.J., McMaster, D.G., Harrison, T., Hershmiller, A., & Plews, T. (2011). A reverse auction for wetland restoration in the Assiniboine River watershed, Saskatchewan. *Canadian Journal of Agricultural Economics 59,* 245–258. doi: 10.1111/j.1744-7976.2010.01215.x

Hoeven, J., & Dwelle, T. (2014). *North Dakota's water quality monitoring strategy: 2008-2019.* North Dakota Department of Health: Bismarck, North Dakota. Retrieved from https://www.epa.gov/sites/production/files/2015-10/documents/nd-wpp.pdf

Hood, G.A., & Bayley, S.E. (2008). Beaver (*Castor canadensis*) mitigate the effects of climate on the area of open water in boreal wetlands in western Canada. *Biological Conservation, 141,* 556-567. doi: 10.1016/j.biocon.2007.12.003

Hood, G.A., & Larson, D.G. (2014a). Beaver-created habitat heterogeneity influences aquatic invertebrate assemblages in boreal Canada. *Wetlands, 34*, 19–29. doi: 10.1007/s13157-013-0476-z

Hood, G.A., & Larson, D.G. (2014b). Ecological engineering and aquatic connectivity: a new perspective from beaver-modified wetlands. *Freshwater Biology, 60*, 198–208. doi:10.1111/fwb.12487

Hood, G.A., & Yarmey, N. (2015). *Mitigating human-beaver conflicts through adaptive management*. Prepared for Beaver County. Retrieved from www.beaver.ab.ca/public/download/documents/13293

Horwitz, P., & Finlayson, M. (2011). Wetlands as settings for human health: incorporating ecosystem services and health impact assessment into water resource management. *Bioscience*, *61*, 678-688. doi: 10.1525/bio.2011.61.9.6

Hough, P., & Robertson, M. (2009). Mitigation under Section 404 of the Clean Water Act: Where it comes from, what it means. *Wetlands Ecological Management, 17*, 15–33. doi: 10.1007/s11273-008-9093-7

Houlahan, J.E., & Findlay, C.S. (2003). The effects of adjacent land use on wetland amphibian species richness and community composition. *Canadian Journal of Fisheries and Aquatic Sciences, 60,* 1078-1094. doi: 10.1139/F03-095

Hubbard, D.E., & Linder, R.L. (1986). Spring runoff retention in prairie pothole wetlands. *Journal of Soil and Water Conservation, 41*,122-125.

Huel, D., Harrison, T., Foster, A., & Pawana, N. (2000). *Managing Saskatchewan wetlands – A landowner's guide*. Regina, Saskatchewan: Saskatchewan Wetland Conservation Corporation. Retrieved from: http://www.southsaskriverstewards.ca/ckfinder/userfiles/files/ManagingSaskatchewanWetlands.pdf

Jackson, M.J., Gow, J.L., Evelyn, M.J., Meikleham, N.E., McMahon, T.J.S., Koga, E., Howay, T.J., Wang, L., & Yan, E. (2009). *Culex* mosquitoes, West Nile virus, and the application of innovative management in the design and management of stormwater retention ponds in Canada. *Water Quality Research Journal of Canada*, *44*, 103-110.

Johnson, C.W. (1984). *An economic valuation of South Dakota wetlands as a recreation resource for resident hunters*. (Master's Thesis). South Dakota State University, Brookings, South Dakota. Retrieved from http://ageconsearch.umn.edu/handle/34043

Johnson, D.H. (2001). Habitat fragmentation effects on birds in grasslands and wetlands: A critique of our knowledge. *Great Plains Research 11*, 211-31.

Johnson, W.C., Millett, B.V., Gilmanov, T., Voldseth, R.A., Guntenspergen, G.R., & Naugle, D.E. (2005). Vulnerability of northern prairie wetlands to climate change. *BioScience, 55*, 863-872. doi: 10.1641/0006-3568(2005)055[0863:VONPWT]2.0.CO;2

Johnson, W.C., Werner, B., Guntenspergen, G.R., Voldseth, R.A., Millett, B., Naugle, D.E., Tulbure, M., Carroll, R.W.H., Tracy, J., & Olawsky, C. (2010). Prairie wetland complexes as landscape functional units in a changing climate. *BioScience, 60*, 128–140. doi: 10.1525/bio.2010.60.2.7

Kao, C.M., Wang, J.Y., Chen, K.F., Lee, H.Y., & Wu, M.J. (2002). Non-point source pesticide removal by a mountainous wetland. *Water Science and Technology, 46,* 199–206.

Kayranli, B., Scholz, M., Mustafa, A., & Hedmark, Å. (2010). Carbon storage and fluxes within freshwater wetlands: A critical review. *Wetlands, 30*,111–124. doi: 10.1007/s13157-009-0003-4

Kinsley, C. (2015). *Development of knowledge translation tools to foster the uptake of constructed wetland technologies to treat rural wastewaters*. Canadian Water Network. Retrieved from http://www.cwn-rce.ca/assets/End-User-Reports/Agri-Food/Kinsley/CWN-EN-Kinsley-2014-5pager-Web.pdf

Kirby, J., Giles, N., Davidson, N., Owen, M., & Spray, C. (2004). *Waterbirds & wetland recreation handbook: A review of issues and management practice*. The Wildfowl & Wetlands Trust: Gloucestershire, UK. Retrieved from https://www.researchgate.net/publication/44130262_Waterbirds_and_wetland_recreation_handbook_a_review_of_issues_and_management_practice

Kolozsvary, M.B., & Swihart, R.K. (1999). Habitat fragmentation and the distribution of amphibians: patch and landscape correlates in farmland. *Canadian Journal of Zoology, 77,* 1288-1299.

