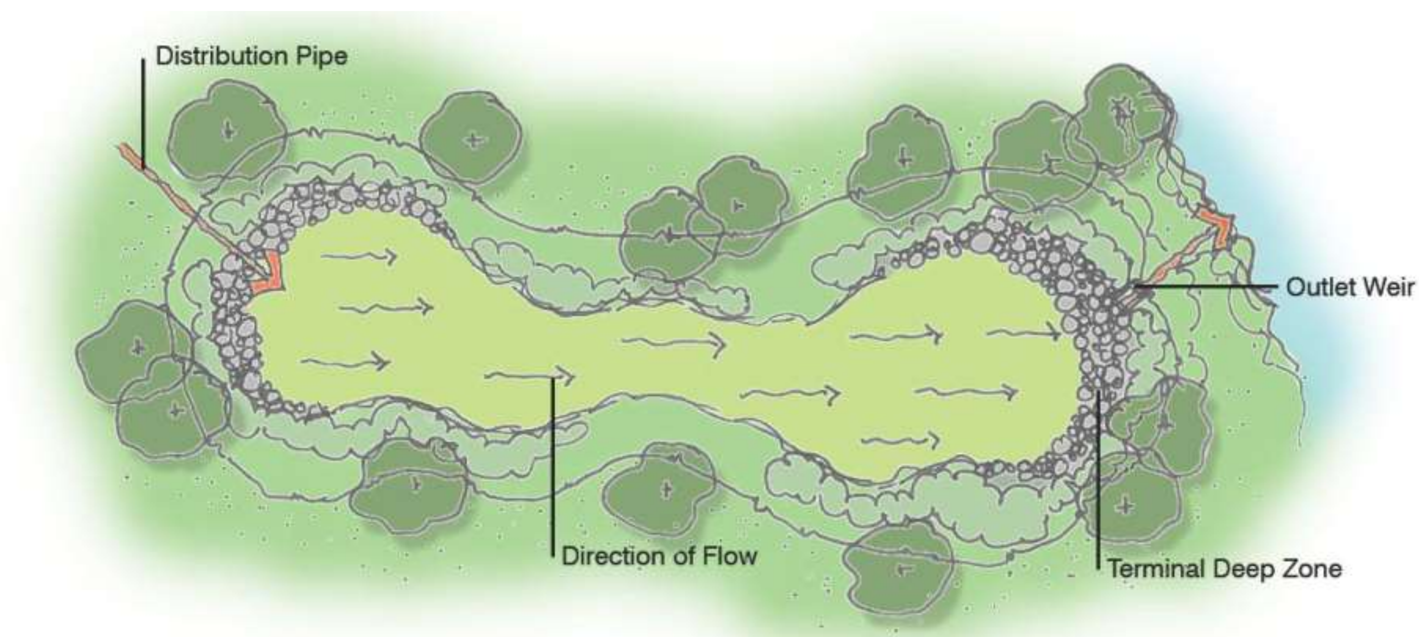
Associated Environmental

FINAL REPORT

Okanagan Basin Water Board

Constructed Wetlands for Stormwater Management: An Okanagan Guidebook



March 2018

ISO 9001 and 14001 Certified | An Associated Engineering Company

Canada's Best Managed Companies Platinum member

Acknowledgements

Associated Environmental Consultants thanks the 26 individuals and organizations that took the time to respond to the questionnaire that was distributed for this project in the Okanagan Valley. Thank you to Josie Symonds, Lisa Scott (FLNRO) for wetland photographs, and John Friesen (RDNO) for invasive species information, document review and photographs, and the following who reviewed the draft document and provided comments: Natasha Lukey, Tara Montgomery and others at the Okanagan Nation Alliance.

The project was directed for the Okanagan Basin Water Board by Nelson Jatel, Water Stewardship Director. The project team at Associated consisted of Carrie Nadeau, R.P.Bio., Hugh Hamilton, Ph.D., P.Ag., Lawrence Bird, M.Sc, and Kristen Anderson, PWS, CPESC. The drawings were prepared by Jason Bennett, CLSA, Brian de Jong, C.E.T. and Dan Austin, MGIS, GISP of Associated. Professional editing was completed by Barb Kissinger, B.Sc., and Corinna Hoodicoff, M.Sc., R.P.Bio.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

Abbreviation	Meaning
BC	British Columbia
BOD	Biochemical oxygen demand
C	Concentration of a contaminant (C_{out} = CW outflow target concentration, C_{in} = CW inflow concentration, C* = background concentration in a wetland).
CW	Constructed wetland
DFO	Fisheries and Oceans Canada
ESOC	Emerging substances of concern (e.g. pharmaceuticals, fire retardants, personal care products, etc.)
ET	Evapotranspiration
HLR	Hydraulic loading rate
HRT	Hydraulic retention time
HW	Habitat wetland
MOE	BC Ministry of Environment
MWR	*Municipal Wastewater Regulation*
N	Nitrogen
NPS	non-point source
OBWB	Okanagan Basin Water Board
ONA	Okanagan Nation Alliance
P	phosphorus
PCIC	Pacific Climate Impacts Consortium
Q	Flow rate (volume per unit time). (Q_{in} = wetland inflow rate,

Abbreviation	Meaning
	Q_{out} = wetland outflow rate)
RDCO	Regional District of Central Okanagan
RDNO	Regional District of North Okanagan
RDOS	Regional District of Okanagan-Similkameen
SAR	Species at risk
SF	Surface flow
SSF	Subsurface flow
TSS	Total suspended solids
WDR	*Waste Discharge Regulation*
WQG	Water Quality Guidelines
WQO	Water Quality Objectives
WSA	*Water Sustainability Act*

Glossary

Term	Meaning
Blue-Listed	Blue-listed species are those indigenous species, subspecies, or ecological communities considered to be of Special Concern in British Columbia because of characteristics that make them particularly sensitive to human activities or natural events. Blue-listed taxa are at risk, but are not Extirpated, Endangered or Threatened.
Bog	This class of wetland is characterized by organic soil of predominantly poorly to moderately decomposed sphagnum moss peats and a water table at or near the surface. Waters are generally acidic and low in nutrients. Bogs are usually carpeted with sphagnum mosses and shrubs, and may be treed or treeless.
Constructed Wetland (CW)	For the purposes of this document the following definition is used: *A water treatment system that uses natural processes involving wetland vegetation, soils, and their microbial assemblages to improve water quality.* This statement above could also be defined as a treatment wetland, although this document uses the term *constructed wetland* for simplicity. Please note that there are many other definitions and purposes for a constructed wetland including: the creation of wildlife habitat, mitigation of flood impacts, attenuation of water flow, wetland replacement and compensation, and many others including aesthetics. In this document these are called Habitat Wetlands (HW).
Fen	This class of wetland is characterized by organic soil of mainly moderately to well-decomposed sedge and non-sphagnum moss peats and a water table at or near the surface. Waters are mainly nutrient rich with a near-neutral to slightly acid pH. The dominant vegetation includes sedges, grasses, reeds, mosses, and some shrubs. Scattered trees may be present.
Forebay	Is a pool and settling basin constructed at incoming discharge points of

Term	Meaning
	a stormwater system. The purpose of a sediment forebay is to allow sediment to settle from the incoming stormwater runoff before it is delivered to the balance of the system. A sediment forebay helps to isolate the sediment deposition in an accessible area, which facilitates maintenance efforts.
Gleysol	A type of soil (soil order) that has developed in a location that undergoes prolonged saturation most years. Diagnostic properties include presence of mottles (iron stains) and grey, black, blue colouring.
Habitat Wetland (HW)	Designed to provide ecological functions of natural wetlands, including habitat for wildlife, increased biodiversity (especially in dry landscapes), water retention and peak flow attenuation, and groundwater recharge. Designed and built primarily to restore natural wetland function that has been degraded or lost.
Hydrophytes	Plants adapted to grow in waterlogged soils.
Marsh	This class of wetland typically occurs in association with shallow open water ecosystems and is characterized by cattails, bulrushes, grasses, and sedges. Floating aquatic vegetation may also occur and include duckweed and water smartweed.
Plug flow	In wetlands, this is an idealized situation where the flow velocity is consistent through the cross-sectional area of the wetland, enabling maximum water contact with plants and biofilms.
Red-Listed	Red-listed species are those indigenous species, subspecies or ecological communities that have, or are candidates for Extirpated, Endangered, or Threatened status in British Columbia.
Stormwater	Is water that accumulates from precipitation events and snow/ice melt. Stormwater can soak into the soil (infiltrate), be held on the surface and evaporate, or runoff and end up in nearby streams, rivers, or other water bodies (surface water). In urban settings, stormwater needs to be managed to avoid large volumes of runoff water (flooding) and discharge of potential contaminants (water pollution) into other surface water sources.
Subsurface flow (SSF) wetland	SSF wetlands, the water flows beneath the surface through a gravel, crushed rock, or coarse soil bed that is penetrated by the roots of

Term	Meaning
	aquatic plants growing on the surface. The growing media is saturated to just a few centimetres below the surface, but the flow is controlled.
Surface flow (SF) wetland	SF wetlands, most closely resemble natural marshes, the stormwater or wastewater flows across the wetland surface at a depth typically between 0.3 and 0.7 m. The flow velocity is slow, controlled by a shallow gradient and the presence of emergent aquatic plants like cattails and bulrushes.
Swamp	This class of wetland typically occurs along the edge of other waterbodies. It is characterized by vegetation dominated by tall woody vegetation (trees and shrubs), generally over 30% cover, and wood-rich peat laid down by this vegetation.
Treatment train	Multiple ponds and wetlands arranged in series, each designed for a specific function. Typically, the first pond/wetland dampens flow and removes coarse sediment, with subsequent wetlands removing fine sediment and dissolved constituents.
Wet meadow	Saline Meadow – Saline meadows are characterized by alkaline salts that occur within the drawdown zone of shallow or vernal ponds and are generally characterized by unique salt-tolerant vegetation. Alkaline Pond – Alkaline ponds are characterized by alkaline salts that occur within a permanently inundated or seasonal waterbody. Flood Bench (Low and Mid) – Flood ecosystems are not technically wetlands, but occur on sites that are regularly influenced by high water levels and inundation that affects the vegetation present. The low and mid flood bench sites are most frequently inundated and strongly associated with wetland transitions.
Wetlands (general)	Areas where soils are water-saturated for a sufficient length of time such that excess water and resulting low soil oxygen levels are principal determinants of vegetation and soil development. Wetlands have a relative abundance of hydrophytes in the vegetation community and hydric soil characteristics.

1 Introduction

1.1 BACKGROUND

Since 1970, the Okanagan Basin Water Board (OBWB) has identified and addressed water management and water quality issues in the Okanagan Valley. As the population of the Okanagan continues to grow, the effects of stormwater runoff on water quality and aquatic habitat have become a serious concern. Increased stormwater volumes associated with land development also play a role in flood hazard. The use of **constructed wetlands** in stormwater management could help to maintain water quality and contribute to the multiple-barrier approach to the protection of the Okanagan's water sources. OBWB's Okanagan Wetland Strategy Project ("the Okanagan Wetland Strategy") has identified the need to organize and provide resources for wetland-related activities, including the need for further wetland inventory, prioritization of high value conservation wetlands, reduction of urban development pressure on wetlands, and reduction of impacts of stormwater discharge into natural wetlands. The wetland strategy recommendations include the development of comprehensive and reliable wetland information to support effective planning, law-making, and policy development (Okanagan Wetland Strategy Project Phase I, Patterson et al. 2014).

> OBWB acknowledges that the Okanagan watershed lies within the territories of the Syilx Peoples (Okanagan Nation). Section 3.1 provides additional information.

In August 2017, OBWB retained Associated Environmental Consultants Inc. (Associated) to develop a guidebook for local governments on the use of constructed wetlands for stormwater management in the Okanagan Basin. The guidebook is intended to satisfy the wetland strategy recommendations by producing clear guidelines for implementing constructed wetlands, considering the unique biophysical and social-community characteristics of the Okanagan. This document is the **final guidebook**, which has been reviewed by OBWB, First Nations and stakeholders.

1.2 WHAT IS A CONSTRUCTED WETLAND?

For the purposes of this guidebook, **Constructed wetlands** (CW) are defined as water treatment systems that use natural processes involving wetland vegetation, soils, and their microbial assemblages to improve water quality (US EPA 2017). A CW typically differs from a conventional stormwater pond in that wetland plants are specifically included in the design so that at least 25% of the area is vegetated by cattails, bulrushes, or other aquatic plants. These water treatment systems can also be called treatment wetlands, for simplicity in this guidebook we use the term CW.

In most situations, CWs can provide many of the ecological functions of natural wetlands, including habitat for wildlife, increased biodiversity (especially in dry landscapes), water retention and peak flow attenuation, and groundwater recharge. However, CWs are designed primarily for water quality improvement. Therefore, their design and operation usually differ from wetlands that have been designed and built primarily to restore natural wetland function that has been degraded or lost. In this guidebook, built wetlands of that type are referred to as **habitat wetlands** (HW). Additional information on differences between CWs and HWs is provided in Section 2.

Although CWs are designed primarily for water quality improvement, the design of CWs in the Okanagan should include other ecological functions, as long as they do not significantly comprise their water quality improvement objective. All CWs provide some level of habitat and biodiversity function, so designers can look for ways to optimize these functions while still improving the quality of the stormwater that is released. If there is sufficient space, stormwater CW designers have more flexibility to incorporate pockets of deeper or shallow water than CWs designed to treat municipal or industrial waste streams, thus increasing habitat diversity for plants.

Functioning natural wetlands in the Okanagan Valley are not suitable for alteration to serve as stormwater CW for regulatory (Section 4) and conservation reasons. This guidebook does not recommend the alteration or replacement of existing wetlands with CW, nor should CW be measured as a direct compensation replacement for a habitat wetland.

1.3 GOALS OF THIS GUIDEBOOK

The overall objective of this guidebook is to provide information to support local governments in designing and implementing CWs for stormwater retention and water quality improvement through treatment, as a component of the implementation of the Okanagan Wetland Strategy. The specific goals to meet this overall objective are to:

- Provide an overview of the water treatment mechanisms of CWs, with an emphasis on stormwater;
- Describe the unique biophysical and socio-community attributes of the Okanagan Basin that are relevant to CW design, and provide guidance on design to optimize CW performance in the Okanagan;
- Describe best practices for CW construction, operations, maintenance, and monitoring;
- Describe the regulatory requirements as wetland establishment and maintenance, including environmental permits, *Water Sustainability Act* requirements, and other applicable regulations.
- Provide guidance on how to incorporate habitat enhancement in CW design, while recognizing that stormwater retention and water quality improvement are the primary purposes of CWs;
- Identify potential funding sources including grant options to support design and construction of CW projects; and
- Describe the role of CWs in contributing to the Okanagan region’s potential for ecosystem-based climate change adaptation.

The use of CWs for water quality improvement began to evolve from an interesting concept in the 1970s to become a mainstream technology by the late 1990s. There are now thousands of CWs treating not only stormwater but also municipal and industrial wastewater, acid rock drainage, oil sands and metal mine leachate, agricultural runoff, and a wide range of other liquid waste streams. The development of this guidebook made use of the design manuals and guidelines published by other jurisdictions (Section 1.4), customizing the information for application in the Okanagan Valley. In addition, the OBWB sent a questionnaire to 26 individuals representing 10 local governments and non-profit organizations in the Okanagan to obtain input on the potential utility of CWs and the desired features of the guidebook. The questionnaire and a summary of the results are provided in **Appendix A**.

1.4 SUPPORTING DOCUMENTS AND TECHNICAL REFERENCES

Appendix B provides a list of the key design manuals, textbooks, and technical guidance documents that can be used for planning, preliminary and detailed design, construction and operation (including website links for online resources on OBWB's website and the reference list in Appendix B and throughout this guidebook). To assist the readability of this guidebook, references within the text are kept to a minimum except where the source material is used directly.

> **Important**: This guidebook is intended to assist with stormwater planning and to help determine the suitability of CWs as a component of stormwater management at the site, drainage catchment, watershed, or local government scale. The detailed design of CWs may require the services of a Professional Engineer (P.Eng.) and/or another Qualified Professional (QP). It is the responsibility of the owner of a CW to determine if the services of a professional are required for the design of the CW or the outfall to a watercourse or waterbody. Regulatory guidance is outlined in Section 4.0.

2 How do Constructed Wetlands Work?

2.1 TREATMENT MECHANISMS

As water moves through a CW, contaminants are removed by the combined effects of several physical, chemical, and biological processes. Table 2.1 provides a summary of the contaminant removal mechanisms in wetlands, highlighting the contaminants that may be present in stormwater or in other sources of runoff in the Okanagan.

Several attributes of wetlands promote the rate of contaminant removal compared to conventional stormwater ponds:

- As an adaptation to extended periods of saturation, wetland plants transfer oxygen from the atmosphere to the rooting zone. This enables both aerobic and anaerobic microbial degradation processes to operate in wetland sediment, and promotes a rich diversity of bacteria.
- The submerged stems of wetland plants provide significant surface area for microbial organisms to attach and form biofilms (e.g., the 'slime' on the stem of a cattail below the water surface). Biofilms also form on organic substrates on the bottom of the wetland. Water flowing through stands of wetland plants interacts with the biofilm bacteria, accelerating microbial degradation. Biofilm bacteria numbers are 1,000 to 10,000 times larger than the numbers of free-floating microbes in the water column, per unit wetland volume.
- The physical barriers formed by plant stems promote filtration and sedimentation.
- Contaminant compounds are taken up by plants (both aquatic macrophytes and phytoplankton).
- Organic compounds exuded by plants and decaying wetland vegetation can be toxic to some microbes, or bind with dissolved metals and nutrients and reduce their bioavailability.

- The genetic diversity of microbes in wetlands means that the number of types of contaminants that can be degraded is greater than in an engineered pond, and the system can withstand shocks such as the sudden release of a large volume of a specific contaminant.

2.2 CONSTRUCTED WETLAND TYPES

There are two basic categories of CWs: surface flow (SF) wetlands and subsurface flow (SSF) wetlands. Within each category there is a range of possible variations, which can be combined to form hybrids. As an example of a surface flow variant, in recent years, there has been increasing interest in ‘floating island’ wetlands for stormwater applications. In addition, it is not uncommon for a CW to be built to discharge to a natural wetland, where the CW is intended to remove a significant proportion of contaminants and the natural wetland serves to polish the discharge.

With **Surface Flow** (SF) wetlands, which most closely resemble natural marshes, the stormwater or wastewater flows across the wetland surface at a depth typically between 0.3 and 0.7 m (Figure 2-1). The flow velocity is slow, controlled by a shallow gradient and the presence of emergent aquatic plants like cattails and bulrushes. The basin that holds the water is formed by excavation, construction of berms, or a combination of excavation and berms. For optimal treatment performance, the water flows through the wetland as ‘plug flow,’ meaning that the flow velocity is consistent through the cross-sectional area of the wetland enabling maximum contact with the plants and biofilms. To achieve this, SF wetlands are usually narrow, with a length-to-width ratio of at least 3:1, and the inlet device (e.g., a weir or inflow pipe) is designed to spread the inflow across the width of the wetland cell. This is to avoid ‘short-circuiting,’ where the water flows quickly through the middle of a wetland without sufficient residence time to enable treatment. Discharge from SF wetlands is usually through an outlet device that controls water level and outflow rate. This can range from a simple weir at the downstream end to an engineered structure that can precisely adjust water level and flow.

With **Subsurface Flow** (SSF) wetlands, the water flows beneath the surface through a gravel, crushed rock, or coarse soil bed that is penetrated by the roots of aquatic plants growing on the surface (Figure 2-2 and Figre 2-3). The growing media is saturated to just a few centimetres below the surface, but the flow is controlled so that no water is usually on the surface (except following major events). The porous media enables large numbers of microbes to attach and form biofilms, and the penetrating roots of the plants disperse oxygen through the subsurface (although much of the subsurface area would be anaerobic). Not surprisingly, SSF wetlands require sophisticated engineering of the inlet and outlet structures to ensure that the water flows through the permeable media at the desired rate. SSF wetlands are usually lined. Given the higher level of engineering (and associated construction costs), SSF systems are sometimes referred to as vegetated submerged beds, hydro-botanical systems, and wetland bioreactors.

For stormwater management, SF systems are more common than SSF systems. SSF systems are well suited to locations where space is limited and are more likely in industrial or municipal wastewater applications, or where year-round operation is needed in cool climates.

Natural wetlands should <u>not</u> be used for stormwater management without previous treatment, because wetlands are legally considered “streams” under the BC *Water Sustainability Act (*WSA), and the discharge of deleterious substances is not permitted under the WSA. However, a site where a wetland was previously drained or otherwise badly degraded can be considered for a CW if the likelihood of restoration by natural processes is low. This is addressed further in Sections 5 and 6. Direct discharge of stormwater to natural wetlands should not occur due to impacts on wetland habitat and hydrology.

