Re-naturalizing the Norquay Channel:
A Strategy to Improve Water Quality

by

Benjamin Boswick

A Practicum submitted to the Faculty of Graduate Studies of
The University of Manitoba
in partial fulfillment of the requirements of the degree of

MASTER OF LANDSCAPE ARCHITECTURE

Department of Landscape Architecture
University of Manitoba
Winnipeg

Re-naturalizing the Norquay Channel

A Strategy to Improve Water Quality

Fig 1. A naturalized Norquay Channel

Table of Contents

Fig 2. View of the Norquay Channel looking east from Road 15 West bridge crossing

Re-naturalizing the Norquay Channel

A Strategy to Improve Water Quality

by Benjamin Boswick

Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirement for the degree of

MASTER OF LANDSCAPE ARCHITECTURE

Department of Landscape Architecture
University of Manitoba
Winnipeg, Manitoba, Canada

Land Acknowledgement

This practicum project was researched and proposed on Treaty One territories, the ancestral land and water of the Anishinaabeg, Anishininewuk, Dakota Oyate, Denesuline and Nehethowuk Nations, and the homeland of the Red River Métis.

I respect the Treaties that were made on these territories, I acknowledge the harms and mistakes of the past, and I dedicate myself to move forward in partnership with Indigenous communities in a spirit of reconciliation and collaboration.

Abstract

Southern Manitoba used to contain multiple marsh and bog wetlands. The wetlands were drained during the early 20th Century to increase the amount of arable land and attract more people to the province. These wetlands provided critical ecological functions such as flood mitigation, water filtration, and increased biodiversity. Since artificial waterways drained the wetlands, the surface water quality of the receiving waterbodies has suffered, with Lake Winnipeg taking the brunt of it. Two research questions drive this practicum: how can we, as landscape architects, integrate ecologically functioning wetlands into major tributaries of the Red and Assiniboine Rivers to improve their water quality? Given its physio-geographical specifics, what form might these take within the Red River Valley?

In response to the prior questions, a constructed wetland design was proposed along a portion of the Norquay Channel. The agricultural landscape of the Red River Valley creates different various constraints for the design. The design includes important characteristics of natural wetlands, such as gentle slopes to facilitate the growth of wetland vegetation and a sediment deposition pond, all while working within a compact space to minimize the amount of agricultural land affected. Since the impact of the individual design site on improving Lake Winnipeg's water quality would be limited, a more significant regional intervention is needed and proposed. Other fourth and fifth-order waterways, similar to that of the Norquay Channel, are proposed for similar interventions. Complete data from 2022 for surface water quality and water flow are used to estimate the impact of the individual design site on the nutrient loading of subsequent waterways. Two leading nutrients, nitrogen and phosphorus, could potentially be reduced within the wetlands by 46 to 56% and 70 to 89%, respectively.

Fig 3. View of the Norquay Channel looking west from the Road 18 West bridge crossing

Acknowledgements

Brenda Brown

I would like to thank my Academic Advisor, Brenda Brown, for all of her support over the last four and a half years. Thank you for being able to help me hold course and offering integral guidance and suggestions along the way.

Kamni Gill

I would like to thank my Internal Advisor, Kamni Gill, for her enthusiasm and insight during this process and for always reminding me to strive for clarity and precision in my design work and writing.

Daniel Rheault

I would like to thank my External Advisor, Daniel Rheault, for his input early on in the project and for his knowledge, suggestions, and encouragement throughout the design and writing process.

To My Parents

I would like to thank my parents, Rob and Adele Boswick, for their never-ending love and encouragement right from the start, and for always being there to help me with the most unique challenges. I could never thank you enough for everything you have given me over the years, I hope I can continue to make you proud.

To My Partner

I would like to thank my partner, Maria Manuel, for her continuous love and support during my work on this project. Thank you for picking me up when I was down and providing your presence when I needed you the most. Mahal kita, Я тебе кохаю.

To My Peers

I would like to thank my peers, all of you, for your friendship over the years and for always being willing to have a chat, go on a walk, and share your ideas with me. The real achievement were the friends we made along the way.

Fig 4. Drone aerial of the Road 15 West bridge crossing on the Norquay Channel before the channel narrows

Purpose

Wetlands are necessary to maintain the health of landscapes and water bodies. Wetlands, especially in grassland prairies, typically referred to as wet prairies, are one of the most endangered landscapes in the world. Not only do they mitigate flooding in prairie landscapes, but they also act as carbon sinks. A wet prairie landscape used to dominate in southeast Manitoba, but now agriculture dominates. For this reason, I have worked to design a landscape in which wetlands, grasslands, and agriculture coexist. My project is aimed at creating wetlands alongside man-made drainage, to improve water quality and limit the amount of nutrients entering downstream waterways.

Research Question

Two research questions drive this practicum: how can we, as landscape architects, integrate ecologically functioning wetlands into major tributaries of the Red and Assiniboine Rivers to improve their water quality? What form might these wetlands take within the Red River Valley, given its physio-geographical specifics?

This Document

Chapter One includes an overview of common wetland typologies in Manitoba, their associated ecosystem services, and Manitoba's Prairie Wetland Classification Guide. Additionally, information on three typical constructed wetland methods is provided. Chapter Two includes an overview of water quality guidelines in Manitoba and two common water quality concerns experienced in Manitoba. The project area is situated within the greater watershed systems that cover most of Manitoba and the wetlands that once covered over 9,000 KM2 in the Red River Valley. Information on the drainage of these wetlands and their relationship with current agricultural land is provided. Chapter Three includes an overview of the history of the land around the Norquay Channel. Observations from my seasonal site visits to the Norquay Channel in 2023 are provided alongside water quality data obtained in May 2023 for the channel. Existing plant species observed on the site are provided. Chapter Four includes the design objectives, considerations, and precedents used in formulating a design. My preliminary design work is provided, including sketches, modelling, and topographic drawings. The conceptual and final design plans are provided in addition to technical drawings and renderings of the proposed site design. Finally, Chapter Five reviews how the design objectives were addressed and provides an estimation of the impact on water quality using a complete dataset from 2022. The potential local and regional interventions are discussed as well.

Fig 5. Bridge crossing at Road 18 West on the Norquay Channel

Page Left Blank Intentionally

Page Left Blank Intentionally

Chapter One

Introduction to Water, Wetlands, and the Red River Valley

This chapter provides background information on wetlands in Manitoba's Red River Valley and definitions of key terms found throughout this document. It also provides an account of this project's purpose and the research questions that drove it. Canada's wetland classification system and the different types of constructed wetlands are explained as are the types of wetland ecosystems and their ecosystem services.

Fig 6. Drone photo of the west-most crossing of the Norquay Channel

Definitions

Key terms used throughout the document:

Wetlands are defined by the US Environmental Protection Agency as areas where water covers the surface, or is present near the surface, during affected times of the year. There are two categories of wetlands, tidal/coastal and inland/non-tidal, the latter of which is what we have in Manitoba.[1]

Constructed Wetlands are defined by the US Environmental Protection Agency as human-constructed treatment systems that utilize wetland vegetation, soils, and associated wetland ecosystem processes to improve water quality.[2]

Drainage defined by the Province of Manitoba Environment and Climate Change department as the natural or constructed method of transferring surface and/or subsurface water from one area to another, typically to allow for optimal agricultural production, rural or urban development and protection of infrastructure such as roads and railways.[3]

A **Drainage District** refers to a political designated area of land that corresponds to natural or constructed hydrological systems of drainage, typically involving varying sizes of drainage channels based on Strahler's Stream Ordering System.[4]

A **Watershed** is defined by Freshwater Inflows as an area of land influenced by topography that drains rainfall and/or snowmelt into various waterways eventually draining to a point at a larger water body.[5]

Surface Water Quality is determined by collecting data from waterways in a specific region, then comparing it against an ideal or standardized measurement for said region. This comparison allows us to determine the waterway's health or quality. Manitoba's water quality guidelines will be explained further in this chapter.

Key terms used to describe components of the Norquay Channel are defined in the following section. These terms are:

Dike – a constructed earthen artificial bank to contain or control water; a raised causeway.[6]

Berm – a shelf or ledge that is typically found at the top or bottom of a slope, such as the transition between a dike and waterway.[7]

Channel – a bed where an artificial or natural stream of water flows.[8]

Ditch – a narrow excavation dug into the earth used for drainage, typically found at the roadside.[9]

Culvert – a transverse drain, typically existing underneath a bridge of some sort to allow for the flow of water.[10]

Fig 7. Current vegetation at the edge of the Norquay Channel

Wetland Ecosystem Services

Wetlands serve many functions in the landscape at different scales. Wetland ecosystem services are environmental processes that help regulate and sustain biotic life.[11] They may include flood mitigation and biodiversity support at the regional scale, and water filtration and carbon sequestration at the microscopic scale.

Biodiversity Support

Wetlands can vary in the amount of water they contain and, therefore, can vary in the number of plant and animal species they support. This variation makes wetlands one of the more biologically diverse ecosystems in the landscape. They provide habitats for waterfowl, aquatic animals, and amphibious animals. By removing wetlands, we lose that diversity in our landscape, and those species of animals lose a habitat.

Carbon Sequestration

Wetlands help regulate climate by acting as large sinks for atmospheric gasses such as carbon. Carbon is absorbed by the open-water pools and vegetation found within certain wetlands and this helps cool the surrounding atmosphere.[12] By removing wetlands, the sequestered carbon re-enters the atmosphere and contributes to climatic instability.

Flood Mitigation

Wetlands act as natural sponges, retaining water during flood events and slowly releasing it afterwards. As the water level returns to normal, the wetlands filter out any particulate matter picked up by the flood waters. Flood water may overwhelm downstream waterways and damage infrastructure and settlements when wetlands are removed.

Water Filtration

Wetlands help purify and filter water in a few different ways. Plant species within wetlands tend to extract dissolved nutrients such as phosphorus and nitrogen as part of the nutrient cycle. When water is retained in wetlands, suspended particles can settle and become part of the soil layer, which also helps promote plant growth.[13] Water that enters the groundwater system is filtered by the base material in wetlands. When wetlands are removed, nutrients the plants would have otherwise taken up can continue downstream, contributing to effects such as eutrophication.

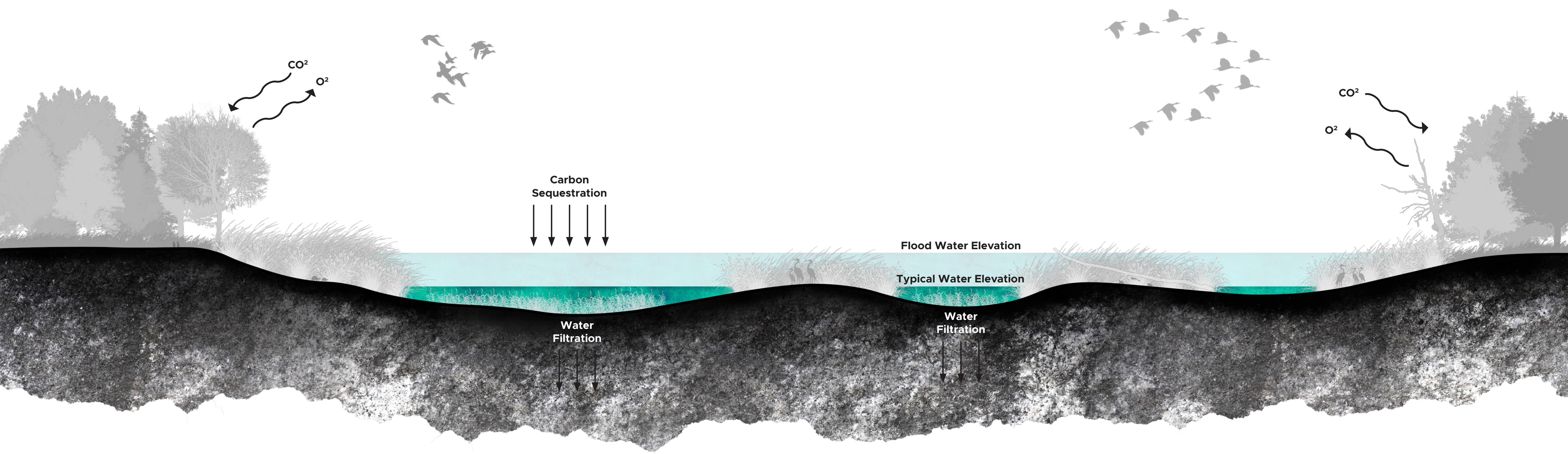


Fig 8. Wetland Ecosystem Services Abstract Section

Typical Wetland Ecosystems in Southern Manitoba

Typical wetland ecosystems in southern Manitoba can vary in form and vegetation based on topography, water source, and soil base. The following are the most common types that once existed in southern Manitoba. The Deciduous Flat Swamp Wetland Ecosystem (Figure 12) influences this proposed project's vegetative and landform characteristics.