Korven, H.C., & Heinrichs, D.H. (1971). *Slough drainage and cropping*. (Agriculture Canada Pub. No. 1440). Ottawa, Ontario: Agriculture Canada.

Kurz, D.J., McGinty, N.A., Stankavich, S.A., Nowakowski, A.J., & Smith, G.A. (2013). Restored wetlands can support mammalian assemblages comparable to those in nonmitigated reference wetlands. *The American Midland Naturalist, 170*, 260-273. doi: 10.1674/0003-0031-170.2.260

Kwasniak, A. (2016). *Alberta wetlands: A law and policy guide*. Calgary, Alberta: Canadian Institute and Resources Law.

Latacz-Lohmann, U. & Hodge, I. (2003). European agri-environmental policy for the 21st century. *The Australian Journal of Agricultural and Resource Economics* 47 (1): 123–39. doi: 10.1111/1467-8489.00206

Lee, K.N. (1993). *Compass and Gyroscope: Integrating science and politics for the environment*. Washington, DC: Island Press.

Lehtinen, R.M., Galatowitsch, S.M & Tester, J.R. (1999). Consequences of habitat loss and fragmentation for wetland amphibian assemblages. *Wetlands, 19,* 1-12.

Lilley, J., & Labatiuk, C. (2001) Edmonton's draft guidelines for constructed stormwater wetlands. *Canadian Water Resources Journal / Revue Canadienne des Ressources Hydriques, 26,* 195-210. doi: 10.4296/cwrj2602195

Louisiana Coastal Protection and Restoration Authority. (2014). *Methodology for coastal wetland creation*. Approved VCS Methodology VM0024. Retrieved from http://database.v-c-s.org/methodologies/methodology-coastal-wetland-creation-v10

Lynch-Stewart, P., Neice, P., Rubec, C., & Kessel-Taylor, I. (1996). *The federal policy on wetland conservation: Implementation guide for land managers*. Ottawa, Ontario: Environment Canada. Canadian Wildlife Service. Retrieved from http://nawcc.wetlandnetwork.ca/Fed%20Policy%20Wetland%20Conserv_Implement%20Guide%20for%20Fed%20Land%20Mgrs.pdf

Main, A.R., Headley, J.V., Peru, K.M., Michel, N.L., Cessna, A.J., Morrissey, C.A. (2014). Widespread Use and Frequent Detection of Neonicotinoid Insecticides in Wetlands of Canada's Prairie Pothole Region. *PLoS one, 9,* e92821- e92821. doi: 10.1371/journal.pone.0101400

Main, A.R., Michel, N.L., Headley, J.V., Peru, K.M., & Morrissey, C.A. (2015). Ecological and landscape drivers of neonicotinoid insecticide detections and concentrations in Canada's prairie wetlands. *Environmental Science & Technology, 49,* 8367–8376. doi: 10.1021/acs.est.5b01287

Maltby, E., & Acreman, M.C. (2011). Ecosystem services of wetlands: Pathfinder for a new paradigm. *Hydrological Sciences Journal – Journal des Sciences Hydrologiques, 56,* 1341-1359. doi: 10.1080/02626667.2011.631014

Mann, J., Grant, C., & Kulshreshtha, S. (2014). Economics of a pricing mechanism to compensate rural land owners for preserving wetlands. *Canadian Water Resources Journal / Revue canadienne des ressources hydriques, 39,* 462–471. doi: 10.1080/07011784.2014.965037

Marton, J.M., Creed, I.F., Lewis, D.B., Lane, C.R., Basu, N.B., Cohen, M.J., & Craft, C.B. (2015). Geographically isolated wetlands are important biogeochemical reactors on the landscape. *BioScience, 65,* 408–418. doi: 10.1093/biosci/biv009

Mazzotta, M., Bousquin, J., Ojo, C., Hychka, K., Gottschalk Druschke, C., Berry, W., & McKinney, R. (2016). *Assessing the benefits of wetland restoration: A rapid benefit indicators approach for decision makers*. United States Environmental Protection Agency (EPA/600/R-16/084). Retrieved from https://www.epa.gov/water-research/rapid-benefit-indicators-rbi-approach

McCauley, L.A., Anteau, M.J., Post van der Burg, M. & Wiltermuth, M.T. (2015). Land use and wetland drainage affect water levels and dynamics of remaining wetlands. *Ecosphere, 6*, 1-22. doi: 10.1890/ES14-00494.1.