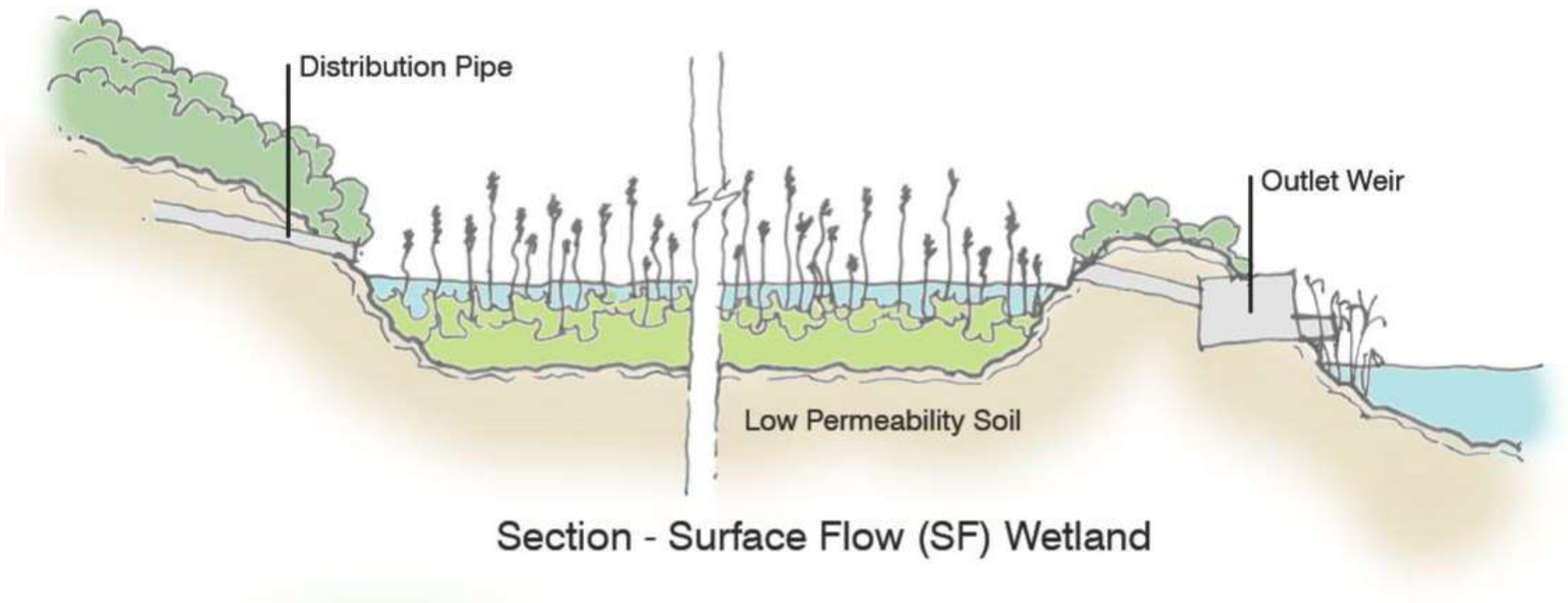


Figure 2-1
Surface Flow Wetland Plan View

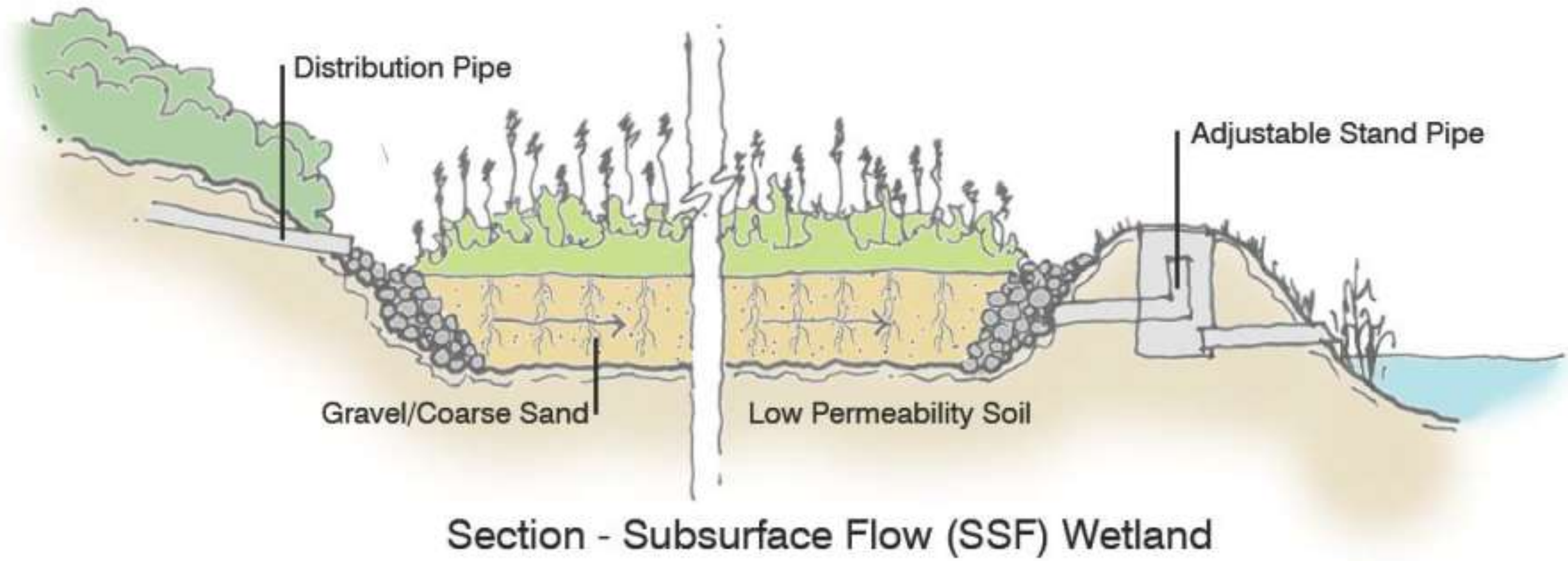


Figure 2-2
Subsurface Flow Wetland Plan View

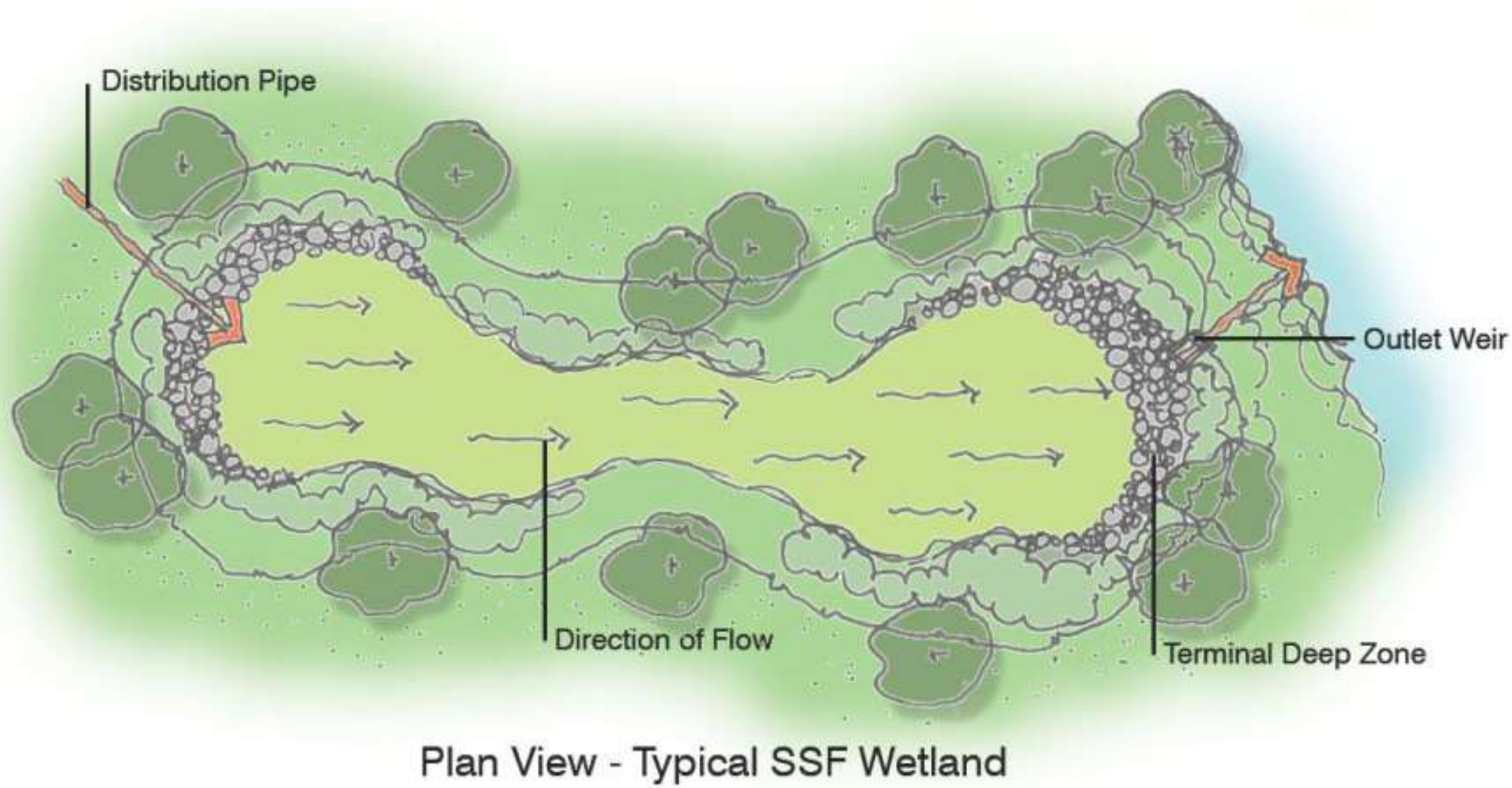


Figure 2-3
Subsurface Flow Wetland

Table 2-1
Contaminant removal mechanisms in wetlands

Mechanism	Description	Contaminants Affected[1]
Physical		
Sedimentation	Gravity settling of solids (and contaminants attached to solids) in open water and marsh areas.	Sediment, organic solids, colloidal solids (BOD, N, P, metals, bacteria, virus, heavier hydrocarbons)
Filtration	Particulates are mechanically filtered as water flows through root masses, substrate, and plant stems.	Suspended solids, colloidal solids
Chemical		
Precipitation	Dissolved compounds react to form insoluble particulates that settle in slow-moving water.	Heavy metals, P
Adsorption	Adsorption onto substrate (sediment & organic particles) and plant surfaces. Adsorption onto suspended particles (e.g., Van der Waals force).	P, metals (organics)
Decomposition	Oxidation and reduction.	Organic compounds
Photo-degradation	Ultra-violet light promotes hydrolysis and oxidation of organic compounds. Short wavelength UV kills or inactivates microorganisms by destroying nucleic acids in their DNA.	ESOCs, trace organics, bacteria
Biological		
Microbial metabolism	Suspended, benthic & plant supported bacteria break down soluble organics & colloids; nitrification/denitrification; oxidation of metals.	BOD, light and refractory organics (incl. ESOCs); organic and ammonia nitrogen; metals; colloidal solids
Plant metabolism	Uptake and breakdown of organic compounds by plants; some root excretions are toxic to enteric microbes.	Organics; bacteria
Plant absorption	Plant uptake through the roots with storage in biomass.	N, P, other nutrients, metals, organics
Natural die-off	The wetland environment (temperature, light) is unfavourable for some pathogens; natural decay.	Bacteria, viruses

Source: Updated from Hamilton et al. (1993); Watson (1989).
Note: 1. Contaminants in brackets are removed incidentally with the other contaminants listed.

3 What makes the Okanagan Unique?

3.1 SYILX PERSPECTIVES ON WATER

All water management decisions in the Okanagan Basin should consider the values held by the Syilx People. The Syilx People of the Okanagan Nation were the first human inhabitants in this geographical area, and have thousands of years of knowledge and understanding of the Okanagan Valleys physical, cultural and social environment.

The Syilx traditional territory extends over approximately 69,000 square kilometres. The northernmost extent of this territory is just north of Revelstoke, BC, and the eastern boundary is between Kaslo and Kootenay Lakes. The southern boundary extends to the vicinity of Wilbur, Washington, and the western border extends into the Nicola Valley (Syilx/Okanagan Nation Alliance 2017).

The Syilx Water Declaration states: "*siwłk*^{w}" is part of us and part of all life. *siwłk*^{w} must be treated with reverence and respect. Our sacred *siwłk*^{w} connects and sustains all life." Syilx People recognize *siwłk*^{w} (i.e., water) as a sacred entity and relative that connects all life (Okanagan Nation Alliance 2014).

For Syilx (Okanagan) people, the ways of knowing *siwłkw* (water) are embedded in our language and bequeathed to us by our ancestors. Maintaining the integrity of *siwłkw* is essential to our identity and is entrenched in our responsibilities to our homelands. *siwłkw* is our most sacred medicine.

Our sovereign, unceded right to self-governance and self-determination are affirmed within our Syilx laws and customs as dictated by our *captikwł*. This is our *stłtałt*, our Aboriginal title and rights. *stłtałt* is an unchanging truth. It is the responsibility of reciprocity that we continue to honour, exercise, and act upon. This responsibility cannot be given away; it is the foundation of who we are and of our continued existence on this land. These natural laws are the truth and cannot be overturned or diminished by contemporary governments. They have, and will continue to be, followed by the Syilx people. Any external process for proposed uses of *siwłkw* or *tmxwulaxw* within our homelands must be premised on our unextinguished Aboriginal title and rights, which includes the right to decide how the water and lands of our territory will be used.

As water leaders we aim to uphold our responsibility to care for the *tmxwulaxw* in order to ensure a healthy and sustainable environment that will continue to nourish our people for generations to come. In the face of current challenges, Syilx people remain steadfast in our dedication to come together to protect the resilience of our *siwłkw*. Together, we are working to support an interdependent balance amongst all of the complex cycles of *siwłkw* and plants, *tmxwulaxw* and animals. Throughout our territory, we are developing strategies, initiatives, methodologies and partnerships to better protect, monitor and restore our *siwłkw*.

3.2 NATURAL WETLANDS IN THE OKANAGAN

Prior to the extensive agricultural and urban development that now characterizes the Okanagan Basin, natural wetlands were found in all ecological zones, despite the Okanagan being one of the warmest and driest regions of British Columbia. They were most common in lower elevations along the lakes and low-gradient streams and at higher elevations where rolling terrain and higher precipitation present suitable conditions. However, wetlands and ponds were also present in depressions and along streams at mid-elevations. High evapotranspiration rates in summer would significantly reduce the volume of water present on the surface, resulting in the accumulation of salts and formation of distinctive wetland and transitional ecosystems.

Many of the wetlands in the Okanagan fall into one of the five main classes defined by the Canadian Wetland Classification System – marsh, swamp, bog, fen, or shallow open water (National Wetlands Working Group. 1997). Marshes, swamps, and shallow open water are minerogenous wetlands (i.e., the inflowing groundwater has been in contact with mineral soils or rocks) and the soils contain only small amounts or peat. Bogs and fens are classes of peatlands, marked by significant accumulations of peat. Bogs are ombrogenous systems (i.e., water is received from precipitation), whereas fens are primarily minerogenous (photo credits to Josie Symonds @ FLNRO, and Carrie Nadeau @ AE).

Marsh – This class of wetland typically occurs in association with shallow open water ecosystems and is characterized by cattails, bulrushes, grasses, and sedges. Floating aquatic vegetation may also occur and include duckweed and water smartweed. **This is the most common wetland class in the Okanagan, and generally found in the valley bottom.**

Swamp – This class of wetland typically occurs along the edge of other waterbodies. It is characterized by vegetation dominated by tall woody vegetation (trees and shrubs), generally over 30% cover, and wood-rich peat laid down by this vegetation. **Swamps are scattered throughout the Okanagan Valley but are relatively rare, and generally found either on floodplains or lakeside areas, or at upper elevations.**

Shallow Open Water – This class of wetland typically occurs in association with marshes and is characterized by intermittently or permanently inundated areas with open water up to 2 m deep. Vegetation includes submerged, shallow emergent, or floating aquatic plants. This wetland class and marshes are commonly adjacent to floodplains and saline meadows. **This is the second-most common wetland class in the Okanagan, and found in both the valley bottom and on the upland plateau.**

Bog – This class of wetland is characterized by organic soil of predominantly poorly to moderately decomposed sphagnum moss peats and a water table at or near the surface. Waters are generally acidic and low in nutrients. Bogs are usually carpeted with sphagnum mosses and shrubs, and may be treed or treeless. **Bogs are uncommon in the Okanagan Valley**.

Fen – This class of wetland is characterized by organic soil of mainly moderately to well-decomposed sedge and non-sphagnum moss peats and a water table at or near the surface. Waters are mainly nutrient rich with a near-neutral to slightly acid pH. The dominant vegetation includes sedges, grasses, reeds, mosses, and some shrubs. Scattered trees may be present. **Fens are uncommon in the Okanagan Valley and are mostly found in the upper elevations of the valley.**

In addition, there are sub-categories of the five major classes of wetlands, which reflect some of the unique biophysical processes found in the Okanagan.

Ephemeral Wetland – are seasonally flooded wetlands that are saturated in the spring by snowmelt and precipitation, and dry out later in the summer and fall. These wetlands are very important in our Okanagan arid grasslands as they support a unique set of wildlife and plant species. These wetlands can be difficult to identify during the dry season.

Saline Meadow – Saline meadows are characterized by alkaline salts that occur within the drawdown zone of shallow or vernal ponds and are generally characterized by unique salt-tolerant vegetation.

Alkaline Pond – Alkaline ponds are characterized by alkaline salts that occur within a permanently inundated or seasonal waterbody.

Flood Bench (Low and Mid) – Flood ecosystems are not technically wetlands, but occur on sites that are regularly influenced by high water levels and inundation that affects the vegetation present. The low and mid flood bench sites are most frequently inundated and strongly associated with wetland transitions.

Reservoirs, Ponds, Lakes, and Golf Course Ponds – These are constructed or modified shallow open water systems (less than 2 m in depth) that provide functional wetland habitats.

3.3 REGIONAL CLIMATE AND CLIMATE CHANGE

3.3.1 Climate of the Okanagan

The Okanagan is in the southern interior of BC and is characterized by hot, dry summers and cool, dry winters. Lying in the rain shadow of the Coast and Cascade mountains, the region is relatively arid due to low rates of precipitation and high rates of evaporation. Table 3-1 presents average climatic conditions for the most recent climate normal period (i.e., 1981-2010) based on climate records collected at Vernon North, Kelowna A, Penticton A, and Osoyoos CS climate stations. In addition, Table 3-1 shows the monthly reference crop evapotranspiration estimates, calculated using the Priestley-Taylor equation[1] and the procedure outlined in Shuttleworth (1993). The Okanagan is characterized by a significant summer soil moisture deficit, where evapotranspiration is much greater than precipitation. This has implications for stormwater wetland design, as evapotranspiration effects must be accounted for in the hydrologic and hydraulic designs of CWs.

Due to the topography of the Okanagan Valley (Section 3.4), higher precipitation and snowfall is typically experienced at higher elevations throughout the valley. In the valley bottom where population densities are highest and stormwater is generated, precipitation rates are comparatively very low (Figure 3-1).

[1] A reference crop albedo value of 0.23 was used at all locations, as well as sunshine hours measured at Kelowna Airport climate station due to the absence of measurements completed at other locations.

Table 3-1
1981-2010 climate normal data and reference crop evapotranspiration for Vernon, Kelowna, Penticton, and Osoyoos

Vernon North (Climate ID: 1128583)													
					Temperature								
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Daily Average (°C)	-2.8	-0.2	4.2	9.4	13.9	17.4	21	20.5	15.3	7.9	1.8	-2.2	8.8
Daily Maximum (°C)	-0.5	2.8	8.7	15.1	19.9	23.3	27.6	27.2	21.4	11.9	4.3	0	13.5
Daily Minimum (°C)	-5	-3.2	-0.3	3.7	7.9	11.4	14.2	13.6	9.1	3.8	-0.8	-4.4	4.2
					Precipitation								
Rainfall (mm)	11.6	11.7	17	27.2	46.3	49.6	35.4	31.9	32.7	40.7	31.1	9.7	344.9
Snowfall (cm)	40.5	13.5	11.7	1.8	0	0	0	0	0	0.9	26.5	47.3	142.1
Precipitation (mm)	52.2	25.2	28.7	29	46.3	49.6	35.4	31.9	32.7	41.5	57.5	57	487
					Evapotranspiration								
Refernce Crop Evapotranspiration (mm)[1]	0.0	3.0	23.5	56.1	96.3	116.8	137.6	117.2	66.5	24.7	3.8	0.0	645.6
Kelowna A (Climate ID: 1123970)													
					Temperature								
Daily Average (°C)	-2.5	-0.9	4.1	8.4	12.8	16.6	19.5	19.1	13.9	7.3	1.6	-2.6	8.1
Daily Maximum (°C)	0.8	3.6	10.1	15.5	20.2	24.2	27.9	27.6	21.7	13.4	5.6	0.7	14.3
Daily Minimum (°C)	-5.8	-5.3	-2	1.3	5.4	9.1	11.1	10.6	5.9	1.3	-2.4	-5.9	1.9
					Precipitation								
Rainfall (mm)	8.9	10	16.9	28.3	39.2	45.9	37.2	32.1	31.7	29.1	24.4	7.6	311.3
Snowfall (cm)	26.9	10.8	4.8	0.8	0	0	0	0	0	0.1	13.6	32	89
Precipitation (mm)	31	19	21.6	29.1	40.2	45.9	37.2	32.1	32.4	29.2	36.7	32.6	386.9
					Evapotranspiration								
Refernce Crop Evapotranspiration (mm)	0.0	3.4	22.2	54.6	92.4	112.4	131.4	110.7	62.1	22.3	3.0	0.0	614.4
Penticton A (Climate ID: 1126150)													
					Temperature								
Daily Average (°C)	-0.6	1	5	9.1	13.9	17.7	21	20.4	15.1	8.8	3.2	-1.1	9.5
Daily Maximum (°C)	1.8	4.7	10.4	15.7	20.8	24.7	28.7	28	22.2	14.3	6.5	1.4	14.9
Daily Minimum (°C)	-3	-2.8	-0.5	2.5	6.9	10.7	13.3	12.7	8	3.2	-0.2	-3.5	4
					Precipitation								
Rainfall (mm)	12.6	14	20.3	25.4	39.3	46.3	28.7	28.3	24.6	26	21.8	11.4	298.5
Snowfall (cm)	18.3	7.6	3.5	0.6	0	0	0	0	0	0.1	7.5	21.1	58.7
Precipitation (mm)	26.9	19.8	23.6	26	39.3	46.3	28.7	28.3	24.6	26	28.1	28.6	346
					Evapotranspiration								
Refernce Crop Evapotranspiration (mm)	0.0	4.7	25.4	57.4	95.8	116.7	137.5	117.2	66.9	24.7	4.3	0.0	650.3
Osoyoos CS (Climate ID: 1125852)													
					Temperature								
Daily Average (°C)	-0.9	1.9	6.1	10.9	15.5	19.2	22.9	22.3	17.3	10	3.4	-0.7	10.7
Daily Maximum (°C)	2	6.7	12.5	18.2	23.1	26.8	31.5	31.1	25.6	16.4	7.4	2	17
Daily Minimum (°C)	-3.8	-2.9	-0.3	3.6	7.9	11.6	14.3	13.5	8.9	3.5	-0.6	-3.5	4.3
					Precipitation								
Rainfall (mm)	0	0	0	0	0	0	0	0	0	0	0	0	0
Snowfall (cm)	0	0	0	0	0	0	0	0	0	0	0	0	0
Precipitation (mm)	0	0	0	9.2	29.4	28.6	33.1	31.8	0.2	12.6	0	0	0
					Evapotranspiration								
Refernce Crop Evapotranspiration (mm)	0.0	4.0	26.2	59.7	99.9	120.6	141.8	121.5	69.9	27.0	5.5	0.0	676.1

Notes:
1. Reference crop evapotranspiration (Erc) estimated using the Priestley-Taylor equation and the procedure outline in Shuttleworth (1993). An albedo of 0.23 was assumed for all locations.