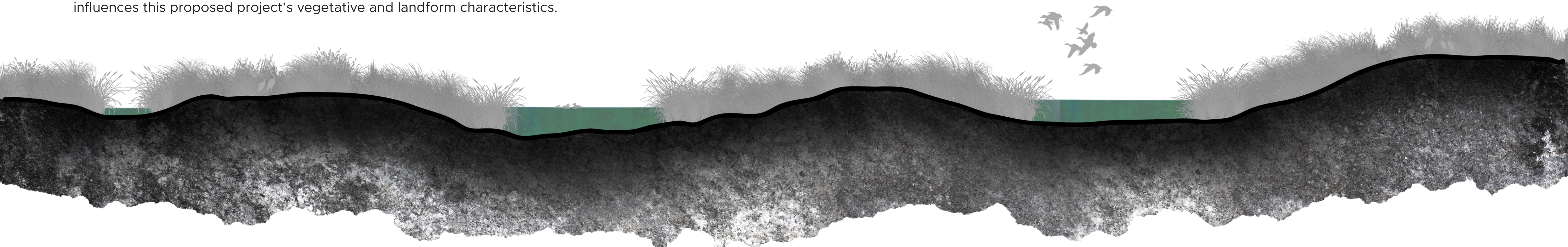


Fig 9. Isolated Marsh Wetland Abstract Section

Isolated Marsh Wetland Ecosystem

A marsh wetland is characterized by shallow water that fluctuates seasonally. Precipitation, surface runoff and groundwater contribute to the saturation of these wetlands. Water retention depends on geological substrates. For example, Isolated (Basin) Marshes occur in topographically defined landscapes, caused by glacial erosion and deposition. Water pH in Isolated Marshes depends on the parent material of the soil, tending to be anywhere from 6 to 8.[15]

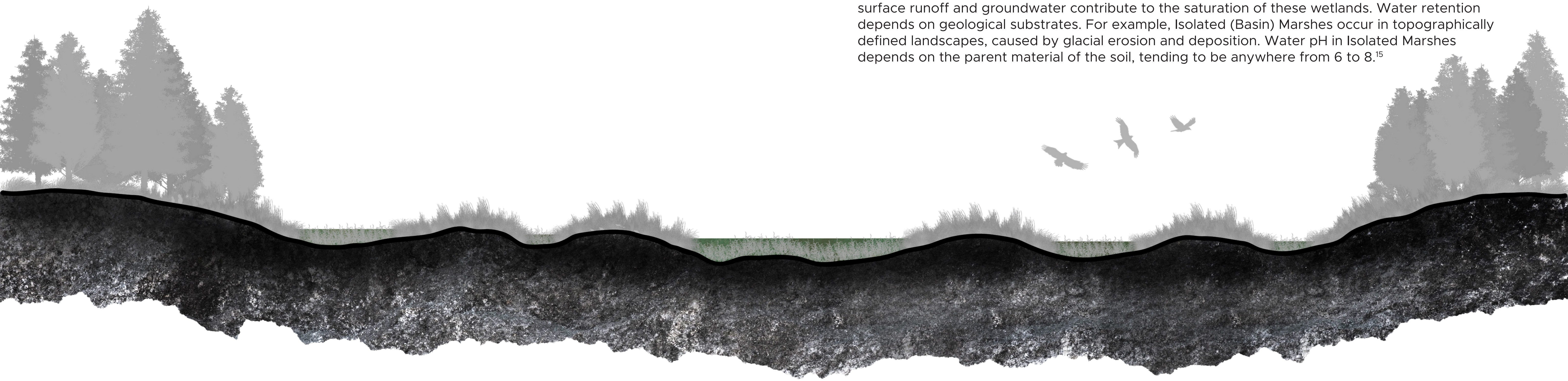


Fig 10. Slope Fen Wetland Abstract Section

Slope Fen Wetland Ecosystem

A fen wetland is a peat landform with a fluctuating water table. Its water contains large amounts of minerals, making it minerotrophic. Groundwater and surface water contribute to the saturation of fen wetlands. The flow and pooling of surface water shapes the landscape of a fen. Vegetation and pH within the fen vary based on the intensity of minerals present. Water pH may range from 5.5 to 6.9.[14]

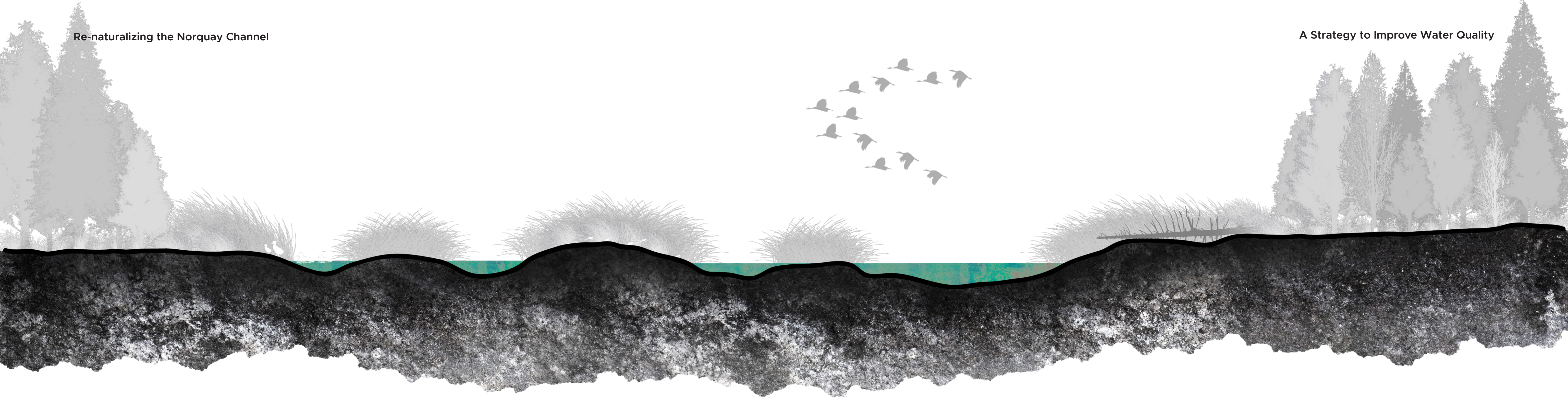


Fig 11. Basin Bog Wetland Abstract Section

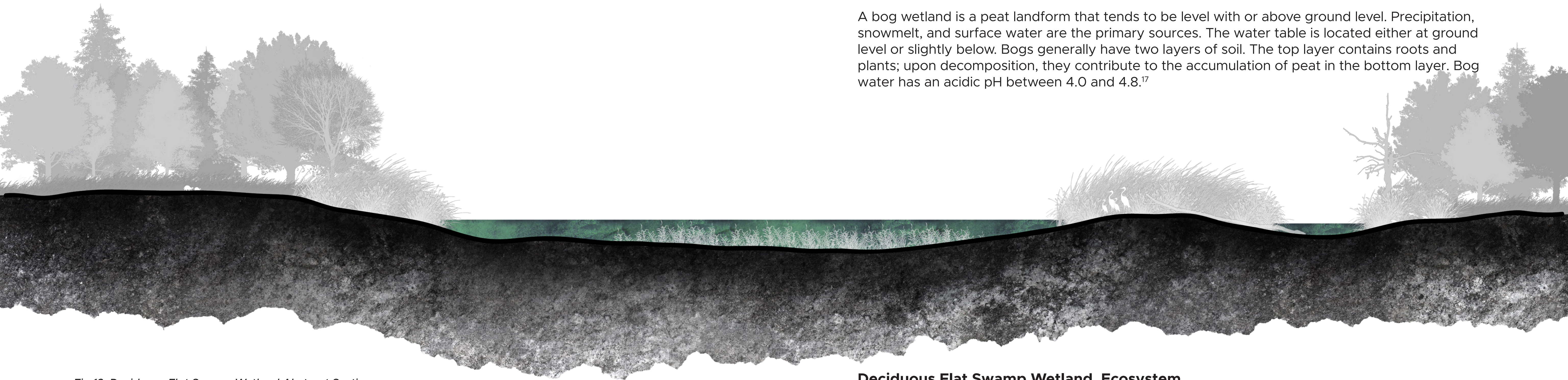


Fig 12. Deciduous Flat Swamp Wetland Abstract Section

Basin Bog Wetland Ecosystem

A bog wetland is a peat landform that tends to be level with or above ground level. Precipitation, snowmelt, and surface water are the primary sources. The water table is located either at ground level or slightly below. Bogs generally have two layers of soil. The top layer contains roots and plants; upon decomposition, they contribute to the accumulation of peat in the bottom layer. Bog water has an acidic pH between 4.0 and 4.8.[17]

Deciduous Flat Swamp Wetland Ecosystem

There are three main types of vegetated swamps: thicket swamps, coniferous swamps, or deciduous swamps. They are differentiated by their vegetation. They can occur in mineral soil or peat landscapes. Flat Swamps occur in topographically defined landscapes, such as glacial lakebeds. Surface runoff, ground water, and precipitation contribute to the saturation of the landscape. Water pH may range significantly from base-rich at 7.0 to base-poor at 4.5 or lower. The condition of pH is represented by the health of vegetation.[16]

Classification of Wetlands in Manitoba

Wetlands are classified under the Manitoba Sustainable Watersheds Act (2018) for water management and licensing approval process for the province.[18] The Manitoba Prairie Wetland Classification Guide, designed by Ducks Unlimited Canada, provides landowners with an efficient and informed classification of wetlands when applying for legal drainage or other water management activities.[19] Together, these documents provide information on the classification of wetlands in Manitoba, which was used to indicate the change in vegetation zones based on water depths (Figure 13). There are five classes. Each has a dominant plant community, depending on how saturated the soil is.