Millennium Ecosystem Assessment. (2005). *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, DC. Retrieved from http://www.millenniumassessment.org/en/index.html

Millett, B.V., Johnson, W.C., & Guntenspergen, G.R. (2009). Climate trends of the North American prairie pothole region 1906–2000. *Climatic Change, 93*, 243–267. doi: 10.1007/s10584-008-9543-5

Ministry of Natural Resources and Forestry. (2016). *Draft: A wetland conservation strategy for Ontario 2016-2030*. Retrieved from http://apps.mnr.gov.on.ca/public/files/er/wetland-conservation-strategy.pdf

Minke, A.G., Westbrook, C.J., & van der Kamp, G. (2010). Simplified volume-area-depth method for estimating water storage of prairie potholes. *Wetlands, 30,* 541-551. doi: 10.1007/s13157-010-0044-8

Minnesota Board of Water and Soil Resources. (2003). *Wetlands regulation in Minnesota*. Retrieved from http://www.bwsr.state.mn.us/wetlands/regulation.html

Minnesota Board of Water and Soil Resources. (2004). *The Minnesota Wetland Conservation Act manual*. Retrieved from https://www.leg.state.mn.us/docs/2007/other/070605.pdf

Minnesota Board of Water and Soil Resources. (2009). *Wetlands restoration strategy: A framework for prioritizing efforts in Minnesota*. Retrieved from http://www.dnr.state.mn.us/wetlands/index.html

Minnesota Department of Natural Resources. (2016). *Definition of public waters*. Retrieved from http://www.dnr.state.mn.us/waters/watermgmt_section/pwpermits/pw_definition.html

Mitchell, B. (1997). *Resource and Environmental Management.* Waterloo, ON: Longman Press.

Mitsch, W.J., & Gosselink, J.G. (2000). The value of wetlands: Importance of scale and landscape setting. *Ecological Economics, 35,* 25-33. doi: 10.1016/S0921-8009(00)00165-8

Mitsch W.J., & Gosselink, J.G. (2007) *Wetlands* (4th ed.) New York: Wiley.

Mitsch, W.J., & Hernandez. M.E. (2013). Landscape and climate change threats to wetlands of North and Central America. *Aquatic Sciences, 75*, 133–149. doi: 10.1007/s00027-012-0262-7

Montana Wetland Council. (2013). *Priceless resources: A strategic framework for wetland and riparian area conservation and restoration in Montana 2013-2017*. Retrieved from http://deq.mt.gov/Portals/112/Water/WPB/Wetlands/StategicFramework2013-2017.pdf

Morrissey, C.A., Mineau, P., Devries, J.H., Sanchez-Bayo, F., Liess, M., Cavallaro, M.C., & Liber, K. (2015). Neonicotinoid contamination of global surface waters and associated risk to aquatic invertebrates: A review. *Environment International, 74*, 291–303. doi: 10.1016/j.envint.2014.10.024

Murkin, H.A. (1998). Freshwater functions and values of prairie wetlands. *Great Plains Research, 8*, 3-15.

Musamba, E.B., Boon, E.K., Ngaga, Y.M., Giliba, R.A., & Dumulinyi, T. (2012). The recreational value of wetlands: Activities, socio-economic activities and consumers' surplus around Lake Victoria in Musoma Municipality, Tanzania. *Journal of Human Ecology, 37*, 85-92.

National Wetlands Working Group. (1988). *Wetlands of Canada*. Ecological Land Classification Series, No. 24. Ottawa, Ontario: Environment Canada and Polyscience Publications Inc.

Native Plant Solutions. (2012). *Naturalized stormwater systems*. Retrieved from http://www.nativeplantsolutions.ca/what-we-do/naturalized-stormwater-systems/

Natural Resources Canada. (2015). *The atlas of Canada*. Retrieved from http://www.nrcan.gc.ca/earth-sciences/geography/atlas-canada

Nature Conservancy of Canada. (2015). *Wild hog*. Retrieved from http://www.natureconservancy.ca/en/what-we-do/resource-centre/invasive-species/wild-hog.html

Naugle, D.E. (1997). *Habitat area requirements of prairie wetland birds in South Dakota* (Master's Thesis). South Dakota State University, Brookings, South Dakota. Retrieved from http://pubstorage.sdstate.edu/wfs/thesis/Naugle-David-E-PhD-1997-2.pdf

Needham, M. D., & Morzillo, A. T. (2011). *Landowner incentives and tolerances for managing beaver impacts in Oregon.* Final project report for Oregon Department of Fish and Wildlife (ODFW) and Oregon Watershed Enhancement Board (OWEB). Corvallis, OR: Oregon State University, Department of Forest Ecosystems and Society. Retrieved from http://www.dfw.state.or.us/wildlife/living_with/beaver.asp

Nelner, T.B., & Hood, G.A. (2011). Effect of agriculture and presence of American beaver *Castor canadensis* on winter biodiversity of mammals. *Wildlife Biology, 17,* 326-336. doi: 10.2981/09-097

North American Wetlands Conservation Council (Canada). (n.d.). *The North American Wetlands Conservation Act*. Retrieved from: http://nawcc.wetlandnetwork.ca/nawca.html