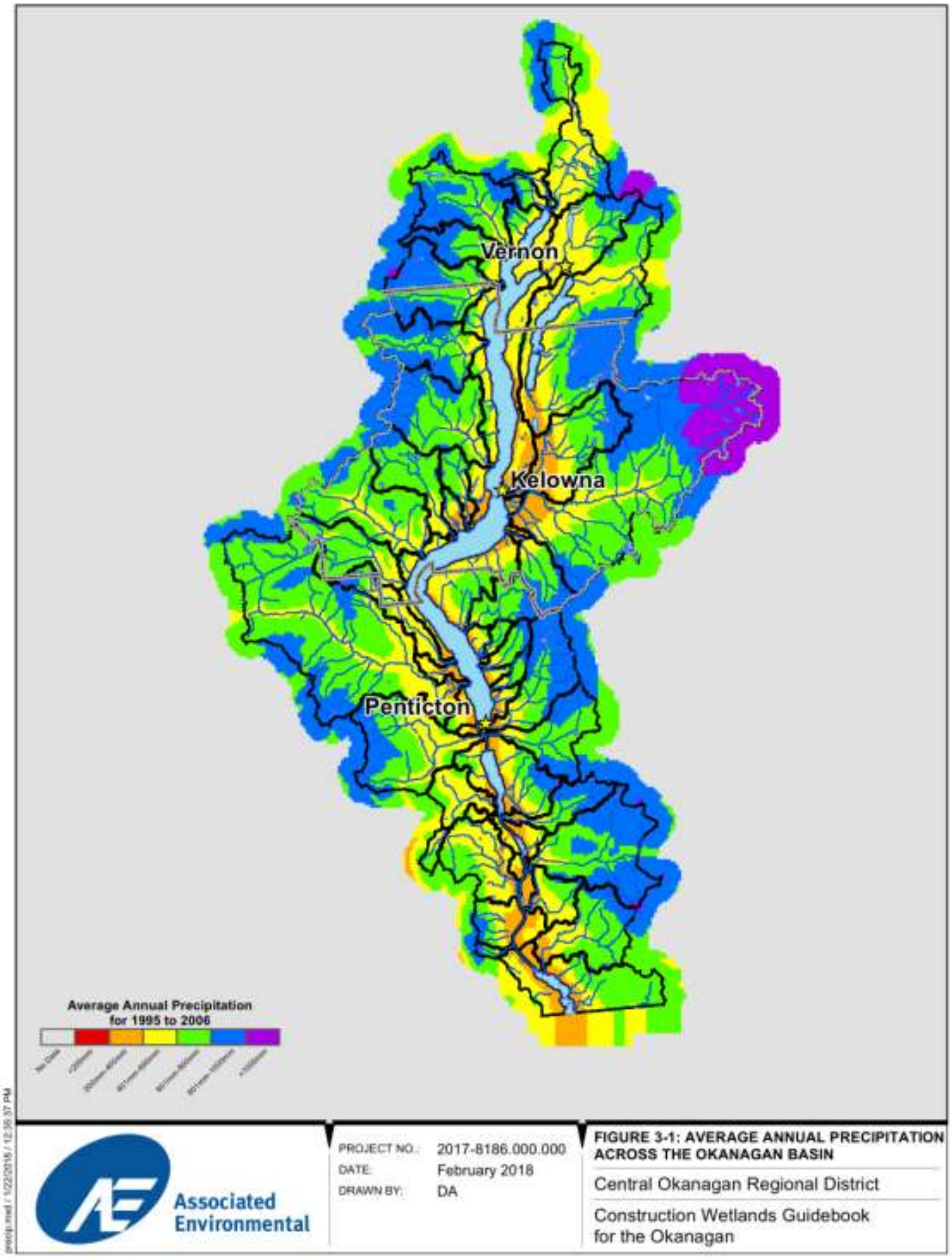


Figure 3-1
Average annual precipitation across the Okanagan Basin (source: Summit 2009)

3.3.2 Future Climate Change Implication for Constructed Wetlands

Over recent decades, climate change has received considerable attention across Canada. Several organizations and institutions have completed climate and hydrological modelling and investigations to better prepare for future climate change.

Recent work at the University of Victoria's Pacific Climate Impacts Consortium (PCIC) and the University of Washington's Climate Impacts Group is directly applicable to the Okanagan. PCIC has developed the 'Plan2Adapt' tool, which provides estimates of future primary climate variables such as temperature and precipitation, as well as more complex parameters derived from these primary variables, for specified geographic areas. In addition, the University of Washington completed a major study of climate change in the Columbia River Basin, and the Okanagan Water Supply and Demand Project completed climate and hydrologic modelling to improve the current and future state of knowledge for water resources of the Okanagan Basin.

The PCIC Plan2Adapt tool and the University of Washington's study use an ensemble of recent (i.e., AR4) climate models[2]. Inconsistencies in the model outputs between the tool and the study may exist due to differences in the modelled areas, baseline periods, emission scenarios, and future prediction periods. However, the general trends for both temperature and precipitation are consistent, and most hydrological implications of the predicted changes in climate are similar.

The PCIC Plan2Adapt tool provides outputs for the three regional districts within the Okanagan (i.e., RDNO, RDCO, and RDOS). Table 3-2 provides a summary of the median and ranges of values expected for the 2020s, 2050s and 2080s compared to the baseline period of 1961-1990. These values are derived from a 15 GCM ensemble, under the A2 and B1 CO_2 emission scenarios.

Based on the available climate change information, the climate and hydrologic trends for the Okanagan are as follows:

- The climate in the Okanagan is predicted to warm, and annual precipitation is predicted to increase. Summer precipitation is likely to decrease and winter precipitation is likely to increase.
- Snowpacks are projected to increase at higher elevations but decrease at lower elevations, creating uncertainty.
- Snowmelt is projected to occur earlier with meltwater runoff expected to decrease due to more winter rain.
- Late fall, winter, and early spring streamflows are projected to be greater; while late spring, summer, and early fall streamflows are projected to be smaller.
- The magnitude of extreme peak flows is projected to increase.

[2] Note that AR4 is not the most recent climate model. AR5 is now available and AR6 is in progress.

Table 3-2
Summary of projected climate changes for the Okanagan

Climate Variable[1]	Time of Year	Projected Change (from 1961-1990 baseline)					
		2020s		2050s		2080s	
		Median	Range	Median	Range	Median	Range
Regional District Okanagn-Similkameen							
Mean Air Temp (°C)	Annual	+1.0 °C	+0.6 °C to +1.5 °C	+1.9 °C	+1.1 °C to +2.7 °C	+2.9 °C	+1.7 °C to +4.6 °C
Precip. (%)	Annual	+4%	-2% to +8%	+6%	-2% to +10%	+8%	+1% to +17%
	Summer	-7%	-14% to +11%	-13%	-26% to +3%	-14%	-37% to -1%
	Winter	+2%	-3% to +10%	+6%	-4% to +16%	+10%	+2% to +26%
Snow Depth (%)	Winter	-6%	-18% to +1%	-14%	-25% to -3%	-22%	-42% to -8%
	Spring	-33%	-59% to -1%	-56%	-75% to -13%	-78%	-89% to -18%
GDD[2]	Annual	+165	+80 to +261	+341	+191 to +515	+525	+303 to +922
HDD[3]	Annual	-377	-526 to -201	-679	-971 to -400	-1030	-1586 to -598
FFD[4]	Annual	+14	+8 to +22	+26	+14 to +37	+39	+21 to +62
Regional District of North Okanagan							
Mean Air Temp (°C)	Annual	+1.0 °C	+0.6 °C to +1.5 °C	+1.9 °C	+1.1 °C to +2.7 °C	+2.8 °C	+1.7 °C to +4.6 °C
Precip. (%)	Annual	+4%	-1% to +7%	+6%	-2% to +11%	+7%	+3% to 14%
	Summer	-5%	-10% to +9%	-10%	-21% to -1%	-11%	-28% to +7%
	Winter	3%	-2% to +10%	+7%	-3% to +16%	+12%	+2% to +27%
Snow Depth (%)	Winter	-7%	-18% to +1%	-15%	-27% to -2%	-23%	-47% to -10%
	Spring	-32%	-57% to +1%	-57%	-77% to -11%	-76%	-90% to -13%
GDD[2]	Annual	+178	+80 to +261	+359	+205 to +531	+549	+309 to +975
HDD[3]	Annual	-354	-517 to -202	-658	-950 to -402	-972	-1524 to -582
FFD[4]	Annual	+14	+8 to +22	+24	+14 to +37	+37	+20 to +62
Regional District of Central Okanagan							
Mean Air Temp (°C)	Annual	+1.0 °C	+0.6 °C to +1.5 °C	+1.9 °C	+1.1 °C to +2.7 °C	+2.9 °C	+1.7 °C to +4.6 °C
Precip. (%)	Annual	+5%	-2% to +7%	+7%	-2% to +11%	+8%	+2% to +15%
	Summer	-5%	-11% to +10%	-11%	-24% to -1%	-12%	-34% to +4%
	Winter	+3%	-2% to +10%	+7%	-4% to +16%	+11%	+3% to +27%
Snow Depth (%)	Winter	-7%	-18% to +0%	-14%	-26% to -2%	-22%	-44% to -9%
	Spring	-33%	-58% to +1%	-57%	-76% to -13%	-77%	-89% to -17%
GDD[2]	Annual	+178	+85 to +283	+359	+206 to +541	+560	+314 to +975
HDD[3]	Annual	-364	-517 to -201	-664	-954 to -400	-993	-1541 to -588
FFD[4]	Annual	+14	+7 to +21	+24	+13 to +36	+37	+20 to +60

Notes:

1. Climate variables derived from temperature and precipitation datasets.
2. GDD - Growing Degree Days (given in degree days)
3. HDD - Heating Degree Days (given in degree days).
4. FFD - Frost-Free Days.

3.4 TOPOGRAPHY, SOILS, AND GEOLOGY

Covering an area of approximately 8,000 km^2 (Golder and Summit 2009), the Okanagan Valley is part of British Columbia's Interior Plateau, characterized by moderately steep valley sides and broad valley bottoms. Figure 3-2 provides an elevation profile for Mission Creek, which is characteristic of watercourses within the Okanagan.

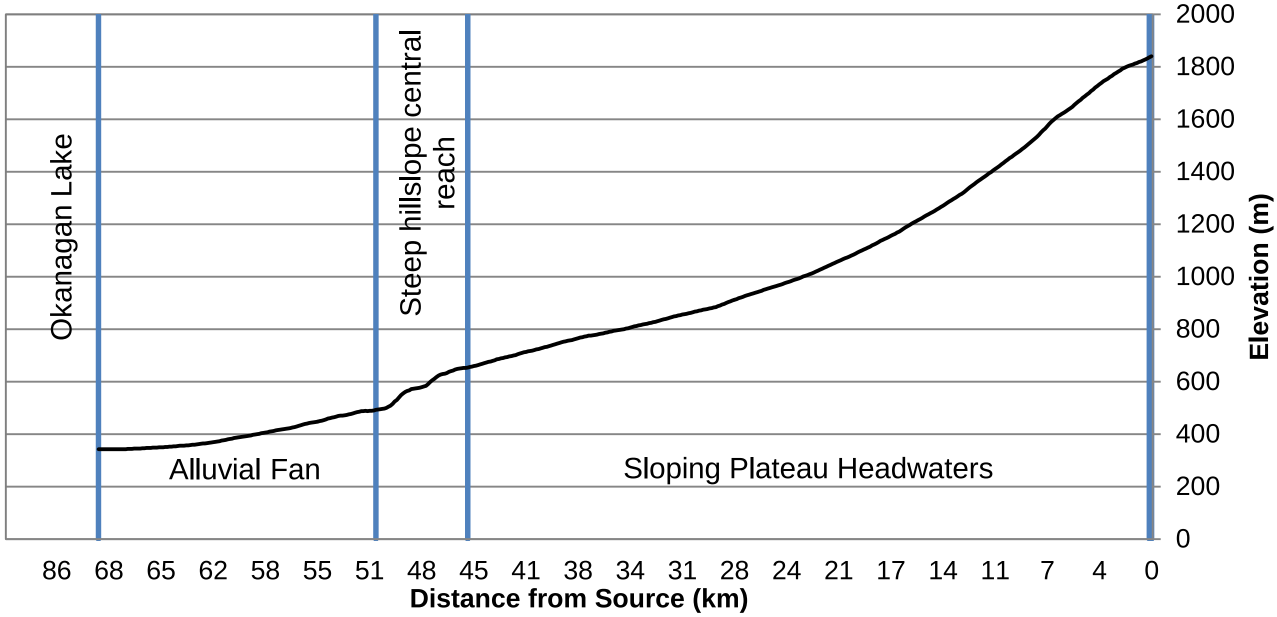


Figure 3-2
Characteristic elevation profile of major watercourses within the Okanagan – Mission Creek

The valley sides through the Okanagan contain a complex array of glacial and post-glacial deposits, many reflecting the period when glacial ice occupied the valley bottom and meltwater from upper elevations carried large volumes of sediment and temporary lakes (e.g. Glacial Lake Penticton) were created at elevations well above the current lake levels. After the valley ice melted, these deposits were eroded and re-worked. Remnant features include raised beaches and alluvial fans, fluvio-glacial terraces, moraines, kettles, and silt bluffs exposing old lake sediments. Recent fluvial processes have carved out the present-day gullies and low elevation floodplains.

One of the outcomes of this topographical complexity is that the texture of surface soils is highly variable, ranging from silts and clays with low permeability to coarse sands and gravels where water readily infiltrates. Often, low and high permeability sediments are in close proximity (both horizontally and vertically). This has implications for the design of stormwater management systems, including the ability of ponds and wetlands to hold water, and the feasibility of discharging stormwater to ground. A careful evaluation of a site's soils and drainage characteristics should be included with any CW feasibility assessment (section 5.4.2).

3.5 SURFACE WATER AND GROUNDWATER

In the Okanagan, water flows from high upland plateau areas in the east and west down to the major lakes and the Okanagan River in the valley bottom. Once in the valley bottom, water flows from north to south through a series of large lakes, regulation structures, and the Okanagan River. The valley bottom lakes include: Swan Lake, Kalamalka Lake, Okanagan Lake, Wood Lake, Skaha Lake, Vaseux Lake, and Osoyoos Lake (which crosses the Canada/USA border).

Water resources in the valley bottom have been regulated since the 1950s with the construction of the Okanagan Lake Regulation System (OLRS). The OLRS consists of three control dams (Okanagan Lake, Skaha Dam, and McIntyre Dam), multiple vertical drop structures and drainage structures, 68 km or dike, 32 km of engineered river channel, and three sediment basins. The OLRS was originally intended to manage flooding; however, water levels in Okanagan Lake are now managed to mitigate both flood and drought, and operational decisions also consider downstream environmental flow needs and recreational values. In addition to the OLRS, water levels in Kalamalka Lake are managed by a control structure at the outlet which discharges flows to Vernon Creek, and Osoyoos Lake is controlled by Zosel Dam in Washington State.

As the population of the Okanagan Valley continues to grow, this major water management infrastructure needs to be augmented by stormwater control systems at the site and small catchment scale to manage flood risk. Many of the aquifers in the valley are naturally recharged by exfiltration from streams that flow down across the unconsolidated sediments on the valley sides. Therefore, slowing the flow off developed areas and promoting infiltration is also important for replenishing aquifers.

3.6 WATER QUALITY

3.6.1 Stresses on Water Quality

The valley bottom lakes in the Okanagan Valley and their major tributaries are critically important to the cultural, ecological, and economic life in the Okanagan Basin. Surface waters provide habitat for aquatic life, and are the source of drinking water for more than 200,000 people in the valley; they are used for agriculture, recreation, industry, and a range of other uses that require good quality water.

In the 1960s and early 1970s, the lakes were showing signs of significant stress, primarily related to the release of phosphorus from the municipal wastewater treatment facilities that were operating in the valley. In response, the treatment systems were upgraded, leading to a 90% reduction in phosphorus inputs to the valley lakes. Since then, these major point-sources have undergone of series of improvements to accommodate increased population growth and regulatory changes. Despite this achievement, significant stresses on water quality remain. Most of these stresses are now from non-point source (NPS) or diffuse sources related to land use activities and development in the watershed. Although the effects of any one activity may be confined to a local area, the cumulative effects on water quality from NPS are potentially significant given the continued population growth in the Okanagan Basin. Stormwater management is a critical component of the overall strategy for protecting water quality. The contaminants of concern that can be routed to streams and lakes in stormwater include sediment; hydrocarbons and heavy metals from vehicle exhaust; brake and other vehicle fluids from small leaks; and nutrients, pesticides, and bacteria from runoff from urban and agricultural lands (MWLAP 2002). Major accidental spills on roads and other compact surfaces would also tend to enter the stormwater conveyance system and be routed to natural watercourses and lakes.

3.6.2 Water Quality Objectives

One of the ways that water quality in the Okanagan is evaluated is through comparison to Water Quality Guidelines (WQG) and Water Quality Objectives (WQO) set by the Ministry of Environment (MOE). WQGs are generic and apply to the whole province. WQOs are derived from guidelines, but customized for specific locations to reflect the baseline water quality, water uses (including aquatic life), water movement, and waste discharges at that location, and are intended to protect the most sensitive designated water use (MOE 2013). Although the WQOs are not 'rules,' they are numeric targets that are official MOE policy, and serve to guide all levels of government when setting procedures for protecting water quality in specific waterbodies. Table 3-3 lists the bodies of water where WQOs have been set or recommended by the Province of British Columbia. WQOs are only set for waterbodies that have or are expected to experience stress from human activities, so the relatively high number of Okanagan sites with WQOs reflect the sensitivity of local streams and lakes to changes in water quality.

Table 3-3
Okanagan lakes and streams with water quality objectives

Waterbody/Watercourse	Water Quality Parameters with WQOs
Coldstream Creek	Nitrate, *E. coli*, turbidity
Kalamalka, Wood, Ellison, & Skaha Lakes	Phosphorus
Okanagan Lake (4 locations)	Total P, Total N, N:P ratio, Secchi depth, DO, several plankton indicators
Deep Creek	Turbidity, TSS, ammonia-N, nitrite-N, nitrate-N, periphyton chlorophyll-a, dissolved oxygen, pH, enterococci, *E. coli*, fecal coliforms
(Lower) Vernon Creek	Turbidity, TSS, ammonia-N, nitrite-N, nitrate-N, periphyton chlorophyll-a, dissolved oxygen, pH, enterococci, *E. coli*, fecal coliforms
Hydraulic Creek	TSS, turbidity, enterococci, *E. coli.*
Mill (Kelowna) Creek	Ammonia-N, nitrite-N, periphyton chlorophyll-a, dissolved

Waterbody/Watercourse	Water Quality Parameters with WQOs
	oxygen, pH, enterococci, *E. coli*, fecal coliforms, aluminum, lead, copper, zinc
Brandt Creek	Fecal coliforms, *Escherichia coli*, enterococci, specific conductivity
Mission Creek	Ammonia-N, nitrite-N, periphyton chlorophyll-a, dissolved oxygen, pH, enterococci, *E. coli*, fecal coliforms, aluminum, lead, copper, zinc
Trepanier Creek	TDS, pH, sodium, dissolved aluminum, total molybdenum
Westbank Creek	TSS, turbidity, pH, sodium, dissolved aluminum, total copper, total iron, total zinc, ammonia-N, nitrite-N, nitrate-N, periphyton chlorophyll-a, enterococci, *E. coli*, fecal coliforms, *Pseudomonas aeruginosa,* residual chlorine, substrate sedimentation
Peachland Creek	TDS, pH, sodium, dissolved aluminum, total molybdenum, total copper, ammonia-N, nitrite-N, nitrate-N, periphyton chlorophyll-a
Osoyoos Lake	Dissolved oxygen, total phosphorus, phytoplankton chlorophyll-a, Secchi depth, cyanobacteria

3.7 BIOTA

Okanagan wetlands support some of the most diverse biota found in the region and in British Columbia, and provide habitat for a high proportion of species at risk found in Canada. Okanagan wetlands have high ecological value as riparian areas and support most wildlife who reside in the dry Okanagan climate. Many species at risk in the Okanagan rely on wetlands as critical habitat for breeding. Wetlands represent only about 0.2% of the regional landscape and provide disproportionally high biological, hydrological, and socio-economic values. According to the Okanagan Wetlands Strategy, over 84% of low elevation wetlands within the Okanagan and Similkameen Valleys have been lost to development activity.

3.7.1 Species and Ecosystems at Risk

In the Okanagan Valley where wetlands occupy less than 0.2% of the regional landscape, wetlands provide critical habitat to a broad range of wildlife species, including **86 wildlife species at risk** (CDC 2017). These wildlife species include the great basin spadefoot, great blue heron, western painted turtle, yellow-breasted chat, western screech-owl, tiger salamander, American avocet, monarch, bats, hawks, sparrows, wrens, shorebirds, and snakes, as well as numerous terrestrial and aquatic invertebrates and aquatic fish species (bird photo credits @All About Birds Org, turtle photo credit Josie Symonds @FLNRO).

These wildlife species at risk are dependent on wetlands for one or all their life stages, including breeding, foraging, hunting, security, and cover. Many of these species only use wetlands for one or two months out of the year, but without wetlands they would not survive in the Okanagan nor complete their life cycle. CWs in the Okanagan can attract some listed species, and the design and/or operational procedures can either encourage or discourage the use of the created wetland habitat by these species. Sections 5.4.4, 6.4, 8.2 and 8.3 include site selection considerations for species at risk, and describe wildlife habitat enhancements, and effectiveness monitoring that can be included in CW to benefit Okanagan species at risk.

The BC Conservation Data Centre classifies **six wetland ecological communities** as at risk within the regions of the Okanagan, and **95 plant species at risk** associated with wetland, riverine and riparian habitat types in the Okanagan (CDC 2017).

3.7.2 Invasive Species

Invasive species are those that do not occur naturally in ecosystems in British Columbia and were introduced through anthropogenic means and not through a natural process. These species pose a great threat to the local environment and are recognized globally as the second greatest threat to biodiversity.

Invasive species are introduced or spread by humans as horticulture products or on transported goods, or by accidental transport on vehicles, clothing, footwear or pets. Soil erosion, construction, off-roading, and other forms of soil disturbance, as well as overgrazing, transporting contaminated soil, and using contaminated grass seed can further spread invasive species. In addition, spread occurs by wind, water, livestock and wildlife. Invasive plants can produce thousands of seeds per plant, which may lie dormant for many years. They pose a threat to the continued existence of native species and to biodiversity in the Okanagan. Some

According to the **BC MFLRO&RD Invasive Plant Website** specific impacts of invasive plant infestations include:

- disruption of natural ecosystem processes,
- alteration of soil chemistry - preventing the regrowth of native plants and economic crops,
- increased soil erosion,
- livestock and wildlife poisoning,
- increased risk of wildfires,
- interference with forest regeneration,
- allergic reactions, severe skin abrasions and burns on people.

native species can also behave like invasive, care should be taken when selecting native species for wetlands.