The five classes are as follows:

Class 1 (Ephemeral Wetland) – Low Prairie Zone

Class 2 (Temporary Wetland) – Wet Meadow Zone

Class 3 (Seasonal Wetland) – Shallow Marsh Zone

Class 4 (Semi-Permanent Wetland) – Deep Marsh Zone

Class 5 (Permanent Wetland) – Permanent Open Water Zone

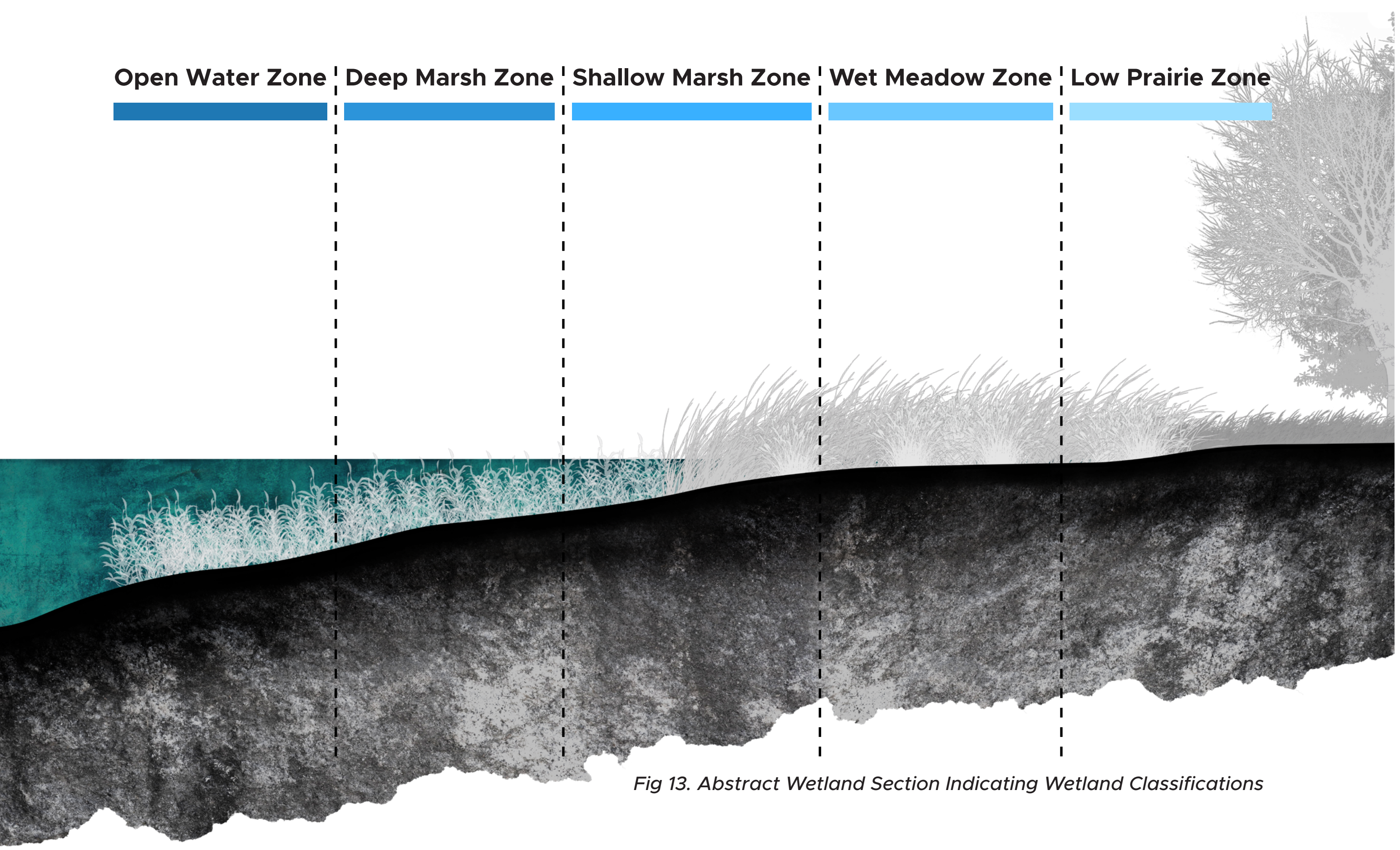
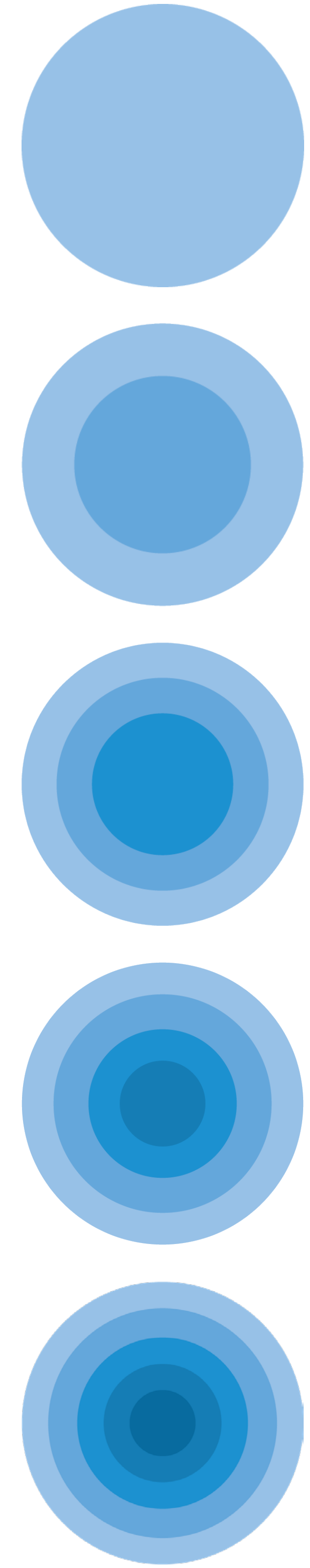


Fig 13. Abstract Wetland Section Indicating Wetland Classifications



Class 1 Ephemeral wetlands are characterized by porous soils that allow water to drain quickly, and surface water present in the spring (depending on winter precipitation). After the ground has thawed, the soil tends to drain quickly. Their plants are adapted to soils with high moisture for short periods. Common species include Kentucky and fowl blue grass, dandelion, field bindweed, kochia, goldenrod, asters, snowberry and wheat grass.[20]

Class 2 Temporary wetlands hold water for two to six weeks after spring snowmelt or several days after fall heavy rains. Their plants are adapted to growing in soils with moderate moisture but not prolonged flooding. Common species include sedges, rushes, cordgrass, dock, potentilla, and foxtail barley.[21]

Class 3 Seasonal wetlands hold water for most of the spring into mid-summer. Land becomes dry by late summer. Their plants grow in soils with shallow flooding for prolonged periods. Common species include soft-stem bulrush, water plantain, water parsnip, water smartweed, sedges, slough grass, and giant bur-reed.[22]

Class 4 Semi-permanent wetlands have surface water from April to October in most years, although land may become dry by late August or September. Their plants are adapted to soils that experience deeper flooding conditions (30 to 60 cm) for prolonged periods. Common species include hard-stem bulrush, river bulrush, and broad-leafed cattails.[23]

Class 5 Permanent wetlands have surface water year-round most years. Their land is dominated by permanent open water zones at the deepest point. Water depths tend to be too deep for emergent plants. Floating or submerged plants such as sago pondweed, hornwort, bladderwort, and algal mats may be present.[24]

Fig 14. Wetland Classes Circular Diagram Indicating Zonation

Free Water Surface (FWS)

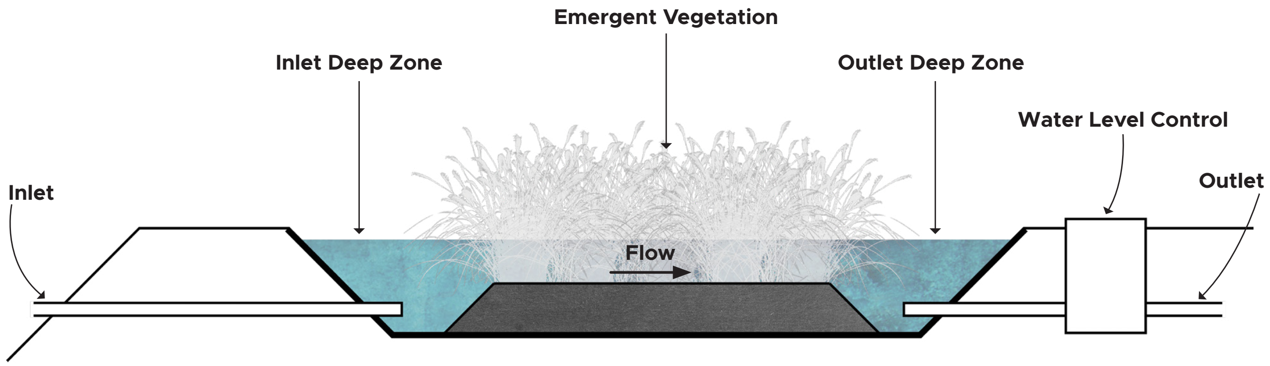


Fig 15. Free Water Surface Constructed Wetland Section

Horizontal Subsurface Flow (HSSF)

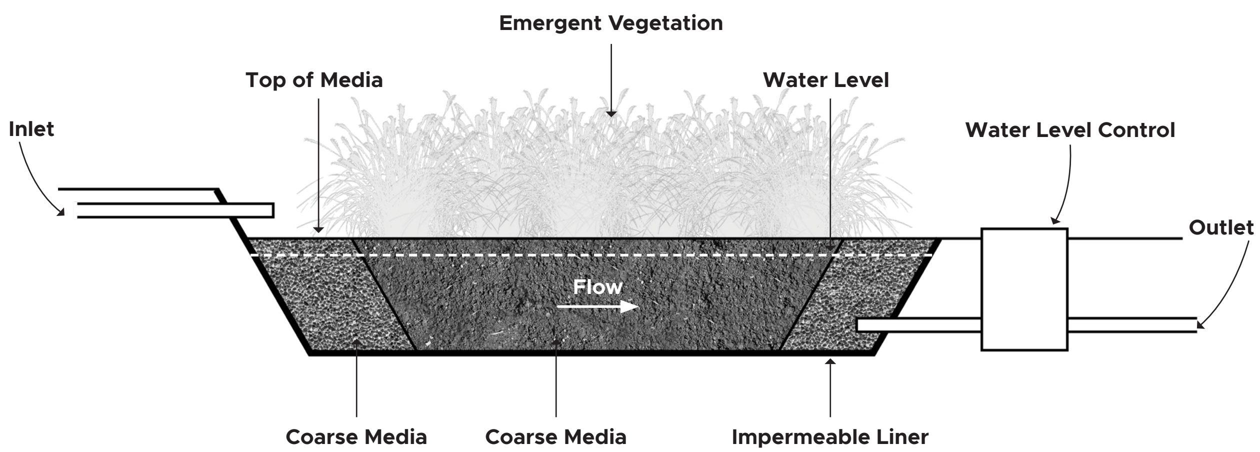


Fig 16. Horizontal Subsurface Flow Constructed Wetland Section

Vertical Flow (VF)

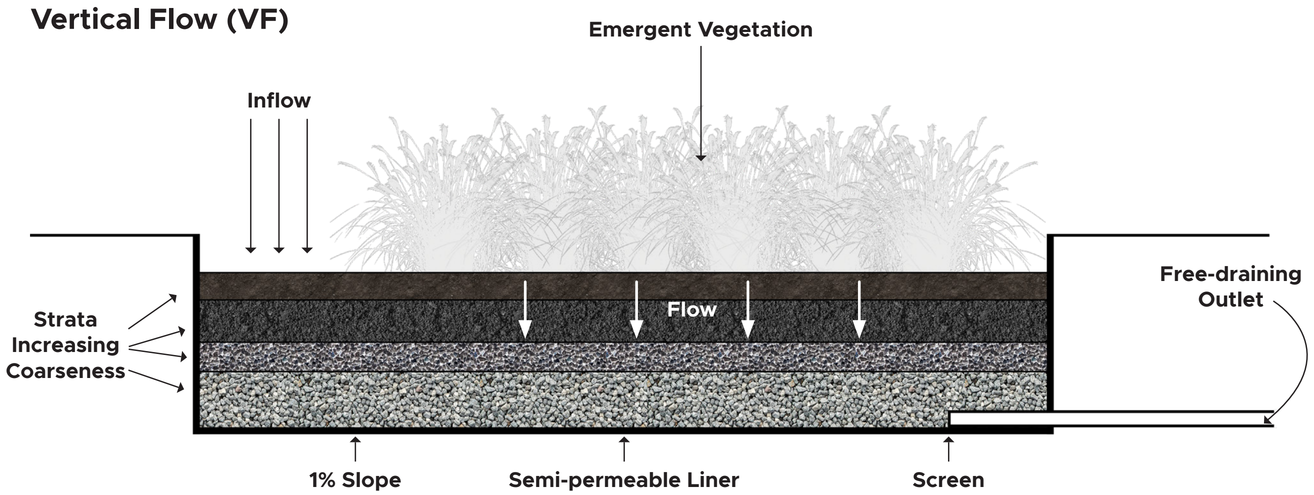


Fig 17. Vertical Flow Constructed Wetland Section

Types of Constructed Wetlands

Constructed wetlands are artificial systems designed to replicate the treatment characteristics of wetland ecosystems and improve an area's water treatment capacity.[30] Currently, there are three main types of constructed wetlands: Free-Water Surface (FWS) wetlands, Horizontal Subsurface Flow (HSSF) wetlands, and Vertical Flow (VF) wetlands. The characteristics of the FWS constructed wetland (Figure 15) influence this proposed project in terms of form and operation.