North Saskatchewan River Basin Council. (2008). *North Saskatchewan River source water protection plan*. Retrieved from https://www.wsask.ca/Global/Water%20Info/Watershed%20Planning/NorthSaskatchewanRiverWatershedSourceWaterProtectionPlan.pdf

Nova Scotia Environment. (2011). *Nova Scotia wetland conservation policy*. Retrieved from http://www.novascotia.ca/nse/wetland/conservation.policy.asp

O'Brien, T. (2016). *Small unmanned aerial vehicles as remote sensors: An effective data gathering tool for wetland mapping* (Master's thesis). University of Guelph, Guelph, Ontario. Retrieved from https://atrium.lib.uoguelph.ca/xmlui/handle/10214/9660

Odum, E.P. (1979). The value of wetlands: A hierarchical approach. In Greeson, P.E. Clark, J.R., & Clark, J.E. (Eds.) *Wetland functions and value: The state of our understanding* (pp. 16-25). Minneapolis, MN: American Water Resources Association Technical Publication.

Off-highway Vehicles Act, RSNS 2010, c. 323, s.1. Available from http://nslegislature.ca/legc/statutes/off-highway%20vehicles.pdf

Ouren, D.S., Haas, Christopher, Melcher, C.P., Stewart, S.C., Ponds, P.D., Sexton, N.R., Burris, Lucy, Fancher, Tammy, and Bowen, Z.H., 2007, Environmental effects of off-highway vehicles on Bureau of Land Management lands: A literature synthesis, annotated bibliographies, extensive bibliographies, and internet resources: U.S. Geological Survey, Open-File Report 2007-1353, 225 p. Retrieved from https://pubs.usgs.gov/of/2007/1353/report.pdf

Partington, M., Gillies, C., Gingras, B., Smith, C., & Morissette, J. (2016). *Resource roads and wetlands: A guide for planning, construction and maintenance*. (Special Publication SP-520E). Pointe-Claire, QC: FPInnovations. Retrieved from https://fpinnovations.ca/ResearchProgram/forest-operations/resource-roads/Pages/guide-for-planning-construction-and-maintenance.aspx

Pattison, J., Boxall, P.C., & Adamowicz, W.L. (2011). The economic benefits of wetland retention and restoration in Manitoba. *Canadian Journal of Agricultural Economics, 59*, 223-244. doi: 10.1111/j.1744-7976.2010.01217.x

Pattison, J.K., Gabor, S., & Scott, T. (2013). *A business case for wetland conservation and restoration in the settled areas of Alberta Vermilion River subwatershed case study*. Commissioned by the Ducks Unlimited Canada. Retrieved from http://www.ducks.ca/assets/2012/06/DUC-AB-Business-Case_Final.pdf

Phelan, J., Jones, P., & Matthews, K. (2015). *Montana Prairie Wetlands and Intermittent/Ephemeral Streams: Hydrologic Needs Assessment for Healthy Watersheds*. RTI Project Number 0213541.004.001.004. Report to the US Environmental Protection Agency. Healthy Watersheds Program, Washington, D.C. Retrieved from https://www.epa.gov/sites/production/files/2015-11/documents/151016mt_final_report_july2015.pdf

Pollock, M.M., G. Lewallen, K. Woodruff, C.E. Jordan and J.M. Castro (Editors) 2015. The Beaver Restoration Guidebook: Working with Beaver to Restore Streams, Wetlands, and Floodplains. Version 1.02. United States Fish and Wildlife Service, Portland, Oregon. 189 pp. Online at: https://www.fws.gov/oregonfwo/promo.cfm?id=177175812

Pomeroy, J.W., Fang, X., Westbrook, C., Minke, A., Guo, X., & Brown, T. (2010). *Prairie hydrological model study final report*. Centre for Hydrology Report No. 7, University of Saskatchewan, Saskatoon. http://www.usask.ca/hydrology/Reports.php

Pope, S.E., Fahrig, L., & Merriam, H.G. (2000). Landscape complementation and metapopulation effects on leopard frog populations. *Ecology, 81*, 2498-2508. doi: 10.1890/0012-9658(2000)081[2498:LCAMEO]2.0.CO;2

Prairie Habitat Joint Venture. 2014. *Prairie Habitat Joint Venture Implementation Plan 2013-2020: The Prairie Parklands.* Report of the Prairie Habitat Joint Venture. Environment Canada, Edmonton, AB. Retrieved from http://www.phjv.ca/pdf/PHJV%20Implemenetation%20Plan%20PRAIRIE%20PARKLAND%202013-2020%20Final.pdf

Prince Edward Island (P.E.I.) Fisheries, Aquaculture and Environment. (2007). *A wetland conservation policy for Prince Edward Island*. Retrieved from http://www.gov.pe.ca/photos/original/2007wetlands-po.pdf

Rafiq, R., Alam, S., Rahman, M., & Islam, I. (2014). Conserving wetlands: Valuation of indirect use benefits of a wetland of Dhaka. *International Journal of Environmental Science and Development*, *5*, 64-69. doi: 10.7763/IJESD.2014.V5.452

Ramsar Convention Secretariat, 2013. *The Ramsar Convention Manual: A guide to the Convention on Wetlands (Ramsar, Iran, 1971)*, 6th ed. Ramsar Convention Secretariat, Gland, Switzerland. Retrieved from http://www.ramsar.org/about/the-ramsar-convention-and-its-mission

Reichelderfer, K., & Boggess, W.G. (1988). Government decision making and program performance: The case of the conservation reserve program. *American Journal of Agricultural Economics*, *70*, 1–11.