Wetlands can be a transport vector for invasive species if they are connected to a flowing waterbody and, as they are wildlife hot posts in the Okanagan, wildlife that use wetlands are key vectors to the spread of invasive species. Invasive species prevention is key to managing the environmental and economic impacts of these species.

Like any other construction project, care should be taken to prevent invasive species from colonizing the site by promptly re-vegetating the site with native species that are adapted to the site conditions you are creating, and using native soil that is free of invasive seeds. The wetland species that are selected should be native, selected according to the site conditions (Section 6.4.1), and planted in sufficient density to allow quick establishment to discourage colonization of invasive species. Maintenance actions will need to occur if invasive species begin growing in the CW, removing invasive species is much harder than preventing their establishment in the first place.

Additional guidance for wetland planning, construction, maintenance and operation is provided in Sections 6.5, 7.0 and 8.2. Key invasive species and their threats to Okanagan wetlands are included in Appendix listed in Table 3-4.

4 Regulatory Guidance

4.1 PROVINCIAL

Water Sustainability Act

Any work in or around water must avoid or minimize potential risks to aquatic ecosystems, fish and fish habitat, and limit water pollution. The *Water Sustainability Act* (WSA) applies to any changes in or about a stream, all wetlands are included in this definition (see definition box below). A CW project that plans to directly connect to a stream (including a natural wetland) requires a WSA Section 11 Notification OR Approval. A project that uses water from an existing watercourse to supplement flow in the CW requires a Water Licence. Proponents must submit a WSA application to the FrontCounter BC prior to construction. The application should be submitted early in the CW design process as it can take anywhere from four months to over a year to be processed.

The *Water Sustainability Act* defines "**Changes in and about a stream"** as:

- Any modification to the nature of a stream, including any modification to the land, vegetation and natural environment of a stream or the flow of water in a stream, or
- Any activity or construction within a stream channel that has or may have an impact on a stream or a stream channel.

"Works" is defined to mean anything that can be or is used to divert, store, measure and convey water; and produce measure, transmit or use energy.

"Stream" is defined as a natural watercourse, including a natural glacier course or natural body of water. Bodies of water described by the term "stream" can include a lake, pond, river, creek, spring, ravine, gulch, wetland, or glacier, whether or not usually containing water, including ice.

More information on Working Around Water can be found here.

Maintenance of the CW will also require a Section 11 application to the WSA, and proponents should contact FrontCounter BC to determine the maintenance requirements for the CW, and WSA regulation requirements for planned maintenance activities.

Waste Discharge Regulation

The *Waste Discharge Regulation* (WDR) of the *Environmental Management Act* (EMA) defines which activities require a formal authorization to discharge waste into the environment. All activities listed in Schedule 1 of the WDR require a permit or other type of authorization, while those in Schedule 2 can operate according to a Code of Practice if the Code is in place; otherwise, they require a permit. Any activity not listed in Schedules 1 or 2 can proceed without a formal permit, although they are still bound by the overall requirement of the EMA to not cause pollution.

Urban stormwater is not listed in the WDR as either a Schedule 1 or Schedule 2 activity, therefore no permit is usually required for discharging water that has passed through a CW. Nevertheless, proponents planning to treat stormwater runoff from land surrounding a Schedule 1 or 2 activity (e.g., a works yard or parking lot) should consult with MOE to verify the discharge requirements, and may need to monitor water quality after construction (Section 8.3).

Riparian Areas Regulation

If the planned CW project footprint is within 30 m of a fish-bearing watercourse, and/or within an environmental development permit area, the *Riparian Areas Regulation* (RAR) will likely apply to the project. This regulation applies to all regions of the Okanagan, apart from the City of Kelowna, which has their own set of regulatory by-laws in place of the RAR. If the project includes the construction of an outlet or a connection channel to an existing waterway, RAR may apply. Proponents should consult local bylaws to determine if the RAR applies to their project.

If the CW project triggers a RAR assessment, a Qualified Environmental Professional (QEP) will need to be retained to conduct a science-based assessment of proposed activities, define the RAR Streamside Protection and Enhancement Area (SPEA), submit a report to the local government and the Province, and recommend what activities can be completed within the SPEA under RAR. This may constrain design options within the SPEA.

Wildlife Act* and *Wildlife Amendment Act

The *Wildlife Act* protects wildlife in BC from human-related harm and disturbance. The Act provides protection for wildlife (such as amphibians and breeding amphibians) and birds and their nests by prohibiting the destruction or disturbance of birds, their eggs, and active nests; as well as a nest of an eagle, falcon, hawk, osprey, heron or owl. The *Wildlife Amendment Act* enables species at risk to be designated by the government and managed as a protected species.

For CW projects, these Acts largely pertain to site preparation and construction. In the Okanagan, the general wildlife activity window is between April 1 and August 30, and for raptors and herons is between February 1 and August 14. Mitigation measures (e.g., work outside of breeding windows, establishment of protective buffers, captures, salvages or relocations) are required as part of the CW construction phase to avoid contravention of the *Wildlife Act*. A *Wildlife Act* permit is required to conduct any wildlife salvage.

Invasive Species Acts

There are several pieces of legislation that control invasive species in British Columbia. CW construction and operational maintenance plans need to incorporate measures to prevent and minimize the spread of invasive species, and control strategies.

The *Ministry of Municipal Affairs and Housing* outlines and supports:

1) The principle of Integrated Pest management; and
2) Environmental Protection Strategies

The *Integrated Pest Management Act* regulates herbicide applications and operational practices that may be used to control invasive plant infestations.

The *Weed Control Act* is enabling legislation that provides authority to Regional Districts to establish a weed control committee. The Act enables Regional Districts to manage provincial and regional noxious weeds, which are those invasive plants listed under the *Weed Control Regulation*. A Community Charter allows Municipalities to regulate nuisances, including invasive plants.

The *Local Government Act* allows Regional Districts the right to regulate nuisance invasive plants.

Heritage Conservation Act

Archaeological sites in BC are protected through designation as “provincial heritage sites.” A permit issued by a federally designated minister (as provisioned by the Lieutenant Governor in Council) is required prior to any alteration of these sites.

If a CW site is planned within a known archaeological site, the CW project will trigger an archaeological assessment. These assessments need to be conducted in accordance with *Heritage Conservation Act* standards and with provincially recognized Archaeological Impact Assessment guidelines set out by the British Columbia Association of Professional Archaeologists.

4.2 FEDERAL

The federal legislation described in this Guidebook may apply to a CW project; however, there may be other federal legislation that apply in certain situations. Proponents should ensure that all applicable federal legislation is followed.

The federal *Fisheries Act*, *Wildlife Act*, and *Species at Risk Act* (SARA) have the greatest likelihood to influence CW design and operations.

Fisheries Act

The *Fisheries Act* requires that projects avoid causing serious harm to fish unless authorized by the Minister of Fisheries and Oceans Canada (DFO). This applies to work being conducted in or near waterbodies that support fish that are part of or that support a commercial, recreational or Aboriginal fishery.

If CW projects, including stormwater management ponds or stormwater CW, are not connected to a fish-bearing waterbody at any time during any given year the proponent does not require a *Fisheries Act* Authorization or DFO Project Review.

If the CW connects to a fish-bearing waterbody, but construction will not occur below the High-Water Mark of the waterbody, the construction of new land-based stormwater management facilities, settling ponds and storage basins do not require a *Fisheries Act* Authorization.

If work occurs below the High-Water Mark of a fish-bearing waterbody, the proponent will need to apply for a DFO Project Review and include a mitigation plan to avoid causing harm to fish and fish habitat. DFO will review the project plans to determine if an Authorization is required. Time to process and obtain an Authorization can be lengthy, and without guarantee of approval. Avoidance of causing harm to fish is the best plan of action.

Some CW maintenance, repair or routine clean-out activities do not require a DFO Project Review application or an Authorization if the existing footprint below the High-Water Mark does not change, additional fill is not placed below the High-Water Mark, and works can follow best management practices and be conducted during the local reduced-risk fish window.

For all cases, proponents are required to avoid causing serious harm to fish and contravening SARA prohibitions. Proponents should following best practices such as those described in DFO Measures to Avoid Causing Harm to Fish Habitat Including Aquatic Species at Risk (measures to avoid harm) to comply with the *Fisheries Act* and SARA.

Species at Risk Act

The *Species at Risk Act* (SARA) protects endangered or threatened species, it is illegal to kill, harm, harass, capture or move species at risk on federal lands. Damage or destruction of habitat is prohibited unless authorized by the federal government.

The location of the CW and timing of the project may be impacted if species at risk or their habitat is present. A Species at Risk Survey, conducted by a Qualified Professional, may be required as part of the site selection analysis.

Migratory Birds Convention Act

The *Migratory Birds Convention Act* protects various species of migratory game birds, migratory insectivorous birds, and migratory non-game birds, including herons, and protects breeding birds and their nests. Conducting vegetation clearing and construction outside of the main migratory bird window (general window for the Okanagan is from April 1 and August 30) will prevent disturbance to bird nests and eggs, and avoid contravening the Act.

4.3 LOCAL BYLAWS

The inclusion of CWs within a stormwater management system is subject to the applicable municipal by-laws that govern drainage and stormwater retention. Most communities, including the cities of Vernon, Kelowna and Penticton, have defined “minor” and “major” systems based on the return intervals of the precipitation events, and have established standards for how minor and major flows are handled. In general, major systems must be designed by a Professional Engineer, including the inclusion of wetland components into the retention and/or treatment structures. Proponents must be sure they understand and are compliant with the local by-laws before undertaking a CW project.

5 Is your Site Suitable?

5.1 SET YOUR OBJECTIVES FOR THE CONSTRUCTED WETLAND

The first step in determining whether to incorporate a CW as part of a stormwater management system is to clarify the site objectives. In general, stormwater CWs provide four main functions:

1. Water quality improvement;
2. Peak flow attenuation;
3. Habitat creation and biodiversity enhancement; and
4. Amenity values – such as enhancing local visual and aesthetic quality and providing educational opportunities.

Peak flow attenuation and water quality improvement are the primary objectives of stormwater CWs, and habitat creation is generally a secondary objective. However, with CWs there is the opportunity to achieve all these objectives to some degree. Proponents should decide on the balance between the functions they are seeking. Some key questions to consider are:

- For flow attenuation, are there specific discharge criteria or a by-law that must be satisfied?
- For water treatment,
  - Are there specific discharge targets (e.g. an 80% reduction in TSS larger than 75 µm)?
  - Does water quality in the receiving stream need to meet Water Quality Objectives or guidelines?
  - Or, is the CW just intended to provide a buffer between to source of the stormwater and the receiving environment?
- For habitat and biodiversity, are specific species or habitats being targeted?

In general, the more specific the objectives for flow and water quality, the more the wetland system must be carefully engineered and operated to meet those targets. This may require some compromises on habitat objectives, assuming the normal constraints of space and budget. Alternatively, if the treatment goals are more modest, there is greater latitude to incorporate wetland features that provide more habitat diversity. An example of this is a system where the stormwater is first retained in a conventional engineered pond that is designed to meet the flow attenuation goal and remove coarser sediment, and the water then flows to a CW for further polishing. An in-series multi-cell system such as the one shown is sometimes referred to as a “treatment train.” This is discussed further below in Section 6.

5.2 CHARACTERIZE THE CATCHMENT AREA AND RECEIVING ENVIRONMENT

The feasibility of using CWs to manage stormwater depends to a large degree on the characteristics of the contributing area or catchment. In many cases, it is the prospect of land use change that drives the need for improved stormwater management; specifically, the conversion of natural or agricultural landscapes to residential, commercial, or industrial land uses with an associated increase in the areas of impermeable surfaces. In the Okanagan Valley, under pre-development conditions, only about 10% of the volume of precipitation that falls on the land runs off, with the rest infiltrating to ground or returning to the atmosphere by evapotranspiration (OBWB 2011). As development proceeds, the volume that runs off increases, with about 30% runoff when the proportion of impervious surfaces is 35%-50%, and about 55% runoff when impervious surfaces exceed 75% of the catchment.

CWs are one of the tools within the Integrated Stormwater Management Plan (ISMP) framework that protects downstream aquatic habitat and property values while enabling population growth development to proceed. Other key tools include measures to promote rainwater infiltration or irrigation use on individual properties, installation of permeable roadways and parking lots, creation of grassed waterways or swales, and conventional stormwater retention and infiltration facilities. Planning for stormwater infrastructure (ponds or wetlands) will include modelling of runoff volumes and storm hydrographs, which establish whether retention is needed to meet stormwater by-laws or guidelines. Situations where CWs are likely to be a beneficial part of the system include:

- The catchment area will include multiple land uses and therefore generate a range of contaminants, including dissolved components that require biological processes to be removed;
- Catchments where development is expected to be spread out over an extended period, so that erosion from construction sites is an ongoing source of suspended sediment;
- Watersheds where natural wetlands and riparian areas have been lost or disturbed, and where the CW would provide help to restore some ecological or hydrological functions; and
- Cases where additional resiliency is needed due to uncertainty about the type and pace of development within the catchment.

The other main component of determining whether a CW would be beneficial for stormwater management is the sensitivity of the downstream receiving environment. The additional treatment benefit provided by a wetland may be warranted if the flow will discharge to a watercourse, natural wetland, or waterbody that:

- is fish-bearing;
- provides aquatic or riparian habitat for species-at-risk;
- is a domestic water supply, with an intake within about one kilometre of the CW discharge point;
- is used for recreation with direct water contact (e.g., swimming) near the CW discharge point; and/or
- is already adversely affected by non-point or point source pollution, or is considered ‘at risk’ from other existing and future land use activities. This includes the streams and lakes where Water Quality Objectives have been set (Section 3.6.2).

5.3 HOW MUCH AREA IS NEEDED?

The land area that is required for a CW is directly linked to the treatment objectives. If a wetland is too small, the Hydraulic Retention Time (HRT) will be too short to enable the physical, chemical and biological treatment processes to act on the contaminants of interest. HRT is calculated as the wetland volume divided by the average flow rate, or:

$$HRT = V \div [(Q_{in} + Q_{Out})/2]$$

Where Q_{in} is the water inflow rate, Q_{Out} is the outflow rate, and V is the wetland volume. Note that the outflow rate will be different than the inflow rate because of the effects of precipitation and evapotranspiration (Section 3.3.1). Wetland volume is calculated as:

$$V = \text{Length} \times \text{width} \times \text{average depth} \times \text{porosity}$$

Porosity (ε) is the factor that accounts for the space occupied by the plants growing in the wetlands. For planning purposes, a value of 0.9 can be used (i.e., plant stems occupy 10% of the volume). One difference between CWs and stormwater ponds is that the depth of a CW is generally less than about 0.7 m, to enable the wetland plants to grow, whereas ponds can be typically up to 3 m deep. Therefore, to get the same volume in a CW, it must occupy a proportionally larger area.

When determining the required area, it is advisable to do a 'first cut' estimate to compare against the available area. The resulting size should then be adjusted during the detailed design (Section 5.1). Kadlec and Knight (1996; Chapter 20) provide a series of preliminary sizing equations for several conventional contaminants including TSS, BOD, total P, and total N. The equations are based on a first-order decay rate (k-C*) model with the general form of:

$$A = \frac{(0.0365 \times Q)}{k} \times \frac{\ln((Ci - C^*)}{Ce - C^*}$$

Where:

A = Required wetland area (ha)
Q = Effluent flow rate (m^3/day)
Ce = CW outflow target concentration (mg/L)
Ci = CW inflow concentration (mg/L)
C* = Background concentration in CW
k = first order areal rate constant (m/year)

For example, if the design flow is 1,500 m^3/day (= 17.4 L/s) and the inflow TSS concentration is to be be reduced from 25 mg/L to 7 mg/L, the required wetland area is 0.084 ha (0.21 acres)[3]. With a 3:1 L:W ratio, the CW would be 16.7 m wide and 50 m long. Note that this assumes an average wetland depth of about 0.5 m. The equation can be re-arranged to provide an estimate of treatment performance for a given available area. This is useful for preliminary cost benefit assessments, such is when only a certain area is available and one wants to know whether the investment will yield sufficient treatment benefit.

By definition, stormwater retention systems (ponds and/or wetlands) must be able to handle surges in the rate of inflow in response to precipitation or rapid snowmelt events (e.g., a rain-on-snow event). This is because, 1) the high velocity flows would tend to damage the wetland plants, and 2) there would be insufficient HRT for treatment. As such, the upstream (inflow) end of the system should include an open

[3] Assumes a background TSS concentration (C*) in the wetland of 2 mg/L.

pond with sufficient volume and freeboard to hold back the flow and enable it to be released to the wetland part of the system at a slower rate, or bypassed in the case of large events. For smaller catchment areas, a forebay (i.e., an open-water pond separated from the wetland by a weir or other control structure) at the inflow end of the system is likely adequate. In this case, the ‘first cut’ sizing estimate described above includes both the forebay and the wetland. For larger catchments[4], an engineered retention pond, designed to meet specific hydraulic criteria, would be required and the sizing calculation applies only to the wetland component.

In addition to the first cut CW size calculations, there are other general rules that can be used for wetland sizing. The simplest are based on HRT or on the hydraulic loading rate (HLR, equivalent depth of inflow per unit time). The literature indicates a wide range in HRT values depending on location and the target contaminants. For suspended solids, the range for planning purposes is from three to seven days (and up to 15 days if high levels of TSS removal is required). The wetland area (A) is derived from HRT from the equation:

$$\text{Area} = (\text{HRT} \times Q) \div (\varepsilon \times \text{depth})$$

For example, if the target HRT is 7 days and the design flow rate is 200 m^3/day, the required area (assuming 0.9 porosity and 0.5 m depth) is:

$$\begin{aligned}\text{Area} &= (7 \text{ days} \times 200 \text{ m}^3/\text{d}) \div (0.9 \times 0.5 \text{ m}) \\ &= 3{,}111 \text{ m}^2 \\ &= 0.31 \text{ hectares}\end{aligned}$$

For HLR, published values range from 0.01 to 0.05 m/day. To estimate area, the flow rate is divided by HLR. Using 200 m^3/day, the resulting area is 4,000 m^2 or 0.40 ha. Again, it is important to note that these area estimates are for planning only, and must be refined during detailed design by use of hydraulic modelling and other tools, depending on the contaminants of interest. Furthermore, the resulting areas from these preliminary calculations are for the wetland/pond treatment area only. When assessing site suitability, the area occupied by berms, control structures, access roads, and other infrastructure must also be considered (Section 6).

5.4 SITE ANALYSIS

5.4.1 Existing Drainage Pathways and Wetlands

Stormwater conveyance, retention and treatment systems are most cost-effective when they are situated to take advantage of existing drainage pathways, so that the water flows by the force of gravity. At the site or urban catchment scale, this tends to place the pond or wetland at the lowest point of the catchment area, with the outflow being directed to a natural drainage pathway or pipe until it reaches to point of discharge to a stream, natural wetland, or other waterbody.

[4] Section 4.3 outlines local government requirements for minor and major storm drainage systems.

As described earlier, a significant number of natural wetlands in the Okanagan Valley were drained, cultivated, or filled in to facilitate agricultural, transportation, or urban development. These natural wetlands tended to occur along the natural drainage pathways, in floodplains, or in depressions such as kettle holes left behind by melting glacial ice. As such, sites that appear suitable for a stormwater CW may be located where a natural wetland previously existed. This possibility can be evaluated by examining historical aerial photographs and soil or surficial geology maps, and by field surveys to look for soil and vegetation characteristics indicative of wetlands. Former natural wetland sites that have been disturbed enough to no longer function as wetlands are potentially good sites for a CW for several reasons. The soils may be naturally capable of holding water, wetland plants will likely thrive, and the CW would at least partly restore the wetland function that has been lost.

Functioning natural wetlands in the Okanagan Valley are generally not suitable for alteration to serve as stormwater treatment wetlands for regulatory (Section 4) and conservation reasons. However, creation of a CW that discharges to a natural wetland may be of benefit if adequate treatment occurs first and only native plants are used. This is because the habitat and hydrologic connectivity values of the natural wetland could be enhanced. Potential effects on connected natural wetlands, both positive and negative, should be assessed during project planning, and water quality and ecosystem function should be monitored after project construction (Section 8.3).

5.4.2 Topography and Soils

Site topography and soils are important factors in CW feasibility assessment because of the cost implications. In addition to the benefits of taking advantage of natural drainage pathways, the topography of the site determines the volume of earth that must be moved to build the CW and the complexity of the water conveyance system. The most cost-effective design would involve construction on a slightly sloping surface with simple berms to hold water, and gravitational flow with no pumping needed. In practice, most CWs will involve fitting the wetland into the landscape and a combination of excavation, filling, and berm construction to obtain the desired configuration (i.e., length:width ratio >3:1; room for forebay, control structures, and access; and the desired hydraulic profile).

The permeability of the native soils influences cost as it determines whether fine-grained material must be imported to line the wetland cells to prevent excessive leakage. This is the case even for CWs where the ultimate discharge of the treated wetland is to ground to recharge groundwater, because retaining the water for the prescribed HRT is needed to improve water quality prior to discharge. Where protection of groundwater is critical, synthetic liners may be needed, significantly adding to project cost. Liners are discussed further in Section 6.3.5.

5.4.3 Access and Neighbouring Land Use

CWs for stormwater treatment have been built on a wide range of sites in Canada, ranging from industrial sites that prevent public access to parks and other public lands that provide an attractive amenity. If public access will occur, the CW must be designed to meet all applicable safety standards, notably low gradient slopes on berms and excavations. In general, this will add to the cost of the wetland because a larger area will be needed to achieve the same hydraulic and treatment goals.

The two most common nuisances associated with CWs are mosquitos and odours. These issues are rare in well designed and managed CWs, but may be a concern for stakeholders if the CW is situated near residential areas or other sensitive sites. For both issues, a hydraulic design that optimizes flow through the system and avoids stagnant 'dead zones' is key to nuisance control.

5.4.4 Species at Risk, Habitat, and Biodiversity

When selecting a site, current habitat conditions and the potential for species at risk to occur should be considered. Avoidance of disturbing species at risk and development of a site that is currently a wetland, or a site has not been previously impacted by development or agricultural practices should be avoided where possible. In the Okanagan, if the site is undeveloped, there is a high likelihood that species at risk are already present. Care should be taken to identify any potential risk to species or their habitat. The BC Conservation Data Centre database[5] provides information on current and historical species at risk occurrences at mapped known locations. By-law conditions of local governments may include habitat classification, environmental assessments, and species surveys to be conducted prior to project approval.