Free Water Surface (FWS)

Free Water Surface (FWS) constructed wetlands include open water portions and replicate the appearance of typical natural marsh wetlands. Vegetation in the form of floating or emergent plants is present. Berms, dikes, and geotextiles may be used to control flow and infiltration. Water is treated through sedimentation, filtration, oxidation, reduction, adsorption, and precipitation. Wildlife tends to be more attracted to this type of wetland due to its similarities with natural marsh wetlands.[25]

Horizontal Subsurface Flow (HSSF)

Horizontal Subsurface Flow (HSSF) constructed wetlands typically utilize an aggregate or soil bed with wetland vegetation. The water is kept below the surface of the aggregate bed and flows horizontally from inlet to outlet.[28] The bed media and rhizomes of the plant roots are meant to filter the water. A significant concern of HSSF-constructed wetlands is clogging the media, inlet, or outlet. Unlike FWS-constructed wetlands, HSSF-constructed wetlands provide little to no benefits involving biodiversity and habitat.[29]

Vertical Flow (VF)

Vertical Flow (VF) constructed wetlands utilize percolation by spreading water over a surface bed planted with wetland vegetation. The media and plant roots filter water.[26] VF-constructed wetlands have the most variations based on the intended use. VF-constructed wetlands in North America tend to be designed as vegetated recirculating gravel filters. These wetlands may be used to treat concentrated wastewater and unsettled raw sewage.[27]

Chapter One Endnotes

1 “What Is a Wetland?” US EPA. May 4, 2023. https://www.epa.gov/wetlands/what-wetland.
2 “Constructed Wetlands.” US EPA. August 24, 2023. https://www.epa.gov/wetlands/constructed-wetlands.
3 Environment and Climate Change. “Drainage & Water Control.” Government of Manitoba. Accessed March 25, 2024. https://www.gov.mb.ca/sd/water/water-rights/drainage-and-water-control/index.html.
4 Environment and Climate Change. “Drainage & Water Control.” Government of Manitoba. Accessed March 25, 2024. https://www.gov.mb.ca/sd/water/water-rights/drainage-and-water-control/index.html.
5 “Watersheds.” Freshwater Inflows. Accessed May 6, 2024. https://www.freshwaterinflow.org/watersheds/.
6 “Dike.” Merriam-Webster. Accessed March 25, 2024. https://www.merriam-webster.com/dictionary/dike.
7 “Berm.” Merriam-Webster. Accessed March 25, 2024. https://www.merriam-webster.com/dictionary/berm.
8 “Channel.” Merriam-Webster. Accessed March 25, 2024. https://www.merriam-webster.com/dictionary/channel.
9 “Ditch.” Merriam-Webster. Accessed March 25, 2024. https://www.merriam-webster.com/dictionary/ditch.
10 “Culvert.” Merriam-Webster. Accessed March 25, 2024. https://www.merriam-webster.com/dictionary/culvert.
11 Shuqing An and Jos Verhoeven, Wetlands: Ecosystem services, restoration and wise use, (Cham, Switzerland: Springer Nature Switzerland AG, 2019), 1.
12 Shuqing An, Wetlands, 4.
13 Shuqing An, Wetlands, 3-4.
14 Barry Warner and A. Rubec, The Canadian Wetland Classification System, (Waterloo, Ont.: Wetlands Research Branch, University of Waterloo, 1997), 27.
15 Barry Warner, The Canadian Wetland Classification System, 45.
16 Barry Warner, The Canadian Wetland Classification System, 37.
17 Barry Warner, The Canadian Wetland Classification System, 19.
18 Ducks Unlimited Canada. “Wetland Classes.” Manitoba Prairie Wetland Classification Guide, accessed November 21,2023, https://www.ducks.ca/assets/2020/05/Ducks-Unlimited-Canada_Landowners-Guide.pdf. 1.
19 Ducks Unlimited Canada. “Wetland Classes.” 1.
20 Ducks Unlimited Canada. “Wetland Classes.” 5.
21 Ducks Unlimited Canada. “Wetland Classes.” 6.
22 Ducks Unlimited Canada. “Wetland Classes.” 7.
23 Ducks Unlimited Canada. “Wetland Classes.” 8.
24 Ducks Unlimited Canada. “Wetland Classes.” 9.
25 Robert Kadlec and Scott Wallace, Treatment wetlands, (Boca Raton, FL: CRC Press, 2009), 5.
26 Robert Kadlec, Treatment wetlands, 5.
27 Robert Kadlec, Treatment wetlands, 7.
28 Robert Kadlec, Treatment wetlands, 5.
29 Robert Kadlec, Treatment wetlands, 6.
30 Robert Kadlec, Treatment wetlands, 5.

Page Left Blank Intentionally

Page Left Blank Intentionally

Page Left Blank Intentionally

Chapter Two

Drainage in the Red River Valley

This chapter provides an overview of general water quality concerns in Manitoba. A large area influences Manitoba's water quality: the Nelson River Watershed. Within the Lower Red River Basin, a watershed within the greater Nelson River Watershed, wetlands once covered over 6,000 square kilometres. These wetlands were drained for European settlement and agricultural production during the first half of the 20th Century. Information on the coordination of early drainage and current standards is provided.

Fig 18. Drone photo of the north part of the Boyne River, east of Carman

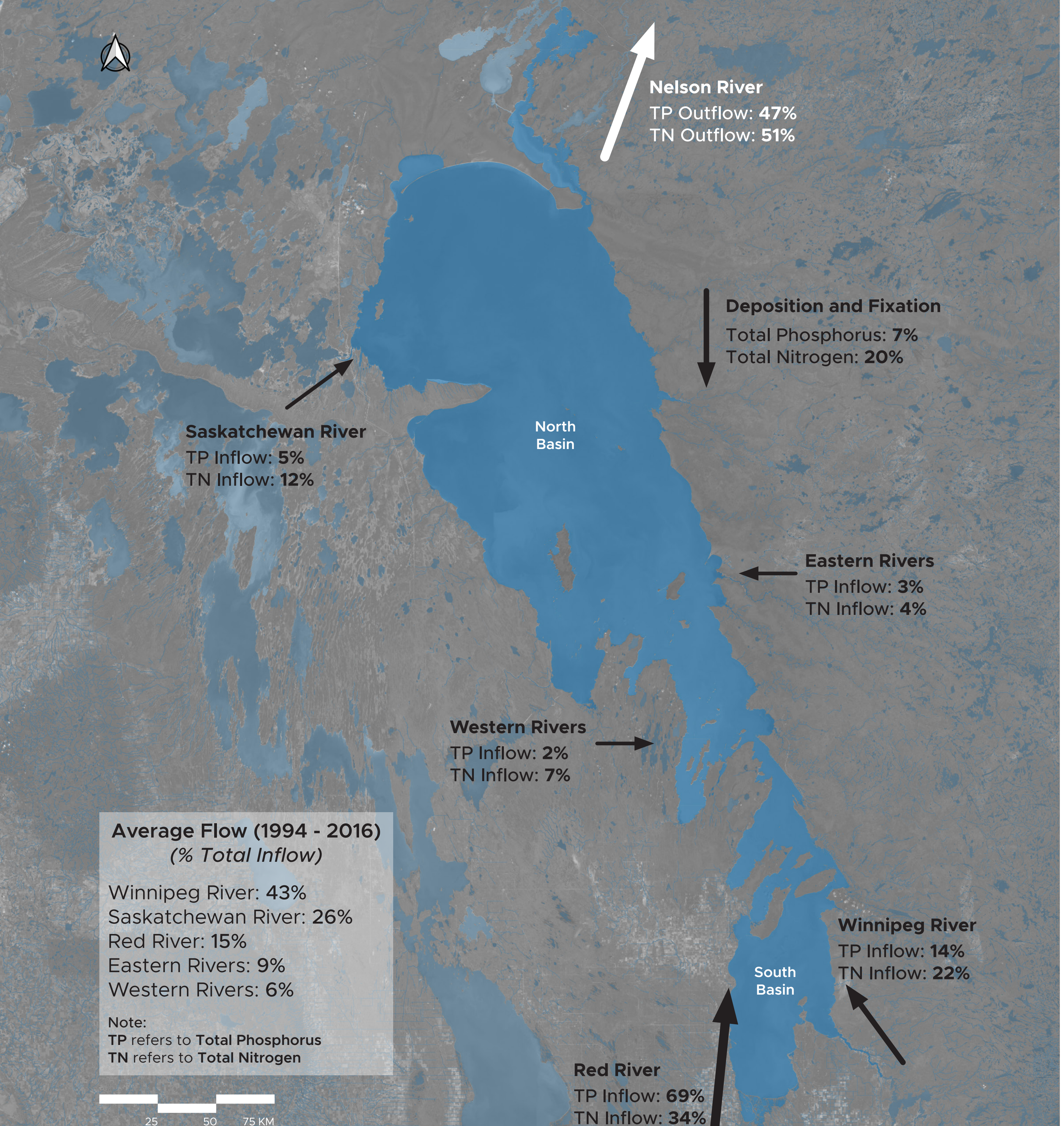


Fig 19. Estimated total phosphorus and total nitrogen loads and flow to Lake Winnipeg (1994 - 2016)

General Water Quality Concerns in Manitoba

Nutrient Loading of Lake Winnipeg

Nutrient loading is said to be the dominant factor impacting the water quality of Lake Winnipeg (Figure 19). The lake is split into two north and south basins and has three main tributaries. The Red and Winnipeg rivers enter the south basin, and the Saskatchewan enters the north. Together, the three tributaries contribute 85% of the flow, 68% of the nitrogen, and 88% of the phosphorus load. Other factors influence the lake's nutrient load, such as the smaller tributaries, atmospheric deposition, and nitrogen fixation. The Red River contributes only 16% of the flow into Lake Winnipeg but 34% of the nitrogen and 69% of the phosphorus.[31] Between 1994 and 2016, on average, Lake Winnipeg received 7,368 tonnes of phosphorus and 72,463 tonnes of nitrogen from its tributaries.[32] Loading of phosphorus and nitrogen varies yearly depending on snowmelt and precipitation.

Inter-/Intra- Annual Hydrological Variability

Nutrient concentrations and loading depend significantly on hydrological conditions. Although changing water levels are a natural part of the hydrological cycle, shifting climatic conditions may make these fluctuations more dramatic. In 2013, with more snowmelt, particulate nutrient concentrations and loads were greater, increasing water turbidity.[33] In 2014, concentrations and loads were lower in tributary streams with reduced snowmelt and greater precipitation.[34] Practices such as crop rotation and fertilizer application timing have been implemented to minimize the amount of excess nutrients entering waterways through runoff. Still, additional care may also need to be given to seasonality differences in the future.[35] The unpredictability of climate change means there is more significant potential for variation in nutrient loading of provincial waterways.