Renton, D.A., Mushet, D.M., & DeKeyser, E.S. (2015). *Climate change and prairie pothole wetlands - mitigating water-level and hydroperiod effects through upland management.* (U.S. Geological Survey Scientific Investigations Report 2015–5004). Reston, Virginia: U.S. Geological Survey. Retrieved from http://pubs.usgs.gov/sir/2015/5004/

Rocky View County. (2010). *Wetland conservation and management policy*. (Policy No. 420). Retrieved from http://www.rockyview.ca/Government/Policies/InfrastructureOperations.aspx

Rooney, R. (2014, February 11). *Wetland function and health: Assessment in service of a new Albertan wetland policy* [Video file]. Retrieved from https://youtu.be/VqyrAfJh76Y

Rooney, R.C., Foote, L., Krogman, N., Pattison, J.K., Wilson, M.J., & Bayley, S.E. (2015). Replacing natural wetlands with stormwater management facilities: Biophysical and perceived social values. *Water Research*, *73*, 17-28. doi:10.1016/j.watres.2014.12.035

Ross, L.C.M., and Martz, D. (2013). *Integrating natural wetlands and improving design of naturalized storm water management facilities in the City of Edmonton: Workshop guidebook.* December 4th and 5th, Edmonton, AB. Retrieved from http://www.edmonton.ca/city_government/environmental_stewardship/wetlands-workshop.aspx

Rozema, E.R., Rozema, L, R., & Zheng, Y. (2016). A vertical flow constructed wetland for the treatment of winery process water and domestic sewage in Ontario, Canada: Six years of performance data. *Ecological Engineering, 86*, 262-268. doi: 10.1016/j.ecoleng.2015.11.006

Russi D., ten Brink P., Farmer A., Badura T., Coates D., Förster J., Kumar R. and Davidson N. (2013) The Economics of Ecosystems and Biodiversity for Water and Wetlands. IEEP, London and Brussels; Ramsar Secretariat, Gland. Retrieved from http://www.teebweb.org/publication/the-economics-of-ecosystems-and-biodiversity-teeb-for-water-and-wetlands/

Sadler, T.S. (2005). *Town of Strathmore wetland conservation plan*. Retrieved from http://www.strathmore.ca/wetlands_policy

Sauchyn, D., Diaz, H., & Kulshreshtha, S. (2010). Conclusion. In D. Sauchyn, H. Diaz, & S. Kulshreshtha (Eds.), *The new normal: The Canadian Prairies in a changing climate* (pp. 353-361). Regina, Saskatchewan: Canadian Plains Research Center.

Selman, M., Greenhalgh, S., Taylor, M., & Guiling, J. (2008). *Paying for environmental performance: Potential cost savings using a reverse auction in program sign-up.* WRI Policy Note Environmental Markets No. 5. Washington, DC: World Resources Institute. Retrieved from http://www.wri.org/publication/paying-environmental-performance-2

Semlitsch, R.D. (1998). Biological delineation of terrestrial buffer zones for pond-breeding salamanders. *Conservation Biology, 12*, 1113–1119.

Semlitsch, R.D., & Bodie, J.R. (2003). Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles. *Conservation Biology, 17*, 1219-1228. doi: 10.1046/j.1523-1739.2003.02177.x

Shook, K.R., & Pomeroy, J.W. (2011). Memory effects of depressional storage in Northern Prairie hydrology. *Hydrological Processes, 25*, 3890-3898. doi: 10.1002/hyp.8381

Shutler, D., Mullie, A., & Clark, R.G. (2000). Bird communities of prairie uplands and wetlands in relation to farming practices in Saskatchewan. *Conservation Biology, 14*, 1441-1451. doi: 10.1046/j.1523-1739.2000.98246.x

Skinner, S. (in press). *Policies and practices for non-native and invasive species management*. BRWA WMP Report. Camrose, Alberta: Battle River Watershed Alliance.

Skogstad, G. (2005). *Policy networks and policy communities: Conceptual evolution and governing realities*. University of Toronto, Toronto, Ontario. Prepared for the Workshop on "Canada's Contribution to Comparative Theorizing" Annual Meeting of the Canadian Political Science Association University of Western Ontario, London, Ontario. Retrieved from http://www.cpsa-acsp.ca/papers-2005/Skogstad.pdf

Smith, A.G., Stoudt, J.H., & Gollop, J.B. (1964). Prairie potholes and marshes. In: Linduska, J.P. (Ed.) *Waterfowl tomorrow* (pp. 39-50). Washington, D.C.: U.S. Fish and Wildlife Service.