The Okanagan Collaborative Conservation Program (OCCP) has mapped many ecologically important attributes in the Okanagan, and completed many useful Land-Use Planning Studies such as: EcoRegion and EcoMapping, Sensitive Ecosystems Inventories, Ecosystem Connectivity Studies, Okanagan Biodiversity Strategy, Designing and Implementing Ecosystem Connectivity and many more. The OCCP habitat mapping tool, the Okanagan Habitat Atlas, is populated by numerous sources of data and can be used to obtain project-specific information, such as wetland occurrence, species and ecosystems at risk, habitat, and wildlife corridor, conservation and biodiversity rankings.

The South Okanagan Similkameen Conservation Program has also compiled numerous resources to help with the ecologically sustainable development of the valley for qualified professionals, land developers, planners, and local landowners.

See Sections 6.3.1 and 6.3.2 for guidance on how to incorporate species at risk habitat and biodiversity attributes into CW design.

5.4.5 Drought and Flood Considerations

Drought and flood risk should be considered for every project as extreme weather events are expected to become more frequent and increase in severity due to climate change. A flood and drought assessment should be completed to determine the likelihood and relative impact of flood and drought conditions. All infrastructure should be designed and constructed to meet local and provincial flood hazard guidelines,

---

[5] See https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/conservation-data-centre.

including the flood mapping guidelines developed by EGBC (2017). Depending on the site location, it may be necessary to consider local bylaw requirements for floodplain and watercourse setbacks and flood construction levels for infrastructure. Existing floodplain maps are available for some areas of the Okanagan, including Okanagan Lake from Westbank to Peachland, Okanagan River and Skaha Lake from Osoyoos to Penticton, Mission Creek, and Mill Creek, as well as other floodplain maps developed by Regional Districts. Design must also consider the effects of flooding on vegetation and biota within the CW.

Drought planning throughout the Okanagan has been a priority over the last two years. Many Regional Districts have completed or are completing drought management plans to assist in drought preparation and response. The effect of water shortages (due to natural drought or infrastructure failure) on vegetation and biota within the CW should be considered. For example, plant selection should prioritize drought tolerance. Stormwater CWs can play a role in drought resilience by retaining storm flows on the landscape and releasing the water slowly so it recharges groundwater or augments streamflow after the storm peak has passed.

5.4.6 First Nations, Public, Stakeholder and Aesthetic Considerations

First Nations, the public and stakeholders may be interested or concerned about a CW in their traditional territory, community, or adjacent lands. Adjacent land owners should be consulted and informed of any plans that may affect the aesthetic values of their property prior to the construction phase of the project. To gain community support for CW projects, local outreach is recommended at the concept stage. Outreach can provide education about CWs and their ecological function on the landscape, aesthetics of wetlands and what they look like can help with project acceptance. If the CW project triggers regulatory approvals, First Nations consultation is part of a Section 11 WSA review; however, engagement with First Nations prior to regulatory applications is recommended. Identification of key players to consider at the initial stages of a CW project can avoid project delays.

Aesthetic considerations should be considered if the CW is within direct sightlines of roads, homes, and businesses. Tall trees that block lake or mountain views may not be appropriate, and invasive weed management to maintain the riparian area and avoid spread of weeds to neighbouring properties should be part of the operations program. A dense thicket of shrubs or trees to block the CW from view could also be an effective strategy. Educational and safety signage should be erected around the property once the CW is constructed. Incorporation of trails, recreational, and educational opportunities could also be incorporated, if appropriate for the property and the project.

5.5 FUNDING SOURCES

There are several provincial and federal funding sources available for the protection of water quality and water source protection, in addition to wetland conservation and species at risk conservation, protection and restoration. Ultimately, the goal of a CW project is to increase water quality by treating stormwater before it is discharged into adjacent waterways; in addition, wildlife enhancements can be successfully incorporated into CW design. **Appendix D** lists some of the major federal and provincial funding sources that a CW project could potentially qualify for. Specific Okanagan funding sources are included in Table 5-1.

Table 5-1
Okanagan-specific funding sources and resources

Funding Source or Local Resource	Information
Okanagan Basin Water Board Water Conservation and Quality Improvement (WCQI)	The WCQI program provides funds to local government to support innovative, tangible, on the ground water quality and conservation improvement initiatives. In 2017, the OBWB awarded $300,000 in WCQI grants, matching funds from municipalities and private funders.
Okanagan Basin Water Board Funding Partnerships	Occasionally, the OBWB funds projects, coordinates funding partnerships, or provides matching funds for water science projects that are undertaken in cooperation with other agencies, researchers or universities.
Regional District Okanagan Similkameen South Okanagan Conservation Fund	The South Okanagan Conservation Fund covers the communities of Summerland, Penticton, Oliver, and rural electoral areas A, C, D, E and F. The funds are in support of conservation efforts to protect, enhance and restore natural areas, water, environment, wildlife, land and habitat. Proponents must be a registered not-for-profit organization, or organizations may partner with a qualified organization.
Okanagan Collaborative Conservation Program Funding Program	The Okanagan Collaborative Conservation Program is a partnership of organizations and government focused on conservation issues in the Okanagan basin. OCCP exists in part to act as a hub of information and resources that help communities take action to improve environmental protection in the Okanagan.
South Okanagan-Similkameen Conservation Program (SOSCP) Funding Program	The SOSCP is a partnership of 50 organizations that work together to conserve the unique biodiversity and environment of the region. The membership includes government, non-government, First Nations and academic institutions. The SOSCP has been working collaboratively in the South Okanagan Similkameen region, coordinating and facilitating partner activities and improving the effectiveness of conservation efforts.

6 Design Considerations

6.1 SETTING DESIGN TARGETS: WATER RETENTION, TREATMENT & HABITAT

As outlined in Section 5.1, it is necessary that the desired outcomes of a CW project are set, and performance targets are determined before proceeding to design. Any CW will provide some combination of storm flow retention, water quality improvement, and habitat, but priorities must be established because the design parameters for each of these main functions differ. The performance criteria should be set on a case-specific basis, considering the upstream sources of contamination and the downstream values that warrant protection or enhancement (Section 5.2), as well as practical considerations such as available space, access, constructability and maintenance.

Stormwater Quantity Goals: CW design will be driven by the local stormwater retention and release criteria if it is a stand-alone facility (as opposed to being part of a pond-wetland hybrid or train). For example, the City of Kelowna has set specific design criteria for stormwater “wet ponds,” a category of infrastructure that includes CWs. For most parts of the City, developments must provide storage for up to the 100-year event (plus 10% volumetric safety factor) with an outflow rate not exceeding the 5-year return interval of the pre-development condition. Other local governments have similar requirements, and proponents are responsible for making sure that designs meet the local standard. If a CW is selected as the means to achieve this goal, it must be designed with the appropriate storage capacity (e.g., freeboard plus additional volume to account for space occupied by plants) as well as all the other applicable standards (e.g., side-slope, base material permeability).

Constructed Wetland to Reduce Nitrogen Inputs to Coldstream Creek: The District of Coldstream built a surface flow CW to remove nitrate-N from several groundwater seepages that were flowing into Coldstream Creek. It was built on a former pasture site within the creek floodplain, and the wetland cell is contained by berms to prevent flooding. The design target was to reduce nitrate-N concentrations from >10 mg/L to levels that are within the BC guidelines for aquatic life protection. Intended as a low maintenance system, flow through the CW is by gravity with discharge over a rock weir. Cattail was the primary plant species at construction, but other native species are colonizing the wetland. The photo shows the CW at the time of planting.

Water Quality Performance Goals: Water quality treatment performance in CWs can be site-specific, depending on the average and minimum HRT, the condition of the plants and microbial communities, and physical parameters like water temperature. Treatment goals can be either:

- Quantitative, such as removal of 85% of TSS with particle sizes >75 µm, or meeting WQO or WQG at the point of discharge; or
- Qualitative, such as cases where municipal guidelines call for best management practices or some level of ‘polishing’ after first passing through a stormwater pond or in-ground structure.

Like cases with quantitative stormwater retention criteria, achieving specific numeric targets for water quality means that the design will be driven by the need to optimize contaminant removal processes. This will likely require accepting trade-offs with ecological function. When assessing CW feasibility, it is important to estimate treatment performance using the ‘first cut’ sizing equation (Section 5.3) to gain a preliminary understanding or the quality improvements that can be achieved with the available space (and budget). If the quality targets can be achieved, it would then be possible to use the extra space to include habitat features like deep open-water zones, islands, and areas designed specifically to attract priority wildlife.

Habitat and Ecological Goals: The historical loss of wetlands in the Okanagan Valley is one of the most important reasons for including CWs in stormwater management. Even if only a portion of a retention pond can be planted with aquatic macrophytes (e.g., 10%-20% coverage, with the rest as open water), there will be some level of local ecological benefit. However, periodic inundation and changes in water level will stress some species of native vegetation, and species that are tolerant to such variability (e.g., cattail) will tend to dominate.

Likewise, a CW designed primarily for water quality treatment will provide habitat for some wildlife species and contribute to local biodiversity, but not at the same level as a wetland designed primarily to restore those functions. This is where a hybrid wetland or treatment train may be valuable (Figure 6-1), where the upstream part of the system is designed to optimize water retention or treatment, while the downstream portion is designed to balance treatment with habitat creation.

Once the general habitat goals are set, balanced against the other goals, the next step is to establish the site-specific habitat improvement targets, including but not limited to plant diversity that mimics natural marshes in that biogeoclimatic site series, provision of waterfowl habitat, and creation of habitat for specific species at risk.

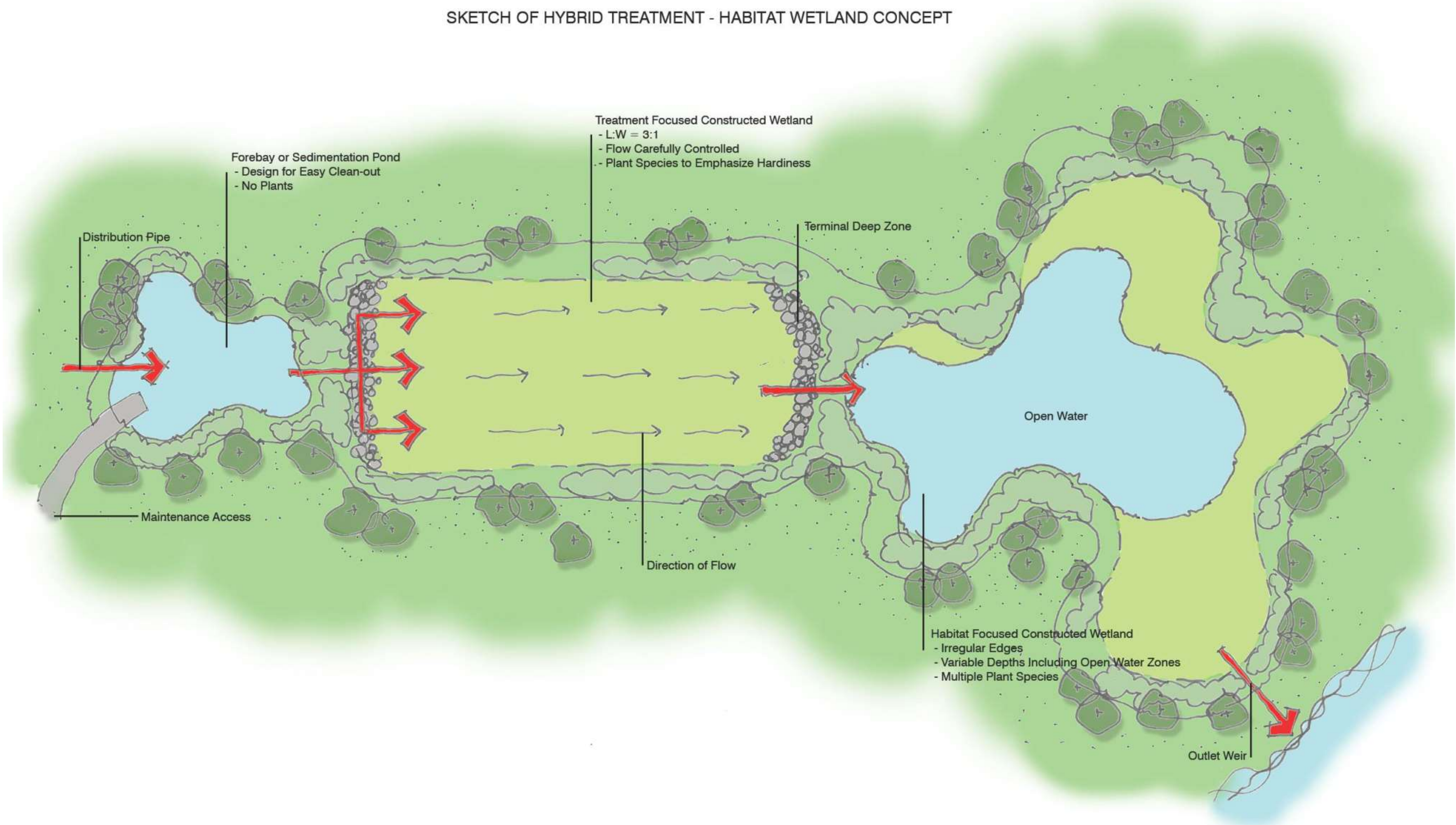


Figure 6-1
Hybrid Wetland /Treatment Train Concept

6.2 Hydrology & Hydraulics and Detailed Sizing

Compared to other applications such as municipal wastewater polishing or mine seepage control, CWs designed for stormwater must have the ability to handle large variations in flow in response to rainstorms or rapid snowmelt events. Stormwater hydraulic design typically begins with modelling the storm hydrograph to predict the design flow peak discharge and volume. When storm events begin, the first flush of flowing water often contains the highest concentration of contaminants mobilized from the contributing catchment, especially after periods of dry weather. This first flush usually occurs before the peak of the storm hydrograph (Figure 6-2) and is the part of the storm flow that should be captured for treatment. The peak flow then can be diverted around a treatment wetland in a by-pass.

Figure 6-3 shows the general layout of a CW illustrating the use of a high-flow by-pass. The forebay at the front end of the wetlands serves to reduce the velocity of the inflow (and promote sedimentation – Section 6.3.1), and would be fitted with a weir or flow gate to direct the first flush flow to the wetland and the excess volume on the rising limb of the storm hydrograph to the by-pass.

Once the volumes of water that are to be treated are determined, the detailed area calculations must be completed to refine the preliminary wetland area estimates from the feasibility assessment (Section 5.3). The two major tools are:

- Water balance calculations to account for precipitation, evapotranspiration, and leakage; and
- The mass balance design model for the target contaminants. This is the first-order decay rate (k-C*) model described in Section 5.3.

In general, the more specific the treatment targets are for substances other than TSS, the greater the need to have this part of the design completed by a qualified wastewater specialist. Detailed guidance on process design and wetland sizing is provided in Kadlec and Knight (1996). The process calculations should be augmented by a literature review to document treatment performance at other locations. The scientific literature contains numerous examples of treatment wetland performance, and care should be taken before directly transferring the design recommendations to the Okanagan, considering differences in climate.

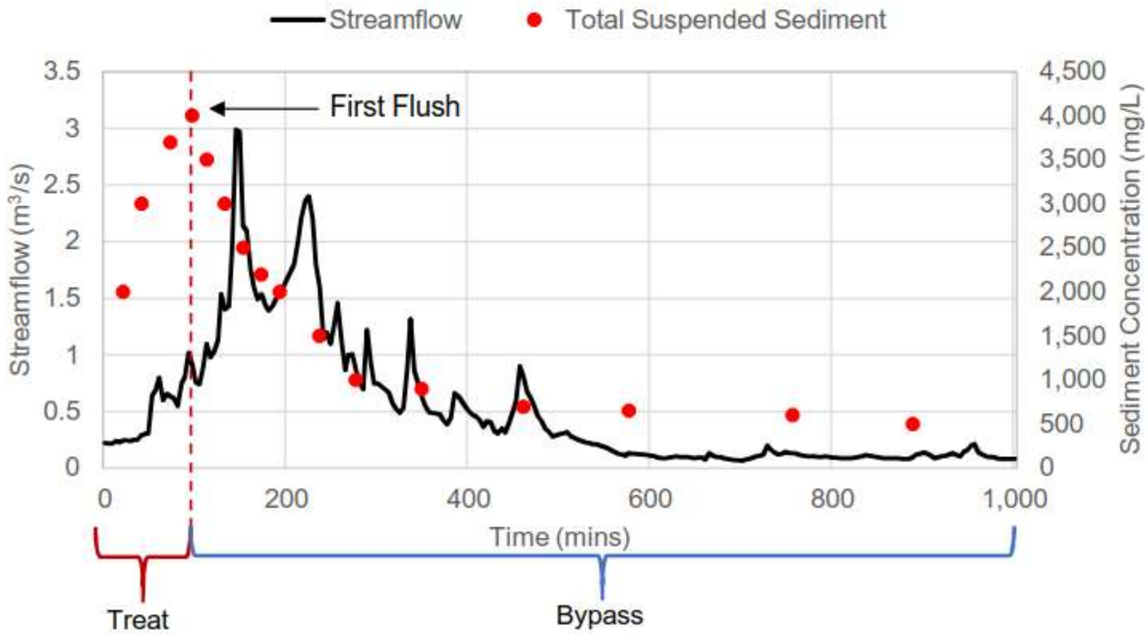


Figure 6-2
Hypothetical storm hydrograph illustrating "first flush" and portion treated

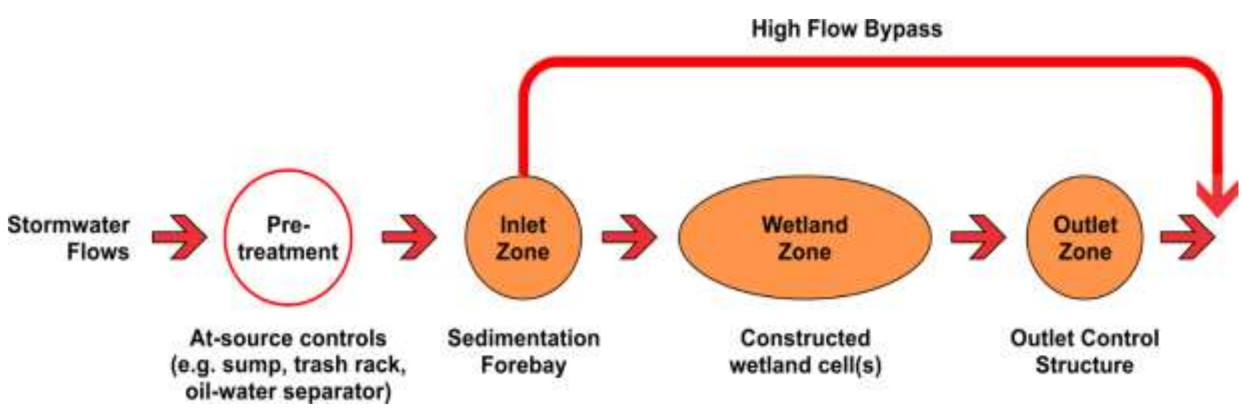


Figure 6-3
General constructed wetland layout showing forebay and high-flow bypass

6.3 Structures and Soils

6.3.1 Wetland Cells and Configuration

CWs are typically configured into one or more cells, connected by a pipe or open channel to convey the flow downgradient. For stormwater, at least two cells are required because of the need to dampen the peak flow before it enters the part of the wetland that is planted with aquatic vegetation, and avoid both scouring and excessive sediment deposition. The initial cell is called the forebay, and is designed to slow the flow velocity and thus cause the coarse sediment in the flow to drop to the bottom. It should be designed to enable easy access by a small excavator to periodically remove the accumulated sediment. The size of the forebay is determined from the inflow hydraulics and the characteristics of the sediment, but is typically about 10% of the total CW area or volume. In cases where the CW is located after a conventional storm pond, the forebay may not be needed, although an open water zone near the inlet should still be considered to enable sediment clean-out.

After the forebay, the rest of the CW can be in a single cell or in a series of cells. Multiple cells provide opportunities to customize the design and operations, or to simplify maintenance. For example, despite a forebay, the upper part of the wetland would tend to accumulate sediment. Having two wetland cells in series allows the first cell in the train to be cleaned out, as needed, without disturbing the downstream cell. Cells in series also allow for the upper cell(s) to be designed with a treatment focus and the lower cell(s) to be designed to focus on habitat and biodiversity benefits (Figure 6-3).

For contaminants that tend to accumulate in wetlands, such as heavy metals and phosphorus, it may be necessary to construct cells in parallel trains, utilizing one side for a few years before switching to the other side and cleaning out the first cell. Unlike some organic compounds (e.g., those that break down to carbon dioxide and water) or nitrogen (i.e., partly concerted to N_2 gas and removed to the atmosphere), metals and P will eventually build up in the wetland sediments, potentially reach saturation, and begin to be re-released to the water. In these cases, the cell must be cleaned out and re-established (Section 8.4). A parallel cell configuration allows treatment to continue in the second cell while the first cell is renovated.

Wetland treatment depends on the hydraulic retention time, so wetland cells are designed to promote plug-flow and avoid short-circuiting. Plug-flow is a condition where each water molecule leaves the wetland in approximately the same order that it entered. This is achieved with rectangular-shaped wetland cells with a length:width ratio of at least 3:1 (i.e., the aspect ratio) and by having the inflow spread across as much of the width as possible. There is usually little benefit of an aspect ratio >6:1, so the CW can be fit to the site if >3:1 aspect ratio is achieved and the inlet is correctly designed (Section 6.3.4). Without this rectangular shape, water entering the wetland can flow directly across to the outlet, and the average HRT will be less that the design HRT, thus compromising performance.

6.3.2 Hydraulic Profile and Water Conveyance

The flow of stormwater through a CW is driven by gravity, so the bed of the wetland must be sloped enough from the inlet to the outlet to convey the water at the designed rate, but not too steep as to reduce the HRT or create a flow velocity that prevents particle deposition, or create undesirable depths (too shallow near the inlet, too deep near the outlet). The average slope will be less than 1%, but determination of the hydraulic design criteria requires careful consideration of factors including the expected range of inflow rates, effects or precipitation and evapotranspiration, the length:width ratio, vegetation density, and whether the depth will be allowed to temporarily increase in response to storm events (Section 6.3.3). The design of the outlet structure is a key part of the hydraulic design, and should include a mechanism to adjust the water level to fine-tune operational hydraulics (Section 6.3.4).

6.3.3 Wetland Depth: Excavation and Berms

Determining the depth of the wetland cells is a critical part of the design process because depth (with area) determines the volume capacity and HRT, and affects the viability of wetland plants. The water depth in a SF wetland should be about 0.3 m to 0.4 m to enable a variety of rooted aquatic plants to become established in sufficient density to promote physical (e.g., filtration) and biological treatment processes. Some species, such as bulrush, can thrive in deeper water, but water deeper than about 0.7 m will not supported rooted, emergent plants. Deeper open-water areas can be incorporated in the design to help optimize hydraulics and enhance habitat (e.g., by providing landing space for waterfowl) and to create anaerobic conditions that are important for some treatment processes.