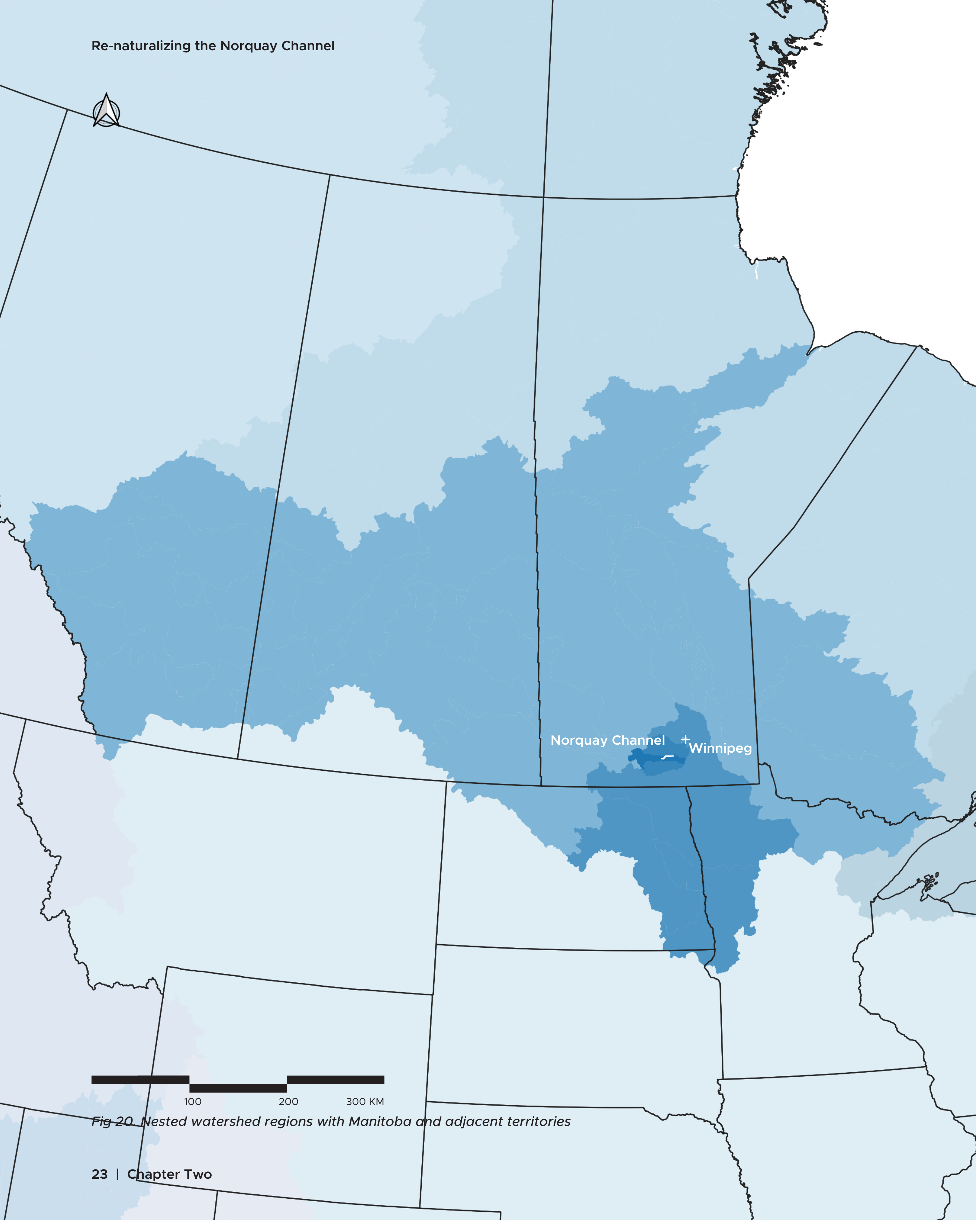


Fig 20. Nested watershed regions with Manitoba and adjacent territories

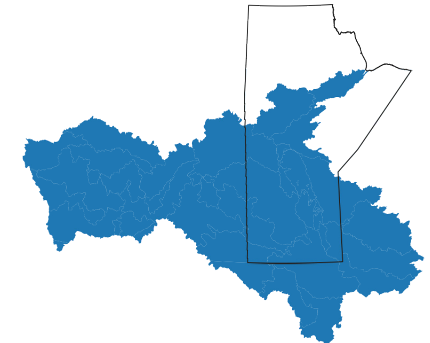


Fig 21. Nelson River Watershed Area

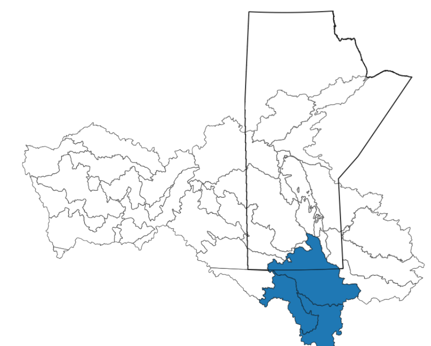


Fig 22. Red River Basin Area

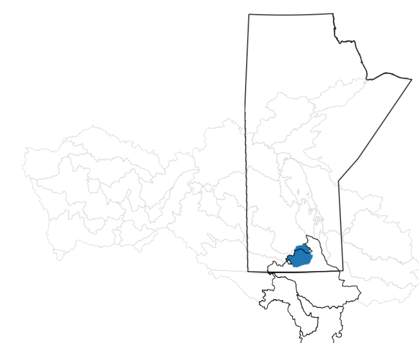


Fig 23. Redboine Watershed District Area

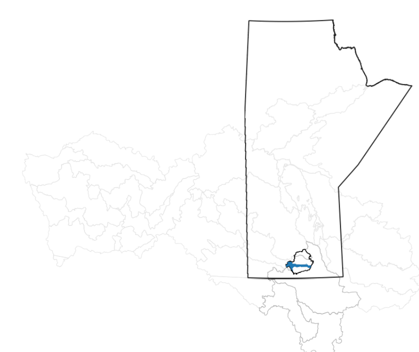


Fig 24. Norquay Channel Drainage District Area

Watersheds in Manitoba

Four scales (Figure 20) situate the Norquay Channel site within larger hydrological systems. Three of the four watersheds are naturally occurring, whereas the Redboine Watershed District is politically determined.

Nelson River Watershed

Coverage : 1,150,000 SQ KM

The first and largest watershed that encompasses southern Manitoba is the Nelson River Watershed (Figure 21). This watershed stretches over four provinces and three U.S. states, far beyond Manitoba's provincial borders. Therefore, it is not only Manitoba's population, agriculture, and industrial practices that stress our provincial waterways and ecosystems. Nearly all of the waterways within this region first drain into Lake Winnipeg.

Red River Basin

Coverage : 140,000 SQ KM

The Red River Basin (Figure 22) comprises the Lower Red River, Devils Lake-Sheyenne, and the Upper Red River. A significant amount of land within the Red River Basin is dedicated to agriculture, meaning that most nutrient-rich water from farmers' fields drains into the Red River and later into Lake Winnipeg.

Redboine Watershed District

Coverage : 8,500 SQ KM

The third area overlaps the Red River Watershed and a small portion of the Assiniboine Watershed. The district covers nineteen municipalities, the city of Portage la Prairie, and the towns of Carman and Morris. The Redboine Watershed District (Figure 23) is nearly completely comprised of crop lands, meaning that the waterways within this district experience significant nutrient loading primarily during times of intense precipitation and during the spring melt.

Norquay Channel Area

Coverage : 1,900 SQ KM

The Norquay Channel Drainage District (Figure 24) is one of eleven drainage districts within the Redboine Watershed District. The drainage district is named after the Norquay Channel, the primary waterway connecting the Boyne River to the Morris River. The drainage district comprises two subdistrict watersheds: Boyne River and Morris River-Norquay Channel.

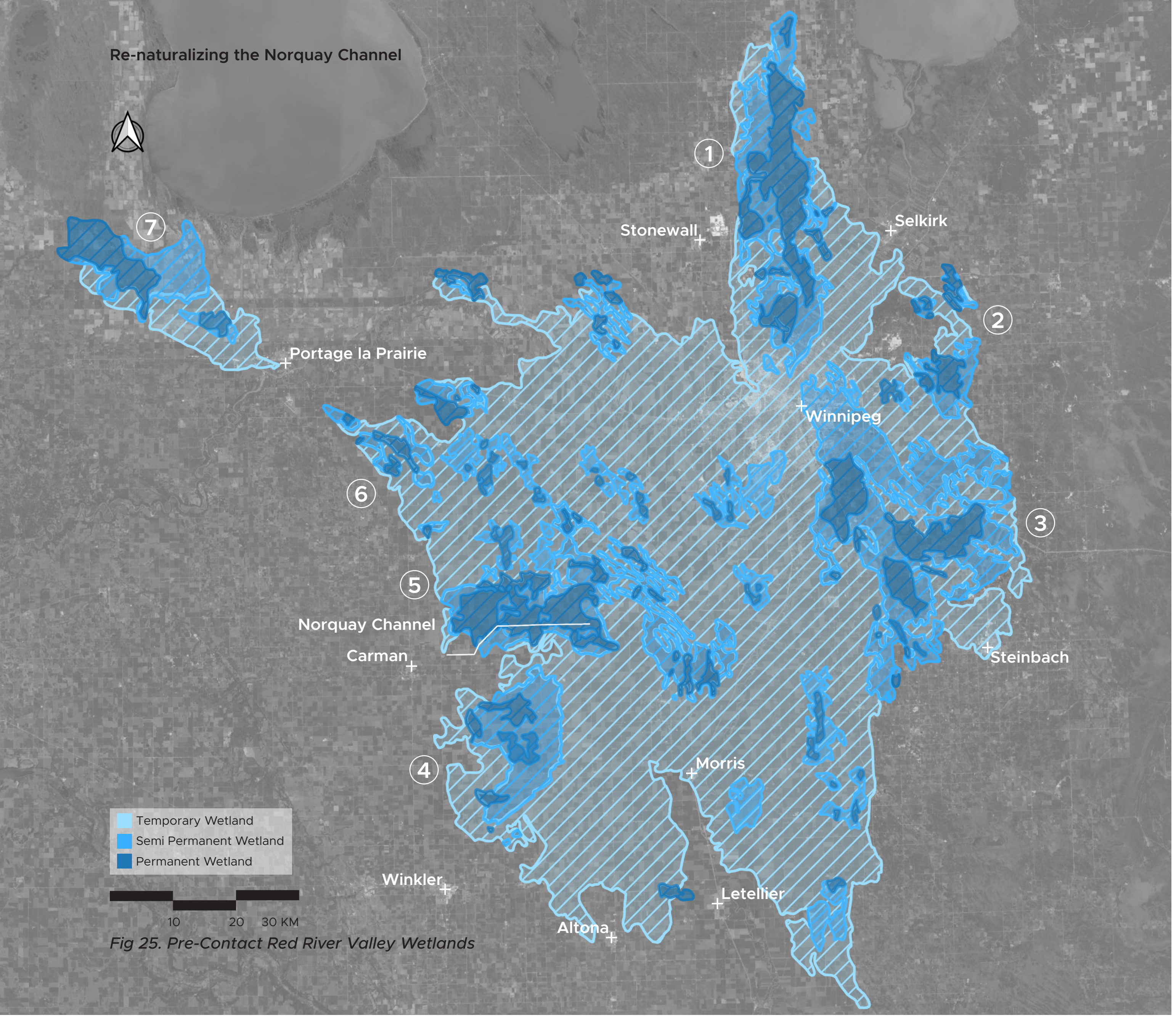


Fig 25. Pre-Contact Red River Valley Wetlands

(1) **Balmoral Marsh**
Area of Permanent Wetlands : **185 SQ KM**
Area of Semi-Permanent Wetlands : **181 SQ KM**

(2) **St. Andrews Bog**
Area of Permanent Wetlands : **48 SQ KM**
Area of Semi-Permanent Wetlands : **137 SQ KM**

(3) **Ste. Anne Bog**
Area of Permanent Wetlands : **238 SQ KM**
Area of Semi-Permanent Wetlands : **671 SQ KM**

(4) **Tobacco Creek Swamp**
Area of Permanent Wetlands : **55 SQ KM**
Area of Semi-Permanent Wetlands : **206 SQ KM**

(5) **Boyne Marsh**
Area of Permanent Wetlands : **184 SQ KM**
Area of Semi-Permanent Wetlands : **434 SQ KM**

(6) **Elm Creek Swamp**
Area of Permanent Wetlands : **66 SQ KM**
Area of Semi-Permanent Wetlands : **131 SQ KM**

(7) **Westbourne Bog**
Area of Permanent Wetlands : **95 SQ KM**
Area of Semi-Permanent Wetlands : **125 SQ KM**

Total Area of Temporary Wetlands : **6,557 SQ KM**

Pre-Contact Wetlands in the Red River Valley and their Subsequent Drainage

The total area of pre-contact seasonal, semi-permanent and permanent wetlands (Figure 25) was around 9,480 square kilometres. Most wetlands were colloquially named, but primarily consisted of marshes and bogs. They provided ecological services, such as flood mitigation, sediment and nutrient retention, and increased biodiversity.

(1) **Balmoral Marsh**, connected to St. Andrews Bog, was located north of Winnipeg and towards the north end of St Andrews Bog. Its landscape is best represented with the Swamp, Marsh, and Bogs cross-sections (see Page 9 - 10). Most of the permanent wetland consisted of open-water marshland, with the semi-permanent wetland resembling a Swamp landscape, and the seasonal wetlands appearing more as Bogs. There is now a town located near the site of the original wetlands with the same name.