Söderqvist, T., Mitsch, W.J., Turner, R.K. (2000). Valuation of wetlands in a landscape and institutional perspective. *Ecological Economics*, *35*, 1–6. doi: 10.1016/S0921-8009(00)00163-4

South Dakota Interagency Wetlands Working Group. (2001). *Wetland conservation and management guidelines for South Dakota state agencies*. SD Department of Agriculture, SD Department of Environment and Natural Resources, SD Department of Game, Fish and Parks, SD Department of Transportation: Pierre, South Dakota. Retrieved from https://sdda.sd.gov/legacydocs/Forestry/publications/PDF/wetlandmanagement.pdf

Specht, E. (2015). *Using beaver as a watershed management tool: Articulating Alberta's regulatory context.* Unpublished manuscript, University of Alberta Augustana Campus.

Stevens, C.E., Paszkowski, C.A, Foote, A.L. (2007). Beaver (*Castor canadensis*) as a surrogate species for conserving anuran amphibians on boreal streams in Alberta, Canada. *Biological Conservation*, *134*, 1-13. doi: 10.1016/j.biocon.2006.07.017

Stewart, A., Reedyk, S., Franz, B., Fromradas, K., Hilliard, C., & Hall, S. (2010). *Field manual on buffer design for the Canadian prairies*. Agri-Environment Services Branch, Agriculture and Agri-Food Canada. Retrieved from http://publications.gc.ca/site/eng/387724/publication.html

Stewart, R.E., & Kantrud, H.A. (1971). *Classification of natural ponds and lakes in the glaciated Prairie Region*. Resource Publication 92, published by the Bureau of Sport Fisheries and Wildlife, U.S. Fish and Wildlife Service, Washington, D.C. 57pp.

Stoneham, G., Ha, V.C.A., & Strappazzon, L. 2003. Auctions for conservation contracts: An empirical examination of Victoria's bushtender trial. *The Australian Journal of Agricultural and Resource Economics 47*, 477–500. doi: 10.1111/j.1467-8489.2003.t01-1-00224.x

The Economics of Ecosystems and Biodiversity (TEEB) (2011), The Economics of Ecosystems and Biodiversity in National and International Policy Making. Edited by Patrick ten Brink. Earthscan, London and Washington. Retrieved from http://www.teebweb.org/publication/teeb-in-national-and-international-policy-making/

Thompson, J., & Young, D.A. (1992). The optimal use of prairie pothole wetlands: An economic perspective. *Canadian Water Resources Journal / Revue canadienne des ressources hydriques, 17*, 365-372. doi: 10.4296/cwrj1704365

Tierra Resources. (2013). *The nation's first wetland carbon pilot 1*. Retrieved from http://tierraresourcesllc.com/wp-content/uploads/2013/12/Tierra-Luling-description_PRINT-2.pdf

Tippie, S. (2010). *Working with beaver for better habitat naturally*. Wildlife 200 & The Grand Canyon Trust. Retrieved from http://www.rockies.ca/beavers/files/ut_workingBeaver2010.pdf

Town of Strathmore. (2007). *Strathmore wetland conservation policy*. (Policy No. 6605). Retrieved from http://www.strathmore.ca/wetlands_policy

Turner, R.K., van den Bergh, J.C.J.M., Söderqvist, T., Barendregt, A., van der Straaten, J., Maltby, E., van Ierland, E.C. (2000). Ecological-economic analysis of wetlands: scientific integration for management and policy. *Ecological Economics, 35*, 7–23. doi: 10.1016/S0921-8009(00)00164-6

UNEP and CIFOR 2014. *Guiding principles for delivering coastal wetland carbon projects.* United Nations Environment Programme, Nairobi, Kenya and Center for International Forestry Research, Bogor, Indonesia, 57pp. Retrieved from http://www.unep.org/publications/

United States Department of Agriculture (USDA). (n.d.a). *2014 Farm Bill - Agricultural conservation easement program – NRCS*. Retrieved from http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/easements/acep/?cid=stelprdb1242695

United States Department of Agriculture. (n.d.b). *Conservation reserve program*. Retrieved from https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/index

United States Department of Agriculture. (n.d.c). *Farmable wetlands program*. Retrieved from https://www.fsa.usda.gov/programs-and-services/conservation-programs/farmable-wetlands/index

United States Department of Agriculture. (n.d.d). *Wetland conservation provisions (swampbuster)*. Retrieved from http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/programs/alphabetical/camr/?cid=stelprdb1043554

United States Environmental Protection Agency (EPA). (2015a). *Clean water rule factsheet*. Retrieved from http://www2.epa.gov/cleanwaterrule

United States Environmental Protection Agency. (2015b). *Summary of the Clean Water Act*. Retrieved from https://www.epa.gov/laws-regulations/summary-clean-water-act

United States Environmental Protection Agency. (2015c). *What the Clean Water Rule does*. Retrieved from https://www.epa.gov/cleanwaterrule/what-clean-water-rule-does

United States Environmental Protection Agency. (2016a). *National wetland condition assessment.* Retrieved from https://www.epa.gov/national-aquatic-resource-surveys/nwca

United States Environmental Protection Agency. (2016b). *Section 404 of the Clean Water Act: Memorandum of agreement.* Retrieved from: https://www.epa.gov/cwa-404/memorandum-agreement