Depending on the site, the CW basin can be created by excavation, berms, or a combination. To maintain a viable plant population in stormwater wetlands, some depth of surface water must be present. This is the permanent storage volume. Additional stormwater detention volume gained by higher berms and/or deeper excavation, so that the water level can rise in response to an event. Aquatic plants can survive short-term exposure to depths >0.4 m, although some are less tolerant than others (Section 6.3.6).

Local governments have established the design criteria for berms and side slopes for safety and geotechnical stability reasons. Typically, an outside berm that holds water in place would have a 3:1 (horizontal:vertical) slope and a top surface width of 1 m. Shallower slopes may be installed in locations where a shallow littoral shelf is desired to create habitat diversity. Interior berms separating wetland cells or compartments can be steeper (e.g., 2:1) and narrower (e.g., 0.5 top width). Local by-laws and standards must be consulted before proceeding with design. If the CW is built within a floodplain, the outside berms would also have to be designed to maintain the physical integrity and functioning of the system during a flood event.

6.3.4 Inlet and Outlet Flow Control Structures

The CW inlet and outlet structures work together to control the rate, depth, and spatial distribution of water flow through the wetland. They should be located to maximize the HRT and avoid short-circuiting by being as far apart as possible. Stormwater CWs generally rely on gravity flow, although pumping may be employed in special situations.

For water quality improvement, the design of the inlet structure is a critical part of treatment performance. It should be designed to spread the inflowing water broadly across the width of the CW cell to create sheetflow conditions and maximize contact with the plants. This can be accomplished in several ways, including multiple inlet points, gated distribution pipes, a broad-crested weir, and a level swale spreader. In situations where regular inspection and maintenance of the inlet may not be possible, the inflow from a single open channel or pipe can be deflected around boulders near the inlet to spread the water laterally (Note that placement of boulders near the inlet can be considered for all inlet designs to reduce inflow velocities and avoid erosion or the re-suspension of sediment). Generally, the wider the CW, the more important it is to have an inlet structure that spreads the flow evenly across the width. The inlet structure may also need to be designed to divide the storm flow and by-pass the peak, although the by-pass structure could be placed in the forebay upstream of the treatment CW(s).

The outlet structure controls water elevation and the rate of discharge from the CW. The outlet structure also plays a role in avoiding short-circuiting, as a single point of discharge can cause water to be drawn towards it and create dead zones in the downstream end of the CW. A way to minimize this is to create a terminal deep zone across the width of the CW before the outlet, with a single outlet. Outlet options include adjustable weirs, flumes, and riser pipes where the level of the inflow can be adjusted. The outlet should be designed to pass the average daily or weekly maximum flow, including allowance for rain falling directly on the CW.

As a general design principle, inlets and outlet should be as simple as possible to reduce maintenance needs and operational costs. However, the key functions of spreading out the inflowing water across the CW and controlling the flow rate should not be compromised.

6.3.5 Wetland Bottom and Use of a Liner

The bottoms of stormwater ponds and CWs should be constructed to minimize infiltration to ground. This will help ensure that the water is adequately exposed to plants and microbes for treatment. An exception would be where the CW is constructed on a level, low elevation site with a water table at or near the surface year-round, and low risk of water completely draining from the wetland basin. The bottom of the CW can be built using locally obtained clay soils or bentonite. Synthetic liners made of high density polyethylene (HDPE) or other materials can be considered for smaller sites, but could be cost-prohibitive for larger wetlands. For larger wetlands, some local governments have established permeability standards for the bottoms and interior side slopes (e.g., 1 x 10^{-6} cm/s in Kelowna), so designers must ensure that the correct standards are included.

6.3.6 Wetland Substrate

CW designs should include provisions to remove and stockpile native soils from the site before the wetland cells are excavated, and then replace the soils to provide a growth medium for the aquatic plants. This means that the depth of excavation must account for the soil replacement. The topsoil layer should be at least 25 cm thick, but a thicker layer (30-40 cm) would help the plants to become established. The combined thickness of the soil layer and the compacted clay layer must be enough to prevent penetration of the liner by plant roots and thus avoid leakage. If the CW is built on a site without topsoil (e.g., on an industrial site), then topsoil, peat or another soil alternative should be obtained. In addition to helping the wetland plants to become established, the organic matter and fine mineral particles provide exchange sites that bind up contaminants. Furthermore, biofilms develop on the substrate surface, greatly increasing the total microbial biomass available for the treatment processes.

6.4 PLANTS AND WILDLIFE

6.4.1 Plant Selections and Specifications

Selecting appropriate plant species is crucial to achieve CW treatment and ecological function objectives and the desired wetland habitat. In the Okanagan, only native non-invasive species should be used for treatment and ecological functions. For treatment, the key attributes in plant selection are tolerance to variations in water level and water quality, hardiness, and below-water surface area (for biofilm attachment). Contaminant uptake potential varies among species, but it is less important for overall performance than the ability of a plant to thrive and therefore provide a biofilm surface, physically filter the water, and transfer oxygen to the wetland sediments. Once these goals are achieved, designers can choose additional wetland plants to meet the biodiversity and habitat goals.

Regardless of the mix of treatment and habitat goals, the design should make use of natural processes to foster the sustainable establishment of plants that are compatible with natural wetlands in the same biogeoclimatic variant. Section 6.4.2 and 6.4.3 outlines how to create a wetland for specific habitats in the Okanagan and how to enhance biodiversity by using natural processes. Application of natural processes will facilitate continued function.

Wetland Zones

Wetland areas can be planted successfully where the soil substrate, moisture regime and inundation frequency is considered. Establishing a variety of hydrologic zones in a CW (i.e. differing inundation frequencies) is beneficial because each zone provides specific functions and supports a different plant community. The use of multiple zones allows stormwater to be distributed over a variety of conditions maximizing water quality improvement function and creating a diverse ecosystem. The wetland be divided into 5 hydrologic zones based on the range in topography as shown in Table 6-1.

Table 6-1
Hydrologic Wetland Zones

Zone	Name	Average Depth of Water	Descriptions*
I	Deep Pool	50-80 cm	Deep pools are designed to be at least at least 50 cm deeper that the water level at normal pool and ideally are installed such that several small deep pools are scattered around the wetland.
II	Transition from Deep to Shallow	10-50 cm	The transition connects deep and shallow zones and should be designed with a maximum slope of 1.5:1. It occupies the smallest area in the wetland and only few plants can tolerate the hydrologic regime.
III	Shallow Water	5-10 cm	Shallow water zones are flooded during low flow periods, and may be dry during drought periods. The oxygenation present enhances nutrient transformations. The shallow water allows a much greater number of species to survive.
IV	Temporarily Flooded	0-5 cm	Acts as a flood plain and is inundated only when the design storm event is exceeded. This zone is designed such that the ground elevation extends from 0 to 30 cm above normal pool. A variety of vegetation can survive in the zone.
V	Uplands	0 cm	This area surrounds the constructed wetland (riparian area) and is an important component for wildlife, the wetland edges must tie into it. Gently slopes are important to minimize erosion and allow for maintenance. Several species can be planted.

* Based on Hunt et al 2007

Figure 6-1 illustrates the plan view of a hybrid CW while Figure 6-4 below, shows a cross-section of the interior wetland zones. Functions of each wetland zone are critical to water quality improvement and habitat. Deep pools (Zone I) are capable of dissipating flow energy, trapping sediment, providing an anaerobic environment that enhances nitrate treatment, provide water storage that increases infiltration and evaporation to reduce outflow volumes in sites with a low water table, provide refuge for aquatic organisms during drought periods, and provide year-round habitat for mosquito predators (Hunt et al 2007). The Shallow Water (Zone III) becomes dry during extended drought, but when inundated, the zone will provide breeding habitat for amphibians, and rearing habitat for amphibians and invertebrates, which are important for nutrient transformations such as nitrification (Hunt et al 2007). Table 6-2 illustrates two different types of wetlands common to the Okanagan that can easily be incorporated into a CW hybrid design.

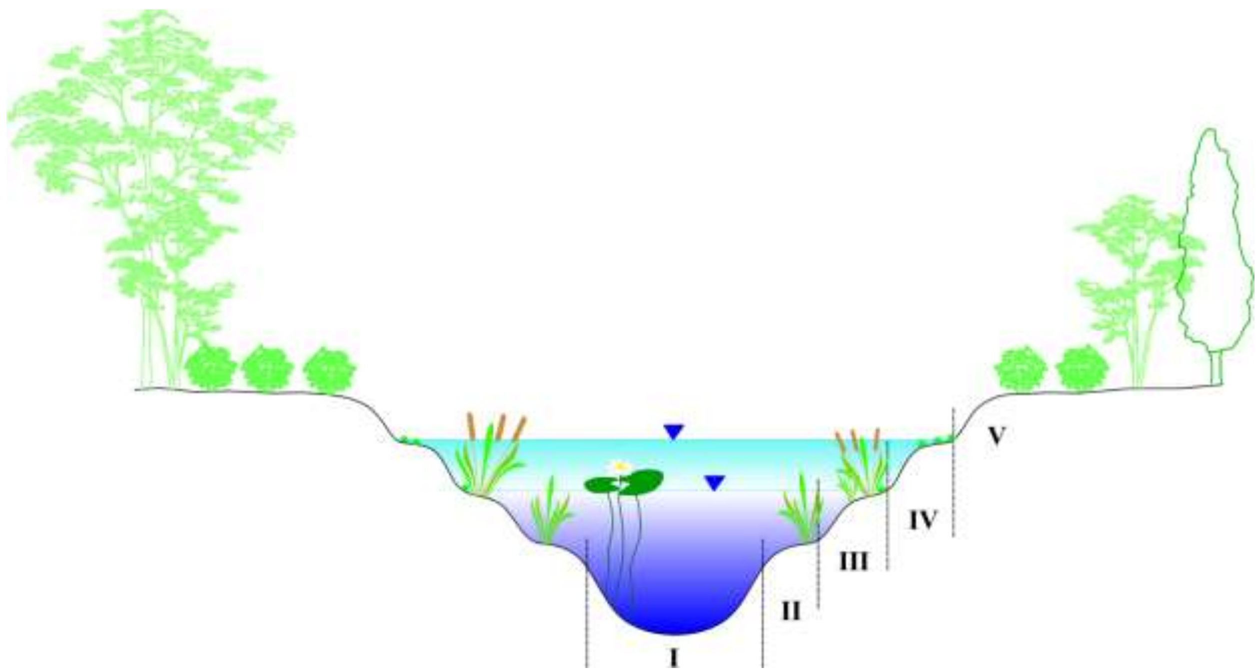


Figure 6-4
Wetland Zones Cross-Section

Table 6-2
Wetland Type Specifications

Class	Description	Soils	Water Level	Plant Species
Marsh	Characterized by an association with shallow open water ecosystems, frequently inundated, site dominated by emergent plants with <10% shrub/tree cover.	Soils are gleysol mineral or peat soils, influenced by fluctuating water levels.	Fluctuating water level, but permanently to seasonally flooded (up to 3 m).	Douglas Fir Ponderosa Pine Cottonwood Grasses Cattail Bulrush Rush Sedge Duckweed Pondweed Smartweed Water Lily
Shallow-open water	Characterized by intermittently or permanently inundated areas with open water up to 2 m deep.	This wetland class and marshes are commonly adjacent to floodplains and saline meadows, with gleysolic mineral soils.	Permanently flooded, water generally <2 m deep and still or flowing	Cottonwood Willow Red osier-dogwood Grasses Cattail Bulrush Rush Sedge Duckweed Pondweed Smartweed Water Lily

Plant Selection
Selecting the appropriate species for planting in each zone is important because species differ in tolerance for flooded or saturated conditions. The frequent and significant changes in water depth are conditions of a stormwater wetland that differ greatly from natural systems. Therefore, the performance of individual species that can tolerate these conditions require continued study. Table 6-3 identifies a sample of recommended species appropriate for planting in each zone, arranged from wettest to driest. Use of non-native and invasive species should be avoided. Many **wetlands plants** are used by **Indigenous Peoples** for **traditional purposes**, such as the great bulrush used to create woven mats for ground covers, roofs and wall coverings. For example, cattails have had many traditional uses such as a food source (starchy rhizomes and young leaf stalks), a material (leaf blades) to make mats, insulation and stuffing (seed heads), and a topical ointment (gelatinous substance at the base of the plant) to relieve insect bites, hives

or toothaches. E-Flora BC provides habitat requirement information and species distribution maps on a species-specific basis.

Timing of aquatic plant installation is important to consider, planting is recommended to occur in late May to mid-June or fall when conditions are moister to allow for a vigorous growing period in the Okanagan. In addition, **sufficient time should be allotted to secure plant orders**. Pre-ordering wetland plants, planning local seed collection, and germinating should be planned during the design phase and will need to be completed 6 months to one year prior to the desired planting time. Planting plans must consider several factors related to maintenance. For example, willow and poplar may create root clogging issues near inlet and outlet components or obscure access for maintenance activities, such as removing accumulated sediment or debris from outlet structures. Sections 6.5, 7.0 and 8.2 include additional detail for planting timing in the Okanagan, as well as planning for maintenance and discouraging invasive plant establishment (Photo credit Josie Symonds @ FLNRO).

Table 6-3
Plant species habitat requirements

Plant Type	Okanagan-specific Species for Low Valley Wetlands	Wetland Zone and Plant Type	Habitat Requirement	Moisture Tolerance
Fescue	Rough/Idaho	V - Terrestrial	Moist to dry soils, above the water table	Some tolerance to minor flooding
Blue joint	Canadian	V - Terrestrial	Wet, moist to dry soils, above the water table	Some tolerance to minor flooding
Rose	Nootka, Baldhip, Prickly	V - Terrestrial	Moist to dry soils, above the water table	Some tolerance to minor flooding
Alder	Sitka, Mountain	V - Terrestrial	Moist soils, generally above the water table	Some tolerance to minor flooding
Hawthorn	Black	V - Terrestrial	Moist soils, generally above the	Some tolerance to minor flooding

Plant Type	Okanagan-specific Species for Low Valley Wetlands	Wetland Zone and Plant Type	Habitat Requirement	Moisture Tolerance
			water table	
Dogwood	Red-osier *can grow from cuttings	V - Terrestrial	Moist soils, generally above the water table	Some tolerance to minor flooding
Bluegrass	Kentucky	IV/V - Terrestrial	Wet, Moist to dry soils, above the water table	Some tolerance to minor flooding
Cottonwood	Black *can grow from cuttings	IV/V - Terrestrial	Moist soils, generally above the water table	Some tolerance to moderate flooding
Willow	Pacific, Bebb's, Tea-leaved *can grow from cuttings	IV - Terrestrial	Fluctuating water table, that is moist all year round	Some tolerance to moderate flooding
Bulrush/ Rush	Great, Small-flowered, Common spike-rush	III - Emergent	Fluctuating water table, that is moist all year round	Some tolerance to prolonged flooding
Sedge	Water, Beaked, Woolly, Slender-beaked, Crawford's	III - Emergent	Fluctuating water table, that is moist all year round	Some tolerance to prolonged flooding
Cattail		II/III - Emergent, Sub-aquatic	Fluctuating water table, that is moist all year and flooded for long periods of the year	Will tolerate water up to 2 m deep, and spread rapidly into a monoculture, will tolerate prolonged flooding up to 2m deep, will not tolerate prolonged flooding >2 m deep or high levels of shade from surrounding riparian plants. To avoid a monoculture of cattail and create open-water habitat, create pools >2m

Plant Type	Okanagan-specific Species for Low Valley Wetlands	Wetland Zone and Plant Type	Habitat Requirement	Moisture Tolerance
				deep.
Duckweed	Common	I -Aquatic	Aquatic species, requires surface water year-round	Will tolerate short periods of drought, if substrates stay moist
Smartweed		I -Aquatic	Aquatic species, requires surface water year-round	Will tolerate short periods of drought, if substrates stay moist

6.4.2 Wildlife Enhancements

Designing a CW to provide habitat to species with similar requirements will increase the chances of successfully meeting wildlife objectives. When designing a CW, site-specific wildlife habitat enhancements should be evaluated for feasibility, then specific wildlife enhancement habitat goals should be identified and balanced against the other stormwater treatment goals. Specific species should be selected for wetland habitat enhancements, based on available site attributes that can be created with the resources available and the biophysical attributes of the site. Once these are evaluated, wildlife enhancement goals and targets can be established that are measurable (i.e., number of target wildlife species observed using the wetland during a specific time) and monitored through operations of the project.

E-Fauna BC provides habitat requirement information and species-specific distribution maps. The Ministry of Environment, Environmental Stewardship Division Okanagan Region website lists species at risk and their habitat requirements. *Wetland Restoration and Construction* is an extensive technical guide for constructed habitat wetlands (Biebighauser 2011).

Discouraging fish and installing structures to prevent fish from entering the CW is encouraged. The absence of fish will reduce the risk of predation and enable other species to breed.

6.4.3 Wetland Habitat Enhancements

Trees, Wood and Rocks

Fallen trees and rocks installed within the CW will increase topographic diversity on the surface, and provide shelter, security, and breeding locations for many wildlife species and encourage colonization of the habitat by invertebrates and insects, which are a critical food source for many species. Topographic diversity will reduce predation, provide sunning areas for amphibians and reptiles, perching habitat for birds, and shade. Trees with rootwads introduce a greater diversity of plants from the soil attached to its roots. Planting or retaining dead standing trees to create wildlife snags will provide perches and insect food sources for wildlife. Scattered woody debris provide nutrients to the ecosystem and encourage plant growth by providing a broad range of conditions for plants to establish (i.e., shade, sun, dry and moist sites). Rock piles can provide denning and refuge habitat. Rock and wood placement can discourage recreational vehicle use within the CW area if that is a concern.

Open Water vs. Closed Water Habitat

Open water habitats attract duck, shorebird and migratory bird species. Depending on the size of the CW, the area could attract and provide refuge habitat for a large flow of migrating birds. Wetlands that have a continuous cover of vegetation will discourage ducks and shorebirds from using the habitat but will encourage other species such as amphibians (e.g., salamanders, frogs) and small mammals.

Islands

Construction of islands within a wetland complex will increase the diversity of the habitat. Islands increase transition and upper habitat zones within the CW project site. This provides the opportunity for additional planting and creation of potential breeding or refuge sites for wildlife in the middle of the wetted area. From a vegetation maintenance perspective, however, islands can be difficult to access and invasive weed management or follow-up planting may not be feasible. Designing islands to discourage weed growth is recommended, and building islands with suitable substrates for burrowing (loose sandy/loamy soil) could attract toads and turtles.

Turtles

One species of turtle occurs in the Okanagan, the Blue-listed western painted turtle (*Chrysemys picta bellii*). This species requires wetlands, open-water area, vegetated and upland areas, places for basking in sunlight, and light-textured soils on a warm southern aspect slope for nesting. They prefer muddy bottom wetlands with aquatic plants. Turtles build nests in upland areas with a warm aspect, critical for incubating eggs, and dig in friable soils on non-vegetated slopes. If designing CW habitat to attract turtles, the location of the local nesting habitat must be considered in the design so that turtles will not have to cross transportation roads to get to and from their nesting site.

Toads

Toads prefer small, shallow, open-water breeding sites, exposed to the sun and void of fish. The Great Basin spadefoot (*Spea intermontana*) in the Okanagan prefers ephemeral wetlands (i.e., wetted in the spring, dry for the rest of the year) and are tolerant of dry conditions. Inclusion of ephemeral ponds within the CW complex design will encourage and provide habitat for breeding toads and other amphibian species. Ephemeral wetlands can be created by designing shallow depressions void of plants, within the southerly aspect of the margins of the CW. Western toads (or boreal toad) (Threatened [SARA], *Anaxyrus boreas*) also prefer open water warm shallow wetlands; however, they require persistent water into the summer. In addition, non-compacted soil and diversity of habitat including woody debris and rocks surrounding the CW is a critical aspect of providing for toad habitat. Toads bury into friable substrates or take shelter under logs and rocks to evade predators and for daily shelter, temperature regulation, and hibernation.

Frogs

Two frog species occur in the Okanagan. The Northern Pacific Treefrog *(Pseudacris regilla)* is common and occupies a wide variety of habitats, including terrestrial and urban areas. The Columbia spotted frog (*Rana luteiventris*) is not as common, inhabits ponds and wetlands and rarely travels very far from wetted ponds. Wetland design for frogs is straight forward.

Salamanders

Long-toed salamander (*Ambystoma macrodactylum*, most common species in BC) and the blotched tiger salamander (Endangered, *Ambystoma mavortium*) occur in the Okanagan. Salamanders spend most of their adult life in dark moist places, under logs, rocks, and leaf-litter, hibernating in small mammal burrows or rotting logs. They emerge to breed early in the spring and use warm wetted ponds with a high coverage of aquatic and emergent plants. Adults forage in grasslands, meadows, riparian areas and coniferous forests.

Ducks and Migratory Birds

Many migratory and resident bird species use the Okanagan Valley. Ducks are the most common and can be divided into two categories: dabbling or diving. Each require open-water; however, dabbling ducks can use a variety of habitats, including shallow vegetated waters, whereas diving ducks prefer larger deeper open-water habitat for foraging as well as landing and taking off. CW water depth and size can affect what type of ducks are attracted to the wetland. Presence of insects, invertebrates and aquatic plants are required for food sources. Emergent plants, shrubs, trees, overhanging branches, and dense vegetation around the margins of the wetland can provide nesting and shelter habitat. Nesting platforms could be erected within open water areas, or nesting boxes installed in dense vegetation for other species.

The Okanagan Valley is an important corridor for migratory birds and is one the three main migratory routes between Alaska and Mexico. Vaseux Lake (Vaseux Lake Migratory Bird Sanctuary) in the south and Swan Lake (Wildlife Management Area) in the north are two large open-water lakes that support more than 220 species of migratory birds. Additional wetlands within the Okanagan landscape can support the habitat requirements of these migratory species. Many of the migratory species passing through the Okanagan are listed species (CDC 2017). The sandhill crane (*Antigone canadensis*) is a Yellow-listed species, and prefers isolated shallow wetlands adjacent to grasslands and agricultural fields. The Blue-listed American bittern (*Botaurus lentiginosus*) prefers to nest in thick stands of bulrushes, cattails or sedges over shallow water, and forages in adjacent upland habitats. The great blue heron (*Ardea herodias herodias)* is a Blue-listed sub-species that forages for fish and other aquatic prey in wetland habitat.