(2) **St. Andrews Bog** was located north of Winnipeg. The name of the wetland is based on the Parish of St. Andrew, which was part of the Red River Settlement. Originally, the bog was so large that steamboats could carry passengers between Selkirk and Stonewall. By the end of the 1960s, the bog had been reduced to only 60 hectares from over 10,000 hectares. Oak Hammock Marsh is located within the original wetland; it is a wetland restoration that began in 1972. [36]

(3) The **Ste. Anne Bog**, otherwise known as the Grand Marsh, was located mainly southeast of Winnipeg. Its name comes from the Ste. Anne settlement. The landscape contained Bog, Fen and Marsh characteristics (see Page 7 - 10). A significant portion of the wetlands was removed with drains that emptied into other basins, finally ending up in the Rat and Red Rivers.

(4) The **Tobacco Creek Swamp** was located to the west of Morris and north of Plum Coulee; it was part of the southern end of the Great Marsh, which also included the Boyne Marsh. Work to drain the swamp began in 1898 when a plan was put forward to drain the swamp into the Red River. The Tobacco Creek Channel is the primary drain that empties the original wetland. The wetland was named after the creek that once served it, coming from the west, and emptying into the lowlands.[37]

(5) The **Boyne Marsh**, The Boyne Marsh, located southwest of Winnipeg, was a series of permanent, semi-permanent, and seasonal wetlands. Its landscape is best represented in the Marsh cross-section (see Page 7 - 8). Its name comes from the Boyne River which comes in from the west and drains out into the lowlands. Work on draining the marsh began in 1898 when a plan was put forward to drain the Boyne Marsh and Tobacco Creek Swamp into the La Salle and Red Rivers. The Norquay Channel is the primary drainage channel that empties the Boyne Marsh.[38]

(6) The **Elm Creek Swamp** was located west of Winnipeg and immediately south of Portage la Prairie. It is best represented by the Marsh and Swamp cross-sections (see Page 7 - 10). Its name comes from the nearby town of Elm Creek. The Elm River drained into the lowlands to the south of the Assiniboine River before slowly working its way to the La Salle River. The Elm Creek Channel is the primary drain for the original wetland.[39]

(7) The **Westbourne Bog** was northwest of Portage la Prairie and immediately south of Lake Manitoba. Its landscape is best represented by the bog cross-section (see Page 9 - 10). Pine Creek and Squirrel Creek both supplied the wetlands, and seepage came from the White Mud River. The Westbourne Marsh drained northward into Lake Manitoba. Planning for the draining of the bog began in 1880 when the province awarded a contract to the Manitoba and Northwestern Drainage Company to drain the Big Grass Marsh and the Westbourne Bog. It wouldn't be until nearly forty years later that the project was considered complete. [40]

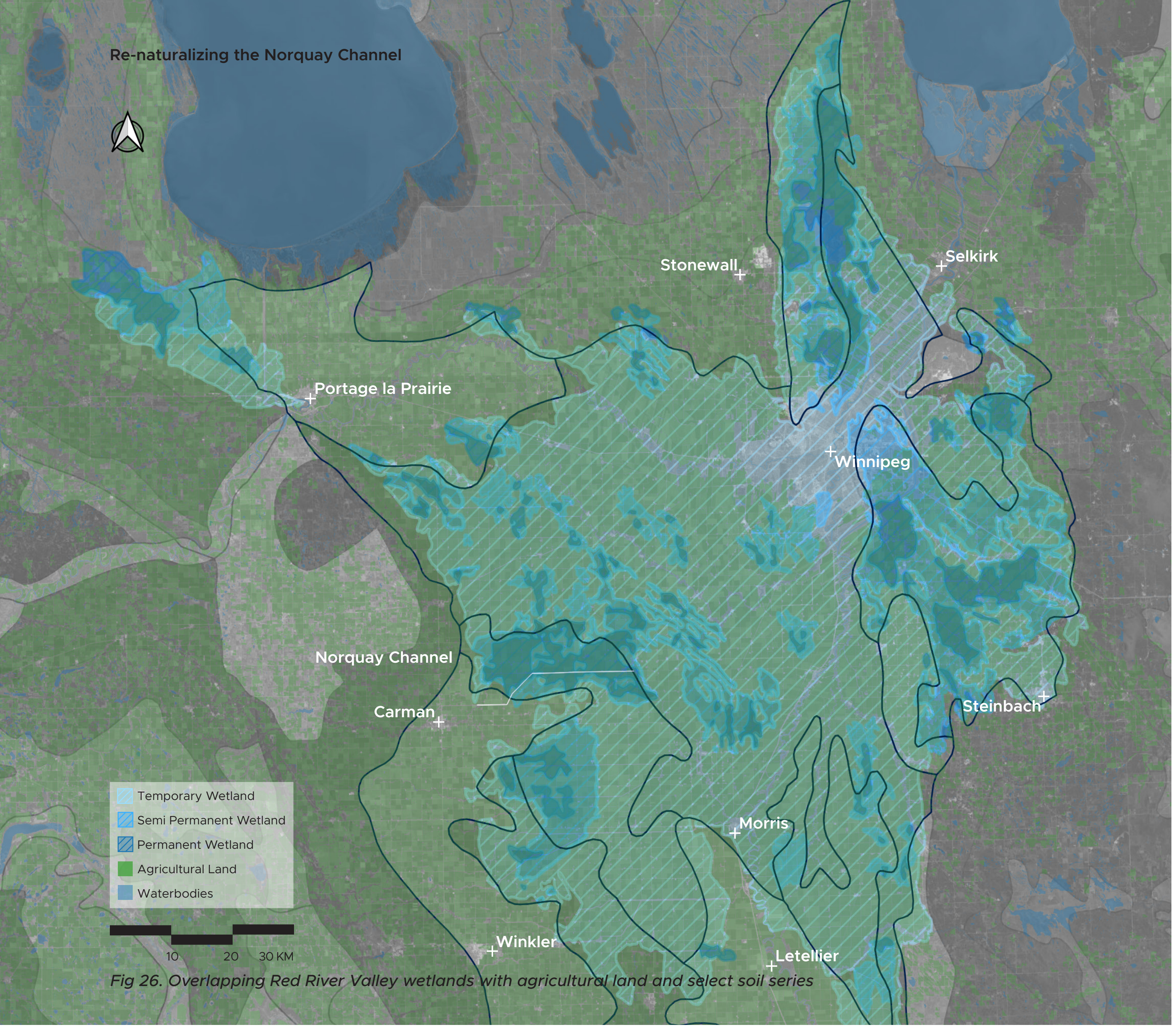


Fig 26. Overlapping Red River Valley wetlands with agricultural land and select soil series

The Relationship Between Agriculture and the Original Wetlands

The distribution of soils in the Red River Valley directly results from Lake Agassiz. As the glaciers retreated, rivers formed, which brought aggregates, clay, and silt into the lake. Most of the coarse aggregates were deposited at the mouths of these rivers, but the clay and silt settled at the bottom of the lake bed.[41] This lake bed became the Red River Valley and formed its wetlands.

A relationship can be observed when overlaying the original wetlands and current agricultural activities over the Manitoba soil series map in Figure 26. The four soil series within this overlap include Red River (RIV), Osborne (OBO), Lakeland (LKD), and Morris (MRS). The retreat of the glaciers brought in the soils, and as water levels lowered, the properties of the soils led to the formation of wetlands ranging in permanence. It makes sense that constructed wetland restorations would occur where the pre-contact wetlands once existed within the Red River Valley region.

Fig 27. Red River Series soil area

The **Red River Series (RIV)** (Figure 27) consists of moderately to strongly calcareous, deep, uniform, clayey, lacustrine deposits. This series occurs in upper positions of gentle slopes on relatively level landscapes. This series has slow permeability, with slow to moderate surface runoff. Red River Soils occur in close proximity to Scanterbury, Morris, and Osborne soils. This series has a high water holding capacity and medium natural fertility – Most soils currently used for crop production are in this series.[42]

Fig 28. Osborne Series soil area

The **Osborne Series (OBO)** (Figure 28) consists of poorly drained Rego Humic Gleysol soils that developed on moderately to strongly calcareous, deep uniform, clayey, lacustrine deposits. The soil occurs in lower to depressional areas of level or nearly level landscapes. It has very slow permeability, and slow to very slow surface runoff with a high water table during the typical growing season. Osborne soils occur in close association with Red River, Morris and Scanterbury soils. This series has a high water holding capacity and medium natural fertility. Native vegetation includes meadow grasses, reeds, sedges, and willow.[43]

Fig 29. Lakeland Series soil area

The **Lakeland Series (LKD)** (Figure 29) consists of imperfectly drained Gleyed Rego Black carbonated soils that developed on moderately to extremely calcareous, dominantly fine loamy sediments. Its topography is level to gently sloping. Permeability is moderate to moderately slow, and runoff is slow. Native vegetation that grows in the series includes meadow grasses with clumps of willow.[44]

Fig 30. Gnadenthal Series soil area

The **Gnadenthal Series (GDH)** (Figure 30) consists of imperfectly drained Gleyed Rego Black Chernozem soils that developed on moderately to strongly calcareous, deep stratified, loamy, fluvial and lacustrine deposits. The soil occurs in the middle of nearly level to gently sloping topography on undulating landscapes. It tends to occur near Reinfeld and Blumenfeld soil series. It has moderate permeability, and run off is moderately slow.[45]

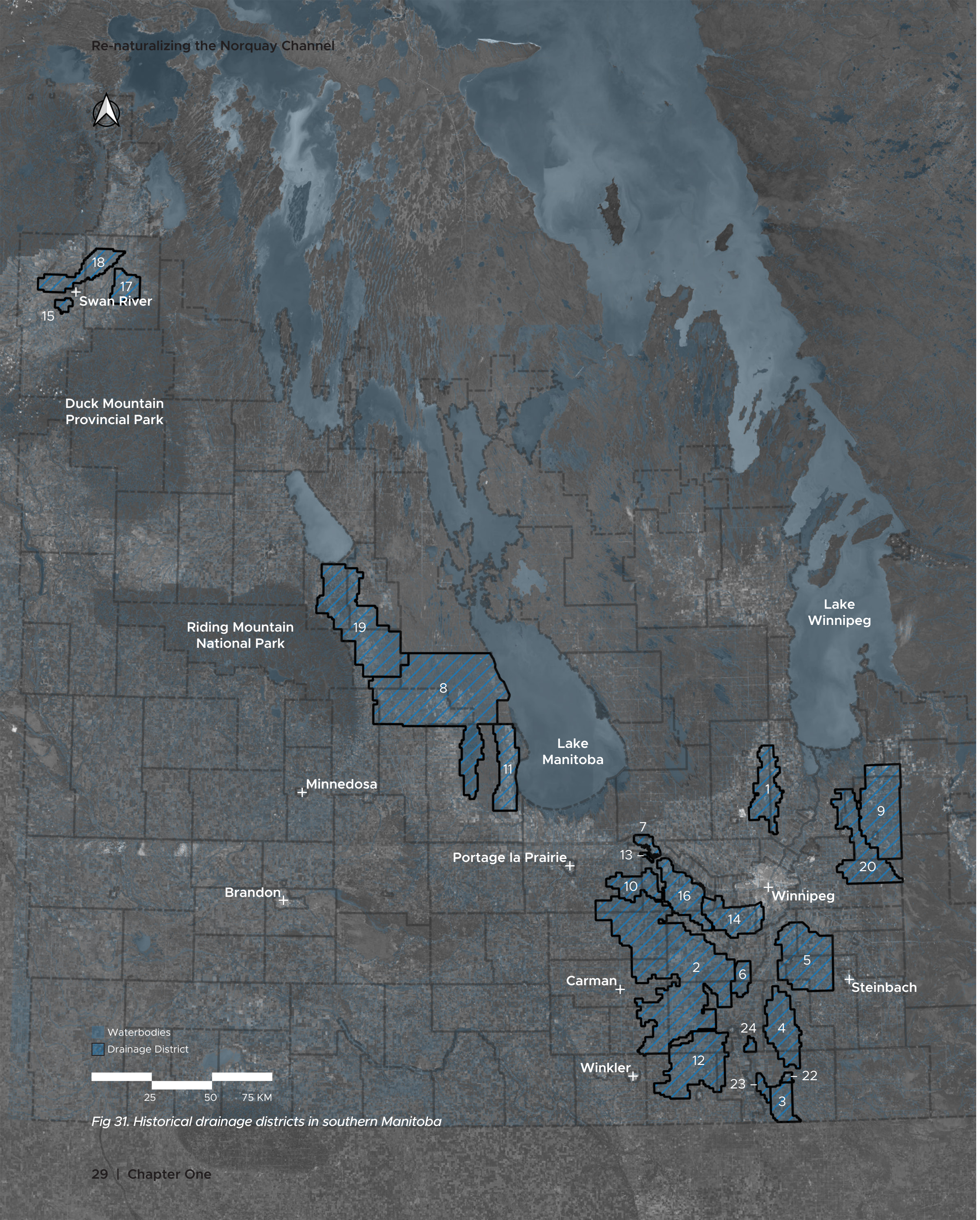


Fig 31. Historical drainage districts in southern Manitoba

Drainage in Southern Manitoba

Drainage districts were created to coordinate the drainage of nearly all Red River Valley wetlands. The district boundaries and drainage methods have been modified over the last century to help provide more dry land for farming in southern Manitoba.