United States Fish & Wildlife Service (FWS). (2014). *Iowa wetland management district: Final comprehensive conservation plan*. U.S. Department of the Interior Bloomington, MN. Retrieved from https://www.fws.gov/Midwest/planning/iowawetlands/index.html

United States Fish & Wildlife Service. (2016a). *Migratory Bird Conservation Commission*. Retrieved from https://www.fws.gov/refuges/realty/mbcc.html

United States Fish & Wildlife Service. (2016b). *North American wetlands conservation act.* Retrieved from https://www.fws.gov/birds/grants/north-american-wetland-conservation-act.php

Utah Division of Wildlife Resources. (2010). *Utah beaver management plan 2010–2020*. DWR Publication 09-29. Utah Division of Wildlife Resources: Salt Lake City, Utah. Retrieved from http://wildlife.utah.gov/hunting-in-utah/hunting-information/furbearer.html

Vance, L., & Chutz, J. (2016). *Montana natural heritage program: Wetland program plan.* Retrieved from https://www.epa.gov/sites/production/files/2016-03/documents/mtnhp_wetland_program_plan_2016-2020.pdf

Vance, L., S. Owen and J. Horton. 2013. *Literature review: Hydrology-ecology relationships in Montana Prairie wetlands and intermittent/ephemeral streams. Report to the Cadmus Group and the U.S. Environmental Protection Agency.* Montana Natural Heritage Program, Helena, MT. 49 pp. plus appendices. Retrieved from http://mtnhp.org/Reports.asp?key=4

van der Kamp, G., & Hayashi, M. (1998). The groundwater recharge function of small wetlands in the semi-arid northern prairies. *Great Plains Research, 8*, 39-56.

van der Kamp, G., & Hayashi, M. (2009). Groundwater-wetland ecosystem interaction in the semiarid glaciated plains of North America. *Hydrogeology Journal*, *17*, 203–214. doi: 10.1007/s10040-008-0367-1

van der Kamp, G., Hayashi, M. & Gallén, D. (2003). Comparing the hydrology of grassed and cultivated catchments in the semi-arid Canadian prairies. *Hydrological Processes*, *17*, 559-575. doi: 10.1002/hyp.1157

Van Meter, K.J., & Basu, N.B. (2015). Signatures of human impact: size distributions and spatial organization of wetlands in the Prairie Pothole landscape. *Ecological Applications, 25(2)*, 451–465. doi: 10.1890/14-0662.1

Venterink, H.O., Davidsson, T.E., K. Kiehl, K., & Leonardson, L. (2002). Impact of drying and re-wetting on N, P and K dynamics in a wetland soil. *Plant and Soil, 243***,** 119–130. doi: 10.1023/A:1019993510737

Water Security Agency. (2015). *Agricultural water management strategy*. Retrieved from https://www.wsask.ca/Water-Programs/Agricultural-Drainage-/Agricultural-Water-Management-Strategy/

Watmough, M., Ingstrup, D., Duncan, D., & Schinke, H. (2002). *Prairie Habitat Joint Venture Habitat Monitoring Program Phase 1: Recent habitat trends in NAWMP targeted landscapes.* Canadian Wildlife Service, Environment Canada, Technical Report Series No. 391. Edmonton. 94p.

Werner, B.A, Johnson, W.C., & Guntenspergen, G.R. (2013). Evidence for 20th century climate warming and wetland drying in the North American Prairie Pothole Region. *Ecology and Evolution, 3*, 3471– 3482. doi: 10.1002/ece3.731

Western Winter Wheat Initiative. (n.d.). *About western winter wheat initiative*. Retrieved from http://www.growwinterwheat.ca/winter-wheat-benefits-advantages/

Weston, M.A., Antos, M.J., & Glover, H.K. (2009). Birds, buffers and bicycles: A review and case study of wetland buffers. *The Victorian Naturalist*, *126*, 79-85.

Wetland Stewardship Partnership. (2010). *A wetland action plan for British Columbia*. Retrieved from http://bcwetlands.ca/tools/wetland-action-plan/

White, B., & Burton, M. (2005). *Measuring the efficiency of conservation auctions.* Proceedings of the 47th Annual Australian Agricultural and Resource Economics Society Meetings, Fremantle, Western Australia, 11–14 February 2004.

White, J., & Gray, M. (2007). *The riparian setback matrix model*. Prepared for Lakeland County. Edmonton, Alberta: *Aquality* Environmental Consulting Ltd.

White, J.S., & Bayley, S.E. (1999). Restoration of a Canadian prairie wetland with agricultural and municipal wastewater. *Environmental Management, 24*, 25–37.

White, J.S., Bayley, S.E., & Curtis, P.J. (1999). Sediment storage of phosphorus in a northern prairie wetland receiving municipal and agro-industrial wastewater. *Ecological Engineering, 14*, 127–138.