Shorebirds
Shorebirds prefer muddy exposed shorelines for foraging, and generally nest along the shoreline in a semi-open area with patches of dense vegetation for sheltering chicks. The American avocet (Red-listed, *Recurvirostra americana*) is unique in that it prefers alkaline muddy bottomed wetlands, with shallowly sloped unvegetated muddy islands to nest.

Raptors and Large Birds of Prey
Hawks and eagles generally prey on small mammals and occasionally amphibians, and balance ecosystems by keeping small mammal populations under control. Too many mammals feeding on native wetland vegetation will have a negative impact on growth and survival of newly planted vegetation. Many species are present in the Okanagan, they generally inhabit wide open species over grasslands, agricultural fields, and riparian areas with large trees for perching and nesting. To attract hawks and eagles, large wildlife trees, tall poles, and planting trees in the riparian will provide sites for perching, and eventually for nesting as trees age.

The Western Screech-Owl (Blue-listed, *Megascops kennicottii macfarlanei)* are restricted to moist woodlands along streams and lakes, this listed subspecies occupies the southern interior of BC. Where available, retain patches of mature riparian forest from 5-10 hectares in size. Suitable screech-owl habitat will be achieved by, retaining or creating large, standing coniferous and deciduous forests including dead wildlife trees with cavities, and constructing nest boxes.

6.5 PLANNING FOR MAINTENANCE

Construction and operational maintenance must be considered early in the CW design process. If maintenance is considered early in the design, operation and maintenance requirements will be reduced. Good design planning and thinking ahead to consider maintenance of CW structures in relation to design considerations (Section 6.0) will reduce overall operation and maintenance costs. Provisions to access forebays or any areas within the wetland to remove sediment build-up should be incorporated into design. Adequate area and supportive infrastructure is required for machine access, and consideration of discouraging public access to CW infrastructure should be considered. The degree and frequency of operational and maintenance requirements will vary for each project depending on layout, size, catchment, climate, hydrology, and upstream and downstream influences. Each CW project should have its own operation and maintenance plan. Sediment removal should be expected as part of routine maintenance and planned for at the design stage. CW maintenance considerations could include:

- Removing sediment;
- Periodic mowing of embankments;
- Removing invasive species;
- Replanting native vegetation or seeding as required; and
- Removing debris from outlet structures.

If the CW connects to fish-bearing waters, appropriate infrastructure to deter fish from entering the wetland will need to be incorporated into the design to avoid creating fish habitat within the CW. Various provincial and federal legislation would apply to the CW project if fish are allowed into the CW and create fish habitat. Maintenance of the sediment forebays would become problematic if fish were present. Fish-deterrent structures can be incorporated into any pipe or open channel that connects the wetland to a stream.

6.6 DESIGN CHECKLIST

Figure 6-4 is a checklist that outlines the key components of stormwater Constructed Wetlands that need to be addressed during feasibility assessment, preliminary design, and detailed design.

Table 6-4
Design Component Checklist - Constructed Wetlands for Stormwater Treatment

Components	Guidance Comments
Site topography and drainage	Select site to optimize gravity flow through the system and avoid pumping or extensive earthworks.
Soils and surficial geology	Permeable soils will require a clay or synthetic liner. Soil survey to locate suitable nearby source of clay. Native soil, if present, should be stripped and saved to serve as wetland substrate or for use.
Ecosystem compatibility	Examine natural wetlands at similar locations (topography, soils, climate) to develop CW plant list. Determine if CW will connect to natural wetland.
Catchment land use & contaminant characterization	Determine the primary and secondary contaminants to be targeted for treatment. Consider both current and future land use.
Catchment hydrology	For calculations of runoff volume and timing, and determine need for pond retention, storm by-pass, and/or forebay before CW. Utilize hydrologic design tools that incorporate climate change (e.g. Intensity Duration Frequency curves).
Pre-treatment (forebay or alternative)	Estimate erosion potential and sediment load to determine forebay design criteria. Consider alternatives if practical for coarse sediment removal.
By-pass	Incorporate routine and emergency by-pass(es) for peak flows.
Active storage depth & available freeboard	Design so that surface water is always present to maintain plants, and sufficient freeboard volume to retain the design flows.
Aspect ratio (Length to Width ratio)	Should be a least 3:1 with flow spread as evenly as possible across width.
Inflow and outflow control structures	Design for operational simplicity. Inflow structure should distribute flow across full width of CW. Outlet design should allow CW depth to be adjusted and include spillway or similar for large events.
Winter operations	Consider effects of freezing and ice build-up on inlet and outlet structure. Should be able to increase minimum depth in winter to leave some liquid water beneath an ice layer.
Berms and excavated slopes.	Must meet local design standards. Consider shallower side slopes if CW

Components	Guidance Comments
	is in a public place, for safety.
Wetland bottom	Bottom must be level to promote even flow. Lengthwise gradient to be determined from hydraulic design to create “steady but slow” flow.
Soils	Native topsoil (if any) should be retained for CW substrate. If the CW requires excavation, depth must allow for soil replacement.
Liner	CW must retain water to maintain active storage. Liner option selection (e.g. clay, HDPE) to consider local source and need to protect groundwater. Where groundwater recharge is desired, CW can discharge to infiltration basin.
Deep zones	Consider deep zones (e.g., 0.8 – 2.0 m deep) at inflow and outflow to promote even flow distribution, and at intermediate location(s). Proportion of vegetated and open/deep zones depends on treatment and habitat goals.
Vegetation in CW cells	Mix of species to be based on hardiness, resiliency to variations in depth, subsurface area (for biofilm colonization), and biodiversity goals. Use native species only, from local seed source.
Vegetation on CW edges and riparian	Mimic natural assemblages of plant on edges and banks if space allows. Use native species only, from local seed source. Consider needs of Okanagan species-at-risk in plant selection and design of edges and riparian zone.
Habitat creation	In general, stormwater CW designs emphasize hydrologic and treatment functions, but identify opportunities to provide habitat where space and operations allow. Habitat design features include open water zones, variable depths, irregular edges, and plant diversity on edges and riparian zones that mimic natural conditions.
Fencing and safety	Consider risks to public when designing slopes, equipment access points, and control structures. Fences may be needed for CWs intended to handle rapid storm flows.
Buffers to residential areas	Determine suitable distance to mitigate odours and potential mosquito issues. Plant trees and shrubs in buffer. If in a public space, include a viewing platform to minimize disturbance of CW and riparian areas.
Signage	Consider signage for public awareness and education.

7 Construction

If the CW connects to a fish-bearing waterbody, or if vegetation clearing and soil grubbing is required, **construction should be timed to coincide with environmental least-risk construction windows** to minimize impacts on fish and wildlife. Depending on the characteristics of the project site and existing habitat conditions, timing windows may need to be considered to minimize impacts on migratory birds, raptors, fish, water quality, amphibians and reptiles. Best Management Practices such as Develop with Care 2014: Environmental Guidelines for Urban and Rural Land Development in British Columbia should be reviewed and mitigation measures incorporated into construction planning. Specific timing windows for the Okanagan are found on the Government of BC Okanagan Region Timing Windows website.

Construction timing should avoid amphibian and reptile breeding (spring) and hibernating (fall/winter). Least risk windows for birds are focused on avoiding nesting and breeding time periods (BC *Wildlife Act*, Section 4.1); generally for the Okanagan these are as follows:

- Raptors (eagles, hawks, falcons and owls): August 15 – January 30
- Herons: August 15 – January 30
- Other birds: Aug 31 – March 31

Specific windows are applied to specific species. If wildlife species are present within the project area, species should be identified and a specific least-risk timing strategy worked into the construction schedule. The Okanagan is home to many fish species, including lake and stream spawning kokanee. Provincially listed wildlife species that could be encountered include western painted turtle, Great Basin spadefoot, great blue heron, and Swainson's hawk. See Section 6.4.2 for wetland enhancements.

Sediment and erosion measures should be considered, and a Construction and Environmental Management Plan should be in place (including outlining the appropriate least risk timing windows) prior to construction. Avoidance of sediment transfer into existing waterbodies is critical. Seeding exposed substrates with an appropriate wetland grass seed mix as soon as possible after construction is recommended.

Construction timing and phasing should consider growing requirements of **wetland plants and wetland seed**, and should be planned to promote rapid growth of plants/seeds and stabilization of exposed soils to discourage the establishment of invasive species. Timing of aquatic plant installation is important and in the Okanagan, is recommended to occur in late May to mid-June to allow for a vigorous growing period. This allows plants to establish prior to Okanagan's hot dry summers, migratory bird stopovers in the fall, and for over wintering. Planting should not be done later than late June as time for establishment is too short and the plants will become too stressed during the summer. Some plant species may be planted outside these windows (i.e. live willow stakes installed during dormancy in late fall or early spring). See Section 8.2 for details on invasive species control.

Machine access should be considered prior to and during construction, and appropriate and safe access to and from the site should be planned. If access is required on public roads or common rights-of-way, consideration should be given to machines entering and exiting the site and tracking mud on roadways, and employing flaggers if entering or exiting onto busy roadways or highways.

8 Operations and Maintenance

8.1 ROUTINE MAINTENANCE

A routine maintenance plan should include an overview of all operation and maintenance tasks required to ensure effective functioning of CW operations for the duration of the project lifespan. This is project-specific and part of the Operation and Maintenance Plan (as outlined in Section 6.6). Details such as the task frequency and schedule should be outlined in an annual timetable. Two categories of maintenance should be considered: preventative and corrective. Preventative maintenance includes the general upkeep of the CW and its supportive infrastructure (e.g., inspections, organics clean-out and collection, sediment removal, monitoring, and record keeping). Corrective maintenance includes tasks that arise from unforeseen events (environment or public) or equipment failure.

Maintenance practices for upland vegetation and weed control (Section 8.2) should aim to increase the growth and spread of desired vegetation species and decrease the spread of invasive species. This could include regular mowing to decrease weed spread, if shrubs and trees are spaced far enough apart and if grasses are the infill species.

The success and health of the wetland vegetation community within the CW is a key part in maintaining ecological function and achieving the stormwater management objectives of the project. Plants must have adequate water, be well established and healthy. Changes to the hydraulic regime or changes to water quality can have a detrimental effect on the vegetation community, wildlife and the ecosystem. Consistent water level management will encourage a healthy vegetation community as it responds to a regular hydraulic regime. Water levels and inflows to the CW can be controlled and adjusted to provide optimum growing conditions. Routine maintenance and consistent water level management will ensure a healthy and functioning vegetation community.

8.2 INVASIVE SPECIES CONTROL

All CW operation plans should incorporate an invasive species management plan into the regular maintenance plan. The following strategies should be considered when developing the management plan. Most of this information is provided in FLNRO’s Invasive Alien Plant Program Reference Guide Part I - Module 1.3.

Prevention and Seeding

Prevention of weed establishment is the best way to manage for invasive plants. Operational management practices including re-seeding and re-planting wetland margins annually until the desired vegetation has established will discourage weed growth. Management practices that maintain the desired vegetation in a healthy condition should be an operational goal. Healthy plant communities will discourage the establishment of weeds, and shade from a dense vegetative cover (i.e., trees, shrubs, grasses, and tall native wetland plants) will discourage weed establishment as most weeds are shade-intolerant and prefer sun, compacted soil, and disturbed sites (with the exception of burdock and garlic mustard).

Vegetation should be planted and seed distributed over all disturbed areas as quickly as possible, preferably within two weeks post-construction and during the growing season. If construction concludes in a non-growing season, seed can still be applied, which will remain dormant until appropriate conditions are present. The seed mix should include wetland appropriate species of grasses and legumes that are non-invasive and suitable for the moisture regime and the CW management objectives. Successful seeding should consider the following factors:

- biogeoclimatic unit, soil type(s), slope, and aspect;
- plant species to be used;
- appropriate seeding methods for the site;
- appropriate rates and timing of seeding; and
- CW management objectives.

All seed sold in Canada is subject to the federal *Seeds Act*, and thus is subject to conditions regarding prohibited and primary noxious invasive plant seed.

Management

Management strategies will vary by invasive plant species, severity of the plant invasion, and site characteristics (TIPS Factsheets; Guide to Weeds in BC). Site-specific mechanical, chemical (although there are limited application options in a wetland setting), or biological control methods may be applied. Invasive weeds should be removed prior to going to seed (i.e., remove in early summer). All mature flowers and seed heads should be captured if the removal timing was missed.

Using chemical methods around water are restricted, and must only be applied by a certified Pesticide Applicator. A pesticide management plan may be required if treating on crown land and if treating an area larger than 0.5ha (*Invasive Plant Management Regulation 5.(L)*) The most effective way to manage weeds is prevention and successful vegetation management during operation. Table 8-1 outlines effective non-chemical management options for common invasive species that occur in wetland ecosystems in the Okanagan. Many biocontrol agents are available for species found in the Okanagan; however, biocontrol is a long-term management process and should only be applied as part of a larger program within the Regional District.

Table 8-1
Okanagan wetland invasive species management

Wetland Zone (V=Dry) (III-Wetted)	Species Name	Management Options (TIPS Factsheets)
IV -V	Scotch thistle (*Onopordum acanthuim*)	Dig each rosette out by the root in late spring, use a shovel to sever the rosette from the root 40 cm below the surface, or completely remove the root to prevent regrowth. Mowing can deter stem growth but will not kill the plant alone.
IV -V	Hound's tongue (*Cynoglossum officialle*)	Dig each rosette out by the root in late spring, use a shovel to capture the entire root to prevent regrowth.
V	Sulphur cinquefoil (*Potentilla recta*)	Cannot effectively establish in frequently tilled soils, hand pulling of the upper portion and the root system both need to be removed. Is not controlled by mowing.
IV-V	Common tansy (*Tanacetum vulgar*)	Cannot be controlled by single annual mowing events, but it also. Mowing very low to the ground before July can prevent seed production. If hand-pulling, gloves and other protective clothing should be worn to prevent skin irritation.
II-IV	Japanese knotweed (*Fallopia japonica*), Giant knotweed (*Fallopia sachalenensis*), and Bohemian knotweed (*Fallopia x bohe-mica*)	Three of the four non-native knotweed species are found in the Okanagan. Knotweed can easily be spread from existing populations by transporting small pieces of stem or root fragments to another location. To effectively eradicate knotweed species, multiple herbicide treatments are required. To avoid spreading knotweed, pieces of the plant and their roots should not be disturbed until after successful treatment.
III-IV	Reed canarygrass (*Phalaris arundinacea* L.) and Common Reed species	Cannot be controlled by single annual mowing events, but mowing very low to the ground before July can prevent seed development. Prolonged

Wetland Zone (V=Dry) (III-Wetted)	**Species Name**	**Management Options (TIPS Factsheets)**
	(*Phragmites sp.)*	flooding and tilling have been successful in some wetland applications, multiple years of treatment is required. Hand pulling is not recommended as root fragments will spread, unless it is a very small patch. Herbicide application has had success. Use of shade mats or heavy sheets of plastic have been proven to eradicate small patches.
II-V	Canada thistle (*Cirsisum arvense*)	When controlling near streams, or ditch lines, prevent the movement of plant parts downstream. Mowing is effective at the rosette stage (early spring), regular mowing and tillage (if possible) can help reduce energy stores within the plant but will not likely kill the plant.
II-III	Purple loosestrife (*Lythrum salicaria*)	Small infestations can be removed by hand pulling or digging; however, all plant parts should be removed. Removal should be applied before seed set, mechanical control for large infestations has been unsuccessful.
II-III	Yellow flag iris (*Iris pseudacorus*)	Hand pulling, digging or cutting is risky due to spread by root fragmentation. Laying heavy rubber matting as a benthic barrier to smother the plants causes the plants to respire without photosynthesis, exhausting the plant's energy reserves. Treatments of around 70 days can be effective in eradication attempts.

Disposal of Invasive Plants
If invasive weeds establish and need to be removed, dispose of the plants properly to discourage spread to other locations. The local landfill, regional district, or invasive species regional committee will have specific disposal locations. Add seeds, flowers and all other plant parts to a double black plastic bag.

Additional information on control methods is available in species-specific T.I.P.S, from a regional invasive plant committee coordinator, or online at the FLRNO Invasive Plant Program. The regional invasive plant committees (OASISS and BC Invasives and the regional district Weed Control Officers (weeds@rdno.ca; weeds@cord.bc.ca; OASISS@shaw.ca) have many resources information specific to species control in the Okanagan, and can be contacted for specific information.

8.3 EFFECTIVENESS MONITORING AND INSPECTION

Effectiveness monitoring should be completed to determine if the CW is operating as designed, and should recommend design alterations if performance objectives are not being met. Monitoring should be completed annually at a minimum, and more frequently after construction to ensure the CW is functioning (i.e., twice a year for the first three years). Specific monitoring schedule requirements should be determined through consultation with local government. Water quality parameters and wetland function targets (i.e., survival of planted vegetation, weed invasion, wildlife use of wildlife enhancements) should be determined and included in the Operation and Maintenance Plan (Section 8.1). Aspects that can be considered in the effectiveness monitoring program for wildlife should relate back to goals and objectives for wildlife enhancements that were incorporated at the design stage. Monitoring could include:

- Biodiversity measurements (vegetation species, density, cover, height, health, natural establishment, survival);
- Wildlife use (species, timeline occurrence, number);
- Aquatic vegetation colonization;
- Nutrient cycling (uptake, transformation and removal); and
- Invertebrate and insect presence, species and abundance.

Inspections are essential to effective operation of the CW. Regular visual inspections should be conducted as per the schedule in the Operations and Maintenance Plan. Inspection and maintenance checklists should be developed and included as part of the plan. Checklists could include inlet/outlet control structures, catch basins, manholes, piping/drain systems, monitoring systems, roads, access ramps, vegetation, irrigation, fencing and amenities. Inspections should occur after heavy rainfall events to assess the state of wetland function and to observe any damages to, or clogging of, inlet/outlet components.

8.4 PERIODIC CLEAN-OUT AND REJUVENATION

Constructed wetlands may periodically require partial or total rejuvenation if treatment is compromised by the accumulation of the target contaminants in the wetland. Rejuvenation involves the removal and replacement of the wetland plants and sediment. The accumulation of sediment near the inlet is the most common example of this type of challenge, which can occur if the influent is carrying high TSS concentrations and the flow velocity is effectively reduced by the emergent plants. Therefore, a forebay located before the wetland cell is important for CWs where TSS removal is a priority. If sediment does build up in the wetland, the HRT will be reduced and the flow hydraulics will be altered. In most cases, only the area near the inlet will be affected, and the clean-out and re-planting would only affect wetland performance slightly, and for a short period.

Other contaminants, such as phosphorus and heavy metals, can accumulate to the point where more significant removal and replacement of plant matter and sediment is needed. This is because wetland sediments (including the organic matter contributed from plants), have limited capacity to store materials that are not broken down to either a gaseous form (e.g. nitrogen denitrification to N_2) or to simple compounds like water and carbon dioxide. In the case of phosphorus, the dissolved phosphorus taken up by plants tends to be returned to the water as the plant matter decomposes, so the phosphorus treatment effect may be short-lived. As such, CWs may not be the best option in cases where phosphorus removal is a priority. Figure 8-1 shows how the phosphorus concentration in the outflow drifts up to match the inflow concentration, and when clean-out would need to be considered.

Wetlands also tend to act as a sink for metals, as metals are removed by a combination of sedimentation (for metals bound to organic or mineral particles), chemical precipitation, and plant uptake with subsequent deposition with the bottom sediment. Eventually, the metals may become toxic to the plants within the wetland, exceed regulatory standards for sediments, or be released from the wetland at undesirable levels. However, the system's effective life could be decades or more (unlike phosphorus). Metal retention should be predicted during detailed design, but monitoring (e.g. sediment sampling every 2-3 years) would confirm when rejuvenation is needed. One design approach is to build in redundancy, such as a recent City of Nanaimo project where parallel wetland cells were built to enable one to "rest" while the other is active, and enable one to be cleaned out and re-planted without compromising overall performance.

After sediments and plants have been cleaned out of a CW cell, they should be stored temporarily nearby and allowed to drain, directing the water back to the CW. In most cases the dewatered material can be taken to a municipal Recycling and Disposal Facility or landfill for disposal. Wetland owners should contact the solid waste managers in the municipality to be sure that the landfill will accept the material for disposal or composting. Testing the material may be required to determine that it meets permitted limits for soil/sediment disposal at the facility.

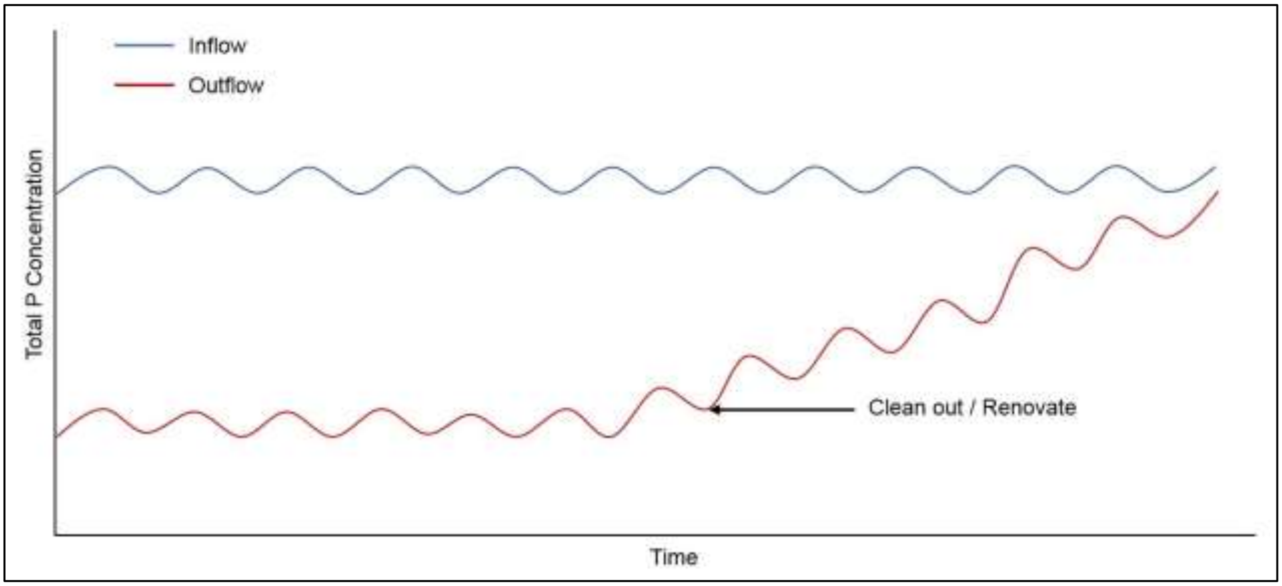


Figure 8-1
Sketch showing inflow vs. outflow Total phosphorus concentrations and CW renovation timing

9 References

Biebighauser. Thomas.R. 2001. Wetland Restoration and Construction. A technical guide. ISBN: 978-0-9834558-1-3

British Columbia Conservation Data Centre (CDC). 2017. BC Species and Ecosystems Explorer. Ministry of Environment, Victoria, BC. Online at: https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/conservation-data-centre/explore-cdc-data/species-and-ecosystems-explorer

Golder Associates (Golder) and Summit Environmental Consultants Inc. (Summit). 2009. Groundwater Objectives 2 and 3 – Phase 2 Okanagan Water Supply and Demand Project. Prepared for the Okanagan Basin Water Board. July 2009.