Historical Drainage Districts

As settlement increased through the 1890s, it became a priority for the provincial government to drain land to increase the amount of arable land.[46] Although previous settlers had made do with their own private drainage projects, there was a call for bigger public works. Municipal lines had previously been drawn irregularly, reflecting the various influxes of homesteaders. Municipalities also had differing opinions and interests when it came to drainage.[47] The problem of where funding would be drawn from and applied also caused a lot of concern. In 1895 the Manitoba Land Drainage Act was passed, allowing for legislation to form drainage districts. The lines drawn for the drainage districts reflected surface water conditions at the time, as well as perceived flooding problems.[48]

In the twenty years following the passage of the Land Drainage Act, twenty-four districts were established (Figure 31). By 1903, there were thirteen districts that had been created, followed by another eight by 1914.[49] Another three districts were added by the mid-1920s. This brought the total land area to well over two million acres. The districts themselves varied in size; District 2 was the largest at 450,000 acres compared to the smallest, District 24, at 4,800 acres.[50]

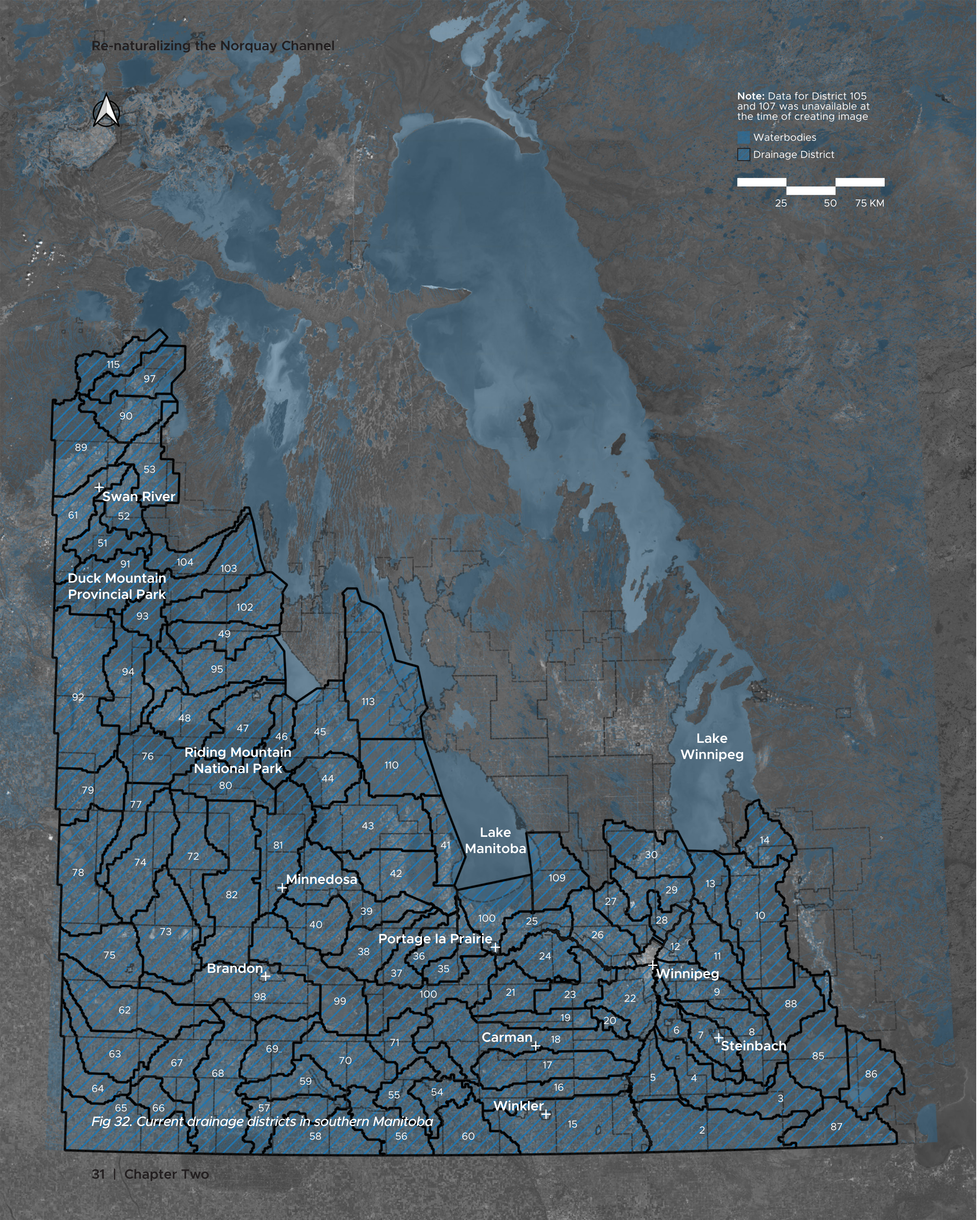


Fig 32. Current drainage districts in southern Manitoba

Current Drainage Districts

Figure 32 shows designated drainage districts and the total land area drained by a particular set of channels. The typical format of the drainage district contains one larger channel with several feeder drains. For example, designated Drainage Area No. 18, is drained primarily by the Norquay Channel. These drainage areas exist within watershed districts.

After the 1895 Land Drainage Act, there was conflict among affected farmers regarding the drainage of their land and the upkeep of these new drains. It was unclear who was responsible for the water and where funds for maintenance would come from. Two sides formed; those from the highlands felt they should not be held responsible for the detriments caused by the modification of their land or to have to pay for the drainage downstream; those from the lowlands had to deal with various waves of flooding throughout the year due to the topographic characteristics of the region. [51]

Many arguments and proposals were made over the decades, but not until the passing of the 1958 Watershed and Soil Conservation Authorities Act did the modern watershed districts, of today form. Other environmental and climatic concerns were addressed in the 1959 The Watershed Conservation Districts Act.[52] Modifications to the drainage channels and districts were made over the following years. In 1961, the Agricultural Rehabilitation and Development Act (ARDA) was created to share costs between provincial and federal governments for agricultural and drainage undertakings along with initiatives for effective land and water management.[53] Improvements were made to the Norquay Channel as the first ARDA project. By 1968, over $10 million had been spent on or committed to drainage projects in Manitoba by the province. [54]

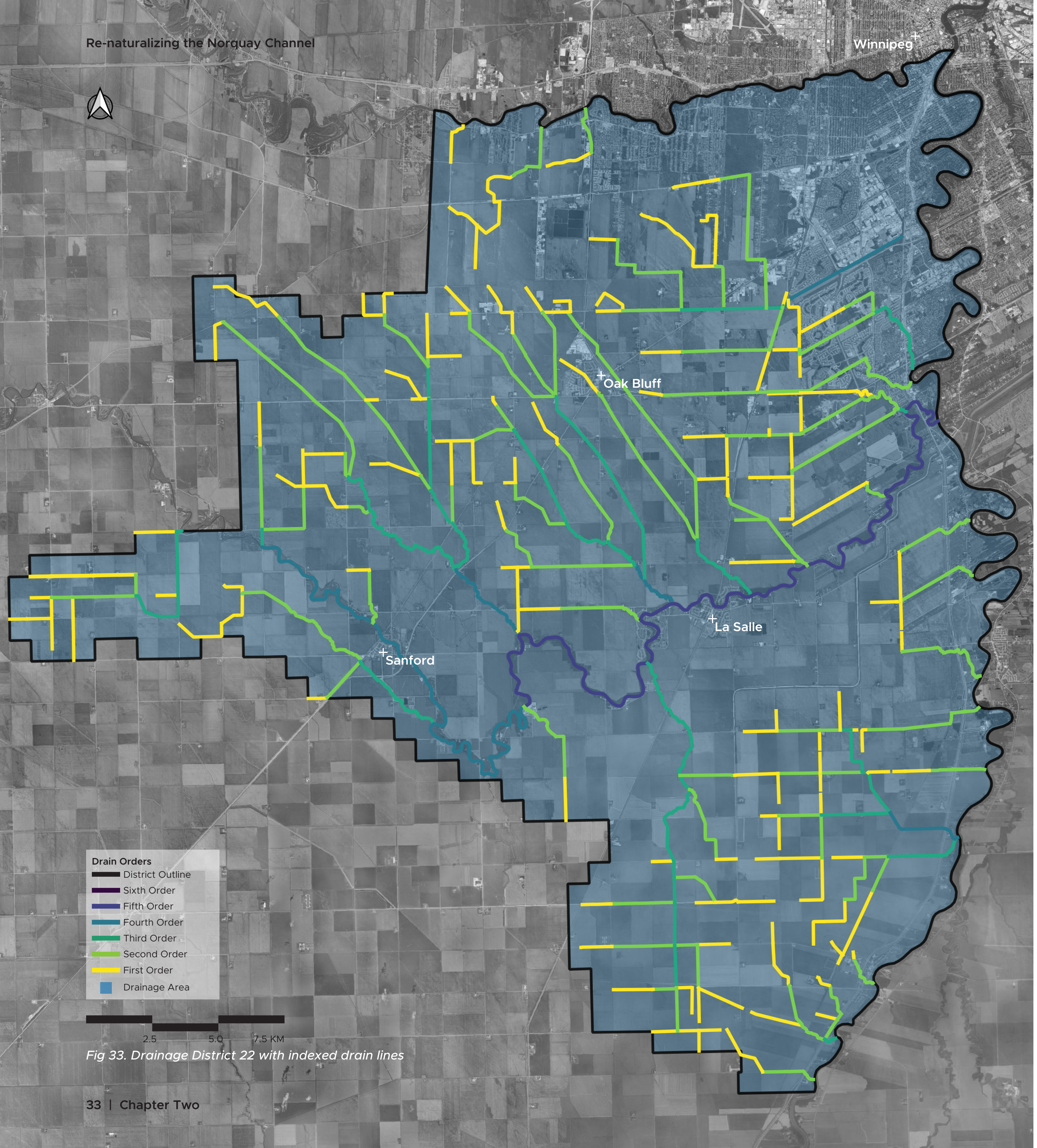


Fig 33. Drainage District 22 with indexed drain lines

Drainage Standards in Manitoba

There are two main methods for land drainage in Manitoba. The first may be classified as surface drainage, where land surfaces are modified to establish slopes that facilitate gravitational flows overland into ditches and channels, through culverts, to an outlet into the Red River. The second method is more extensive; artificial drainage is required when soil conditions are clay and ridge swale loams. A combination of these methods exists around southern Manitoba. Typically, agricultural fields and roads are manipulated so that the water flows into a drain due to gravitational flow. These drains consist of varying magnitudes, referred to as an order, depending on the spatial extent of land being drained.[59]

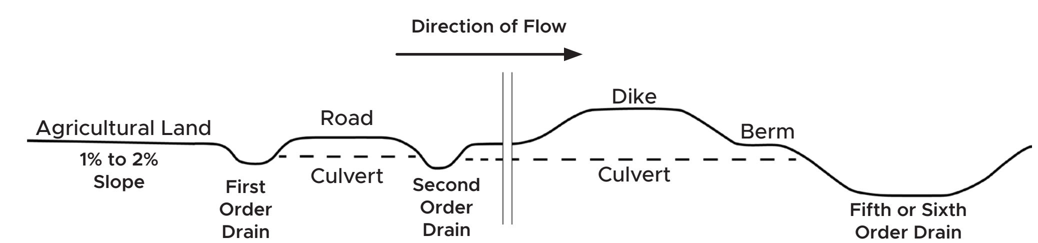


Fig 34. Agricultural Drainage diagram

First Order waterways are upper, single, unbranched tributaries that serve a drainage area no greater than one square mile. Second Order Waterways are drains that occur when two or more First Order waterways converge. Third Order waterways are formed at the confluence of two second-order waterways and may have multiple first and second-order tributaries. Fourth, Fifth and Sixth Order Waterways are similar to the Third, where each order may have a varying number of lower-order waterway tributaries, with the increase in order occurring at the confluence of the following lower-order waterways.[55] Drainage District 22 was chosen as an example for Figure 33 since it demonstrates the branching form of the drains and waterways leading into the La Salle River, a fifth order waterway.