Whited, D., Galatowitsch, S., Tester, J.R., Schik, K., Lehtinen, R., & Husveth, J. (2000). The importance of local and regional factors in predicting effective conservation-Planning strategies for wetland bird communities in agricultural and urban landscapes. *Landscape and Urban Planning, 49,* 49-65. doi: 10.1016/S0169-2046(00)00046-3

Wildlife Act, Revised Statutes of Alberta, (2000 Chapter W-10). Edmonton: Alberta Queen's Printer. Retrieved from http://www.qp.alberta.ca/570.cfm

Wilson, M.J., & Bayley, S.E. (2012). Use of single versus multiple biotic communities as indicators of biological integrity in northern prairie wetlands. *Ecological Indicators, 20*, 187-195. doi:10.1016/j.ecolind.2012.02.009

Wiltermuth, M.T. (2014). *Influences of climate variability and landscape modifications on water dynamics, community structure, and amphipod populations in large prairie wetlands: Implication for waterbird conservation* (Doctoral dissertation). Retrieved from http://gradworks.umi.com/36/70/3670216.html

Wolfe, J. (2006). *Natural values: Linking the environment to the economy #6 – Wetlands.* Ducks Unlimited Canada: Stonewall, MB. Retrieved from http://www.ducks.ca/assets/2012/06/nv6_wet.pdf

Woo, M-K., & Rowsell, R.D. (1993). Hydrology of a prairie slough. *Journal of Hydrology 146*, 175–207.

Wray, H.E., & Bayley, S.E. (2006). *A Review of Indicators of Wetland Health and Function in Alberta's Prairie, Aspen Parkland and Boreal Dry Mixedwood Regions*. Environmental Policy Branch, Alberta Environment. Retrieved from http://open.alberta.ca/publications/9780778567691

Wrubleski, D.A., and L.C.M. Ross. 2011. *Aquatic Invertebrates of Prairie Wetlands: Community Composition, Ecological Roles, and Impacts of Agriculture. In Arthropods of Canadian Grasslands (Volume 2): Inhabitants of a Changing Landscape*. Edited by K. D. Floate. Biological Survey of Canada. pp. 91-116.

Yang, W., X. Wang, T.S. Gabor, L. Boychuk, and P. Badiou. (2008). *Water quantity and quality benefits from wetland conservation and restoration in the Broughton's Creek Watershed*. Ducks Unlimited Canada Publication. 48 pp. Retrieved from http://www.ducks.ca/assets/2012/06/broughtons.pdf

Zedler, J.B. (2003). Wetlands at your service: Reducing impacts of agriculture at the watershed scale. *Frontiers in Ecology and the Environment, 1,* 65-72. doi: 10.1890/1540–9295(2003)001[0065:WAYSRI]2.0.CO;2

Zenner, G., & Hancock, A. (2012). *An occasional drought is good for wetlands!* Retrieved from http://www.iowadnr.gov/Portals/idnr/uploads/Hunting/Drought%20is%20a%20good%20thing%20for%20wetlands.pdf?ver=2012-09-13-122502-123

Zhang, D.Q., Jinadasa, K.B.S.N., Gersberg, R.M., Liu, Y., Ng, W.J., & Tan, S.K. (2014). Application of constructed wetlands for wastewater treatment in developing countries: A review of recent developments (2000-2013). *Journal of Environmental Management*, *141*, 116-131. doi: 10.1016/j.jenvman.2014.03.015

Appendix A

Summary of Wetland Inventories in the Battle River and Sounding Creek Watersheds

	Impact	Basin Count	% Count	Hectares	% Area
Roundhill (1962-2003) *Parkland 51323 Ha*					
	Altered (Cultivation/Dugout)	4,896	46.58%	805.42	13.37%
	Drained (Lost, Altered, Consolidated)	2,367	22.52%	3730.3	61.94%
	Intact	3,248	30.90%	1486.4	24.68%
	Total	10,511	100.00%	6022.12	100.00%
Wetaskiwin (1962-2003) *Parkland 9979 Ha*					
	Altered (Cultivation/Dugout)	941	35.82%	88.95	4.80%
	Drained (Lost, Altered, Consolidated)	1,233	46.94%	1677.11	90.45%
	Intact	453	17.24%	88.19	4.76%
	Total	2,627	100.00%	1854.25	100.00%

	Impact	Basin Count	% Count	Hectares	% Area
Iron Creek (1963-2005) *Parkland* *567479 Ha*	***Altered (Cultivation/Dugout)***	129,949	61%	27,318.04	44%
	Drained (Lost, Altered, Consolidated)	8,737	4%	14,289.65	23%
	Intact	73,914	35%	20,842.09	33%
	Total	212,600	100%	62,449.78	100%
Camrose (1962-2003) *Parkland* *32000 Ha*	***Altered (Cultivation/Dugout)***	2,464	35.49%	239.47	6.50%
	Drained (Lost, Altered, Consolidated)	2,222	32.01%	2960.51	80.30%
	Intact	2,256	32.50%	486.63	13.20%
	Total	6,942	100.00%	3686.61	100.00%

Altered = no drain with riparian and aquatic vegetation absent or disturbed

Drained Altered = outlet drain with riparian and aquatic vegetation present

Consolidated = inlet drain with riparian and aquatic vegetation present

Lost = outlet drain riparian and aquatic vegetation absent

Intact = no drain with riparian and aquatic vegetation present.

This is our battle: the watershed we all share, and the fight to maintain a healthy environment, vibrant communities and a stable economy.

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