Hamilton, H., P. Nix, and A. Sobolewski. 1993. An overview of constructed wetlands as alternatives to conventional waste treatment systems. Water Poll. Res. J. Canada. 28(3), 529-548.

Hunt, W. F., M. R. Burchell, J. D. Wright, and K. L. Bass. (AGW-588-12). 2007. Online: http://www.bae.ncsu.edu/stormwa-ter/PublicationFiles/WetlandDesignUpdate2007.pdf

Kadlec, R.H., and R.L. Knight. 1996. Treatment Wetlands. CRC Press. Boca Raton, FL.

MacKenzie, W.H., and J.R. Moran. 2004. Wetlands of British Columbia: a guide to identification. Res. Br., B.C. Min. For., Victoria, B.C. Land Manage. Handbook No. 52. Online at: http://www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh52.htm

Ministry of Environment (MOE). 2013. Guidance for the Derivation and Application of Water Quality Objectives in British Columbia. Water Protection and Sustainability Branch, Environmental Sustainability and Strategic Policy Division. Victoria. Online at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-objectives/wqo_proc_guidance.pdf

Ministry of Water, Land and Air Protection (MWLAP). 2002. Stormwater Planning: A Guidebook for British Columbia.

National Wetlands Working Group. 1997. The Canadian Wetland Classification System. 2nd Edition. Edited by B.G. Warner and C.D.A. Rube. Published by the Wetlands Research Centre, University of Waterloo.

Patterson A., D. Drieschner, R. Wagner, and K. Hawes. 2014. Okanagan Wetlands Strategy: Phase 1: Outreach, Data Collection, Prioritization, and Mapping. Prepared By: Ecoscape Environmental Consultants Ltd. Prepared For: Okanagan Basin Water Board. Ecoscape File No. 13-1159.

Summit Environmental Consultants Inc. (Summit). 2009. Surface Water Hydrology and Hydrologic Modelling Study "State of the Basin" Report. Prepared for the Okanagan Basin Water Board as part of the Phase 2 Okanagan Water Supply and Demand Project.

United States Environmental Protection Agency (US EPA). 2017. Constructed Wetlands (web site). Online at: https://www.epa.gov/wetlands/constructed-wetlands.

Water Sustainability Act. S.B.C. 2014, c. 15. Online at: http://www.bclaws.ca/civix/document/id/lc/statreg/14015

Watson, J.T., S. Reed, R. Kadlec, R. Knight and A. Whitehouse. 1989. Performance expectations and loading rates for constructed wetlands. In: Hammer, D.A. (ed.) Constructed wetlands for wastewater treatment. Municipal, Industrial, Agricultural. Lewis Publishers. Chelsea, Michigan.

Appendix A - Questionnaire

Appendix B – Guidance Document References

Alberta Environment. 2000. “Guidelines for the Approval and Design of Natural and Constructed Treatment Wetlands for Water Quality Improvement.”

Alberta Environmental Protection. 1999. “Stormwater Management Guidelines for the Province of Alberta.”

Alberta Government. 2014. “General Design Guidelines for a Constructed ‘Habitat’ Wetland – Grasslands Natural Region of Alberta.”

Alberta Government. 2013. *Standards and Guidelines for Municipal Waterworks , Wastewater and Storm Drainage Systems - Part 5: Stormwater Management Guidelines*.

BC Ministry of Forests Lands and Natural Resource Operations. 2015. “Guide to Identification of Low-Elevation Wetlands in the Okanagan Valley Using Primary Indicators.”

BC Ministry of Sustainable Resource Management and Ministry of Water Land and Air Protection. 2004. “Wetlands of the Southern Interior Valleys.”

Bendoricchio, Giuseppe, Luigi Dal Cin, and Jesper Persson. 2000. “Guidelines for Free Water Surface Wetland Design.” *EcoSys Bd* 8: 51–91.

Buckland-Nicks, A. 2016. “Innovative Stormwater Model.”

CH2M Hill. 2014. “Wetland Design Guidelines.”

City of Calgary. 2009. “Principles for Stormwater Wetlands Management in the City of Calgary.”

City of Calgary Water Resources. 2011. “Stormwater Management & Design Manual.”

Ecoscape Environmental Consultants Ltd. 2014. “Okanagan Wetlands Strategy: Phase 1 - Outreach, Data Collection, Prioritization, and Mapping.”

Eugene. 2014. “Stormwater Management Manual.”

FP Innovations, and Ducks Unlimited Canada. 2016. *Resource Roads and Wetlands: A Guide for Planning, Construction and Maintenance*.

Halabisky, Meghan, Se-Yeun Lee, Sonia. A Hall, and Mike Rule. 2017. “Can We Conserve Wetlands under a Changing Climate? Mapping Wetland Hydrology across an Ecoregion and Developing Climate Adaptation Recommendations.”

Hansen, Gail, and Shangchun Hu. n.d. “Guide to Selection and Installation of Stormwater Pond Plants.”

Humboldt State University - Environmental Resources Engineering. 1999. “Free Water Surface Wetlands for Wastewater Treatment: A Technology A Ssessment.” http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Free+water+surface+Wetlands+for+waste+water+treatment+a+technology+assessment#4.

Interagency Workgroup on Constructed Wetlands. 2000. “Guiding Principles for Constructed Treatment Wetlands: Providing for Water Quality and Wildlife Habitat.” http://www.epa.gov/owow/wetlands/pdf/constructed.pdf.

Jurries, D. 2003. “Biofilters (Bioswales, Vegetative Buffers, & Constructed Wetlands) for Storm Water Discharge Pollution Removal.” http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Biofilters+(Bioswales,+Vegetative+Buffers,+&+Constructed+Wetlands)+for+Storm+Water+Discharge+Pollution+Removal#0.

Lorion, Renee. 2001. “Constructed Wetlands: Passive Systems for Wastewater Treatment.” papers2://publication/uuid/083F2A39-72D7-4AE1-91BA-023157F48557.

Mackenzie, William, and Jennifer Moran. 2004. *Wetlands of British Columbia: A Guide to Identification*.

Mark E. Taylor & Associates. 1992. “Constructed Wetlands for Stormwater Management: An Annotated Bibliography.”

Metro Vancouver. 2017. “Region-Wide Baseline for On-Site Stormwater Management.”

Mohamed, Haga Osman, and Hanan Osman Ali. 2014. “Efficiency of Constructed Wetlands in Arid Regions.” *International Journal of Engineering Innovation & Research* 3 (5): 597–603.

New Jersey Department of Environmental Protection - Division of Watershed Management. 2004. “New Jersey Stormwater Best Management Practices Manual - Standard for Constructed Stormwater Wetlands.”

Okanagan Basin Water Board. 2015. “Underground Stormwater Infiltration Model Bylaw.”

Okanagan Basin Water Board, and Insight Environmental Consulting. 2011. “Slow It. Spread It. Sink It. An Okanagan Homeowner’s Guide to Using Rain as a Resource.”

Ontario Ministry of the Environment. 2003. “Stormwater Management Planning and Design Manual.” https://www.ontario.ca/document/stormwater-management-planning-and-design-manual-0.

Pierce, Gary J, and Mallory N Gilbert. 2015. “Wetland Mitigation: Planning Hydrology, Vegetation, and Soils for Constructed Wetlands.”

Pries, John H, Robert E Borer, Ronald A Clarke, and Robert L Knight. 1996. “Performance and Design Considerations of Treatment Wetland Systems for Livestock Wastewater Management in Cold Climate Regions in Southern Canada and the Northern United States.” *Proceedings of the 2nd National Workshop on Constructed Wetlands for Animal Waste Management*, 15–18.

Ross, Lisette. 2013. “Presentation - Naturalized Storm Water Ponds for Storm Water and Water Quality Management.”

Stephens, Kim, Patrick Graham, and David Reid. 2002. “A Guidebook for British Columbia - Stormwater Planning.”

Syilx People. 2014. “Syilx Nation Siw □k^{w} Declaration.”

The Interstate Technology & Regulatory Council Wetlands Team. 2003. “Technical and Regulatory Guidance Document for Constructed Treatment Wetlands.”

Tousignant, Eric, Oliver Frankhauser, and Sarah Hurd. 1999. “Guidance Manual for the Design, Construction and Operations of Constructed Wetlands for Rural Applications in Ontario.” http://agrienvarchive.ca/bioenergy/download/wetlands_manual.pdf.

United Nations University Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES). 2016. “Safe Use of Wastewater in Agriculture: Good Practice Examples.”

United States Environmental Protection Agency. 2016. “A Handbook of Constructed Wetlands: A Guide to Creating Wetlands for Agricultural Wastewater, Domestic Wastewater, Coal Mine Drainage, and Stormwater, in the Mid-Atlantic Region.” https://www.epa.gov/sites/production/files/2015-10/documents/constructed-wetlands-handbook.pdf.

United States Environmental Protection Agency. 1993. “Constructed Wetlands for Wastewater Treatment and Wildlife Habitat.”

United States Environmental Protection Agency. 2000. “Constructed Wetlands Treatment of Municipal Wastewaters.” papers2://publication/uuid/CFC47E02-1FAE-45C4-B299-84D293CA2339.

United States Environmental Protection Agency. 2004. “Constructed Treatment Wetlands.”

United States Environmental Protection Agency. 2009. “Stormwater Wet Pond and Wetland Management Guidebook.”

Urban Systems. 2012. “Integrated Stormwater Management Plans - Lessons Learned to 2011.”

Walsh, Christopher J, Derek B Booth, Matthew J Burns, Tim D Fletcher, Rebecca L Hale, Lan N Hoang, Grant Livingston, Megan A Rippy, Allison H Roy, and Mateo Scoggins. 2016. “Principles for Urban Stormwater Management to Protect Stream Ecosystems.” *Journal of Freshwater Science* 35 (March): 1–13. doi:10.1086/685284.

Wetland Stewardship Partnership. 2009. “Wetland Ways - Wetland Enhancement and Restoration.”

Zhang, Yue. 2012. “Design of a Constructed Wetland for Wastewater Treatment and Reuse in Mount Pleasant , Utah.” *Master Thesis*. http://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1232&context=gradreports.

Zheng, Youbin, Siobhan Dunets, and Eric Rozema. 2013. “Greenhouse and Nursery Water Treatment Information System - Constructed Wetlands.” http://www.natsys-inc.com/resources/about-constructed-wetlands/#.

Appendix C - Wetland Invasive Species Table

Wetland Zone	Species Name (photo credits @ RDNO, USDA, AE, Illustrated Flora of BC, and ISCBC)	Characteristics	Spread	Threats
Aquatic (Zone I)	Zebra (*Dreissena polymorpha*) and quagga mussels (*Dreissena rostriformis bugensis*) 	Small freshwater mollusk with zigzag markings	Adult mussels can attach themselves to boat hulls, trailers, motors, vegetation and equipment. Immature mussels (“veligers”) can float undetected in water in bait buckets, fishing gear, live-wells, pumps and bilges.	No known occurrences of these invasive mussels in British Columbia; however, the BC government is taking action to prevent this species from being introduced to BC. Rapidly colonize hard surfaces, subsequently clogging water intake structures, impacting recreation, altering food webs, and affecting water quality. There is a high risk of invasive mussels not only surviving in some parts of Okanagan Lake, but there is a high potential for massive infestations.
Aquatic (Zone I)	Eurasian watermilfoil (*Myriophyllum spicatum*) 	Rapid growth perennial that grows from a fibrous root system.	Plants form thick mats on the surface of the water. Floating plant fragments can spread by water currents and root in new locations.	A non-native invasive plant, first observed in BC in 1970 in Okanagan Lake. Plants can reach the water surface from depths exceeding 5 m. Thick mats of plants can impede light penetration to underwater plants and animals, hinder boat traffic, clog intake pipes of boats, cause a danger to swimmers, and damage water intake structures. Plants are difficult to contain. Management strategies to address infestations are extremely costly.

Wetland Zone	Species Name (photo credits @ RDNO, USDA, AE, Illustrated Flora of BC, and ISCBC)	Characteristics	Spread	Threats
Transition (Zones III and IV)	Purple loosestrife (*Lythrum salicaria*) 	Shrub-like perennial, up to 3 m tall, purple-pink dense clustered flowers	By seed; a single plant can produce 300,000 seeds, distributed by water	Is a wetland perennial that out-competes most native species in wetland ecosystems. Dense stands reduce plant and animal diversity, including dominating the area to the point of creating a monoculture. In large infestations, purple loosestrife can block water flow and lead to a reduced productivity in agricultural crops.
Aquatic (Zones II and III)	Yellow flag iris (*Iris pseudacorus*) 	Flat sword shaped leaves, yellow flower, three septals curving down, 3 petals pointing up.	By root fragments that form new plants; up to several hundred plants may be connected underwater	Chokes out all other aquatic native wetland plants (e.g., cattails and sedges), does not provide wildlife habitat nesting value, and decreases biodiversity.

Wetland Zone	Species Name (photo credits @ RDNO, USDA, AE, Illustrated Flora of BC, and ISCBC)	Characteristics	Spread	Threats
Lowland (Zone IV)	Japanese knotweed (*Fallopia japonica*), Giant knotweed (*Fallopia sachalenensis*), Bohemian knotweed (*Fallopia x bohe-mica*)  Japanese Knotweed © Illustrated Flora of BC	Perennial, predominantly heart- to triangular-shaped. Green stems, or canes, are hollow with upright, and bam-boo-like with reddish-brown/red speckles. Stems are generally 1-5 m in height and grow in large, dense thickets.	Knotweed can easily be spread from existing populations by transporting small pieces of stem or root fragments to another location.	All knotweeds grow rapidly and form monocultures that limit resources for native plants and wildlife. Its ability to out-compete native species threatens biodiversity and ecosystem function. Knotweed rhizomes and stems can push through asphalt, concrete foundations, retaining walls, septic systems, and drains causing significant damage and potential loss of property values[6,7]. Knotweed threatens biodiversity and disrupts the food chain by reducing available habitat and increasing soil erosion.
Lowland (Zone IV)	Common tansy (*Tanacetum vulgar*)	Perennial, clumps of smoot stems, yellow button flowers in a cluster at the	By seeds and root stalks	Outcompetes native vegetation and reduces biodiversity.

[6] Ministry of Forests, Lands and Natural Resource Operations. 2016. Herbicide Guidelines for Control of Knotweed Species on Crown Lands. June 2016. https://www.for.gov.bc.ca/hra/Plants/management.htm
[7] Invasive Species Council of British Columbia. 2016. Knotweeds TIPS. July 2016. http://bcinvasives.ca/documents/Knotweeds_TIPS_Final_07_22_2016.pdf

Wetland Zone	Species Name (photo credits @ RDNO, USDA, AE, Illustrated Flora of BC, and ISCBC)	Characteristics	Spread	Threats
		top of the plant		
Lowland (Zones III and IV)	Reed canarygrass (*Phalaris arundinacea* L.) 	Perennial grass up to 2 m tall	By seeds and root rhizome fragments	Commonly forms extensive monoculture stands along the margins of lakes and streams and in wet open areas. Out-competes all other lowland vegetation species and reduces biodiversity.
Lowland (Zone III to V)	Canada thistle	Creeping rooted perennial up to 2 m tall	By feathery seeds, distributed by wind	Establishes quickly, very invasive in the Okanagan, and can discourage the establishment of other native species.

Wetland Zone	Species Name (photo credits @ RDNO, USDA, AE, Illustrated Flora of BC, and ISCBC)	Characteristics	Spread	Threats
	(*Cirsisum arvense*) 			
Upland to lowland (Zones IV to V)	Scotch thistle (*Onopordum acanthuim*) 	Woody and branched with spiny wings, up to 3 m tall	By seeds, viable in soil up to 30+ years	Very tall growing hardy thistle, spreads rapidly, takes over grasslands and disturbed areas within 3-5 years. Decreases forage value, aesthetically not pleasing, outcompetes native species. Can take over disturbed upland wetlands areas in a short space of time. Large copses of thistle make is hard to navigate for wildlife and people.
Upland to lowland	Hound's tongue (*Cynoglossum officialle*)	Tap-rooted biennial, grows	By seeds, attached to clothing and	Contains toxic alkaloids that can cause liver damage to livestock, aesthetically unpopular as

Wetland Zone	Species Name (photo credits @ RDNO, USDA, AE, Illustrated Flora of BC, and ISCBC)	Characteristics	Spread	Threats
(Zones IV to V)		up to 1.2 m tall, reddish-purple flowers, produces seeds covered with Velcro-like hairs	animals	seeds get stuck in pets, footwear and clothing, nuisance for maintenance workers and machinery, high risk of spreading due to sticky seeds.
Upland (Zone V)	Sulphur cinquefoil (*Potentilla recta*) 	Perennial, yellow five septal flowers, palmate leaves, 5-7 leaflets	By seed; produces over 1600 seeds per plant	Out-competes native grassland plants, reduces biodiversity and increases soil erosion.
Information Credits: Regional District of North Okanagan (RDNO), Invasive Species Council of BC (ISCBC), E-Flora and E-Fauna				

Appendix D - Funding Sources

Funding Source	Funding Information	Qualifying Bodies
Provincial		
Ministry of Municipal Affairs and Housing Infrastructure Planning Grant Program	Grants up to $10,000 are available to help improve or develop long-term comprehensive plans that include: capital asset management plans, integrated stormwater management plans, water master plans and liquid waste management plans. Grants can be used for a range of activities related to assessing the technical, environmental and/or economic feasibility of municipal infrastructure projects.	Local government
Ministry of Municipal Affairs and Housing Asset Management Planning Program	The intent of the program is to assist local governments in delivering sustainable services by extending and deepening asset management practices within their organizations. Since 2015, 142 grants have been awarded to 100 local governments.	Local government
Union of British Columbia Municipalities Community Emergency Preparedness Fund	The Community Emergency Preparedness Fund (CEPF) is a suite of funding programs intended to enhance the resiliency of local governments and their residents in responding to emergencies. Funding is provided by the Province of BC and is administered by UBCM. CEPF was announced as part of an $80 million announcement from the Ministry of Transportation & Infrastructure.	Local government
Habitat Conservation Trust Foundation Multiple Grants	The Habitat Conservation Trust Foundation has provided over $160 million dollars in grant money to more than 2,500 conservation projects in BC.	Various

Funding Source	Funding Information	Qualifying Bodies
	They fund a variety of conservation work including: •Projects that restore, maintain, or enhance native freshwater fish and wildlife populations and habitats; •Environmental education and stewardship projects; •Projects that acquire land or interests in land to secure the value of these areas for conservation purposes.	
Real Estate Foundation Grants Grant Program	**Built Environment Sustainability** The built environment encompasses the buildings and infrastructure that support where and how people live. By funding initiatives focused on better land use policies, development regulations and building practices that respond to both human and ecological needs, the Real Estate Foundation contributes to more sustainable communities. **Freshwater Sustainability** Interest in projects such as new approaches in land use planning, policy and regulation; mapping studies and applied research that contributes to the health of freshwater systems.	Non-Profit Organizations
Federal		
Federation of Canadian Municipalities Municipal Asset Management Program	The Municipal Asset Management Program is a five-year, $50-million program that will support Canadian cities and communities to make informed decisions about infrastructure, such as the planning and construction of roads, recreational facilities, and water and wastewater systems.	Local government

Funding Source	Funding Information	Qualifying Bodies
Federation of Canadian Municipalities Municipalities for Climate Innovation Program	The Municipalities for Climate Innovation Program provides funding, training and resources to help municipalities adapt to the impacts of climate change and reduce greenhouse gas (GHG) emissions.	Local government
Federation of Canadian Municipalities Green Municipal Fund	The Green Municipal Fund provides funding for plans, feasibility studies, pilot projects and capital projects. Stormwater quality projects must aim to remove contaminants such as total suspended solids (TSS) from runoff leaving a site. A project to improve stormwater quality must aim to remove 80% of TSS from runoff leaving a site. For neighbourhood stormwater management projects, which may involve multiple properties or sites, a project must aim to remove 60% of TSS from runoff leaving a site.	Local government
Environment Canada Habitat Stewardship Program (HSP) for Species at Risk	The overall goals of the HSP are to "contribute to the recovery of endangered, threatened, and other species at risk, and to prevent other species from becoming a conservation concern, by engaging Canadians from all walks of life in conservation actions to benefit wildlife." The HSP allocates approximately $12.2 million per year to projects that both conserve and protect species at risk and their habitats and to those that prevent other species from becoming a conservation concern.	Various
Environment Canada Aboriginal Fund for Species at Risk	The Aboriginal Fund for Species at Risk plays an important role in the recovery of species at risk on Indigenous lands by encouraging	Indigenous associations/ organizations

Funding Source	Funding Information	Qualifying Bodies
	meaningful involvement of Indigenous Peoples and communities in the implementation of the *Species at Risk Act*. Funds are allocated to projects that protect habitat and contribute to the recovery of species at risk, as well as to projects that prevent other species from becoming a conservation concern.	
Environment Canada National Wetland Conservation Fund (NWCF)	The NWCF supports on-the-ground activities to restore and enhance wetlands in Canada. Some objectives of the fund are to: •Restore degraded or lost wetlands on working and settled landscapes to achieve a net gain in wetland habitat area; •Enhance the ecological functions of existing degraded wetlands; and •Encourage the stewardship of Canada's wetlands by industry and the stewardship and enjoyment of wetlands by the public.	Various
Environment Canada Environmental Damages Fund (EDF)	The EDF is a specified-purpose account to manage funds received as compensation for environmental damage. The EDF primarily supports the restoration of natural resources and environment, and wildlife conservation projects in the same geographic area where the damage originally occurred. The EDF also supports research and development on environmental damage assessment and restoration, and education on pollution prevention and the restoration of natural resources.	Various
Environment Canada	The EcoAction Community Funding	Various

Funding Source	Funding Information	Qualifying Bodies
EcoAction Community Funding Program	Program funds projects across Canada to encourage Canadians to take action to address clean air, clean water, climate change and nature issues, and to build the capacity of communities to sustain these activities into the future. Clean water eligible projects focus on reducing or diverting substances that negatively affect water quality or focus on water-use efficiency and conservation (e.g., reduction of nutrient load, contaminants or toxics in waterbodies).	