The provincial waterways policy states that the provincial government assumes jurisdiction through order-in-council of specified watercourses of the third order or higher. This includes artificial and partially altered natural waterways. All other waterways become the responsibility of the municipal governments; they maintain the existing waterways and constructed artificial first, second and some third-order drains.[56]

As of 2004, there were 2700 miles of provincial waterways, consisting of 90% of the main agricultural drains in Manitoba. There were 885 bridge crossings, 1500 major culvert crossings, 1200 gated culvert installations, and 295 gradient control structures.[57] The province's annual maintenance plan had three categories: water allocation, flood damage reduction, and waterway maintenance. [58]

Chapter Two Endnotes

31 Environment and Climate Change Canada, Manitoba Agriculture and Resource Development. "Nutrient Loading." State of Lake Winnipeg – Second Edition, March 2020, https://www.gov.mb.ca/sd/pubs/water/lakes-beaches-rivers/state_lake_wpg_report_tech.pdf. 69.
32 Environment and Climate Change Canada, "Nutrient Loading." 71,75.
33 Rattan, K.J., E.A. Blukacz-Richards, A.G. Yates, J.M. Culp, and P.A. Chambers. "Hydrological Variability Affects Particulate Nitrogen and Phosphorus in Streams of the Northern Great Plains." Journal of Hydrology: Regional Studies 21 (February 2019): 110–25. https://doi.org/10.1016/j.ejrh.2018.12.008. 123-4.
34 Rattan, K.J., "Hydrological Variability Affects Particulate Nitrogen and Phosphorus in Streams of the Northern Great Plains," 123-4.
35 Rattan, K.J., "Hydrological Variability Affects Particulate Nitrogen and Phosphorus in Streams of the Northern Great Plains," 123-4.
36 "History." Oak Hammock Marsh, January 16, 2021, https://www.oakhammockmarsh.ca/about/history-of-oak-hammock/.
37 Carman/Dufferin Municipal Heritage Advisory Committee. "Boyne Marsh." Local Heritage Special Places, accessed November 21,2023, https://carmandufferinheritage.ca/local%20heritage/special%20places/loc-her-spec-pl.html.
38 Carman/Dufferin Municipal Heritage Advisory Committee. "Boyne Marsh."
39 La Salle Redboine Conservation District. "Section 5.0 – Water Resources." La Salle River Watershed: State of the Watershed Report, accessed November 21, 2023, https://www.gov.mb.ca/sd/water/watershed/iwmp/la_salle_river/documentation/summary_lasalle.pdf.
40 Margaret Morton Fahrni and W. L. Morton. Third crossing: A history of the first quarter century of the town and district of gladstone in the Province of Manitoba (Winnipeg, Man.: M. Morton and W.L. Morton, 1946), http://www.mb1870.org/localhistory/024%20-%20Third%20Crossing.pdf.
41 Hoffbeck, Dr. Steve. "The Wondrous Soil of the Red River Valley." Prairie Public Broadcasting. Accessed March 25, 2024. https://news.prairiepublic.org/show/dakota-datebook-archive/2022-06-04/the-wondrous-soil-of-the-red-river-valley.
42 Manitoba Agriculture, Food and Rural Initiatives. "Red River Series (RIV)." Soil Series Descriptions, March 2010, https://agrimaps.gov.mb.ca/agrimaps/extras/info/Soil_Series_Descriptions.pdf.
43 Manitoba Agriculture, Food and Rural Initiatives. "Osborne Series (OBO)." Soil Series Descriptions, March 2010, https://agrimaps.gov.mb.ca/agrimaps/extras/info/Soil_Series_Descriptions.pdf.
44 Manitoba Agriculture, Food and Rural Initiatives. "Lakeland Series (LKD)." Soil Series Descriptions, March 2010, https://agrimaps.gov.mb.ca/agrimaps/extras/info/Soil_Series_Descriptions.pdf.
45 Manitoba Agriculture, Food and Rural Initiatives. "Gnadenthal Series (GDH)." Soil Series Descriptions, March 2010, https://agrimaps.gov.mb.ca/agrimaps/extras/info/Soil_Series_Descriptions.pdf.
46 Shannon Studen-Bower. Wet Prairie: People, Land, and Water in Agricultural Manitoba. (Vancouver, B.C.: University of British Columbia Press, 2011), 32.
47 Shannon Studen-Bower, Wet Prairie, 32.
48 Shannon Studen-Bower, Wet Prairie, 33.
49 Shannon Studen-Bower, Wet Prairie, 78.
50 Shannon Studen-Bower, Wet Prairie, 78.
51 Shannon Studen-Bower, Wet Prairie, 90.
52 Shannon Studen-Bower, Wet Prairie, 156.
53 Shannon Studen-Bower, Wet Prairie, 158.
54 Shannon Studen-Bower, Wet Prairie, 158.
55 Manitoba Drainage Standards Document. Provided by Ron Kaatz, Technical Services Engineer, Water Infrastructure, September 21, 2023. 3.
56 Manitoba Drainage Standards Document. 3.
57 Manitoba Drainage Standards Document. 7.
58 Manitoba Drainage Standards Document. 7.
59 Manitoba Drainage Standards Document. 2.

Page Left Blank Intentionally

Page Left Blank Intentionally

Chapter Three

The Norquay Channel

This chapter provides an overview of the Norquay Channel and its local context. During my various site visits in March 2023 and throughout the rest of the year, this area caught my attention for several reasons, including that it provided an excellent opportunity for a constructed wetland with continuous supply from the Stephenfield Reservoir to the west. A basic review of Manitoba's Water Quality Standards are given to understand the evaluation of surface water quality. Water quality data for the Norquay Channel further reinforced my choice, as this waterway needs improvement. Based on these observations and analyses, I selected a specific site for more detailed design work and intervention creation.

Fig 35. Drone photo of a portion of the Norquay Channel, north of the Blooming Prairie Colony

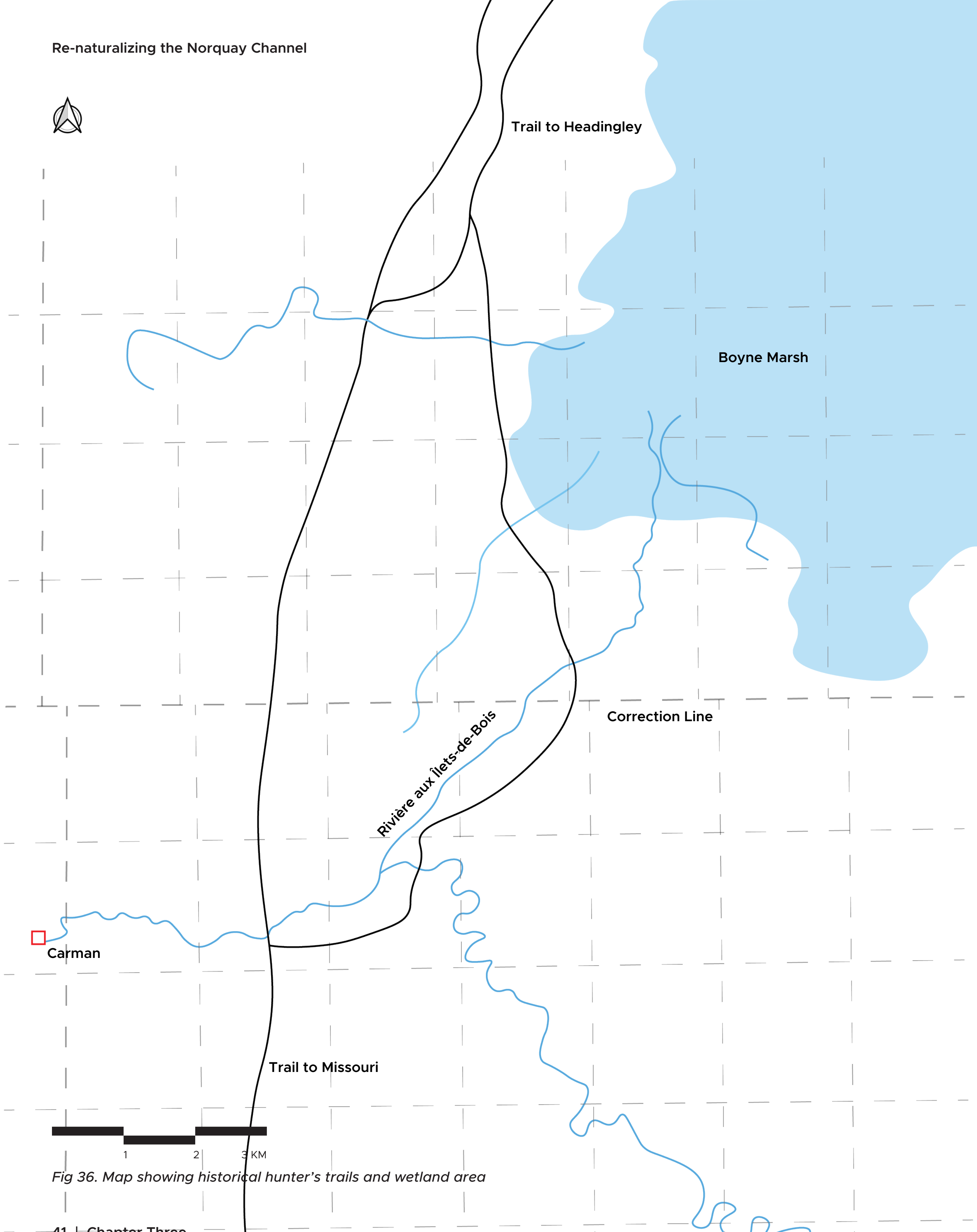


Fig 36. Map showing historical hunter's trails and wetland area

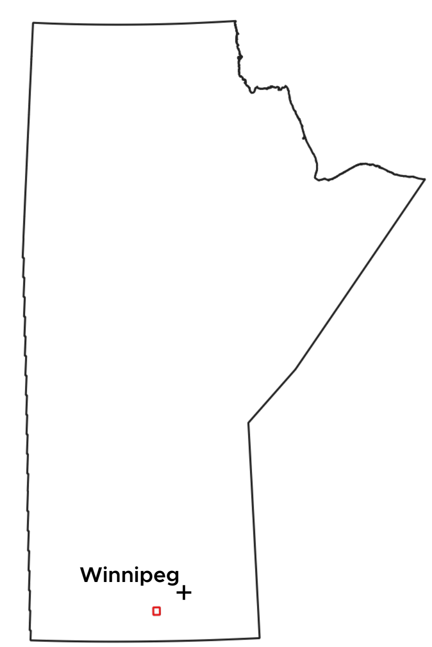


Fig 37. Extent of map over southern Manitoba

Prior to the 1872 Land Survey

Most historical accounts from settlements near the Norquay Channel date from after 1870, from homesteaders and recent settlers. Some information may also be extrapolated from the surveys that were completed for the purposes of settlement and agriculture.[60]

The most defining regional feature of the area is the Boyne River, which is fed by two tributaries that flow out of the western escarpment to later merge.[61] The river provided a means of transportation to Indigenous hunter-gathers as well as fresh water, medicinal plants, and small game.[62] The Boyne River was known as the Rivière aux Îlets-de-Bois to Mètis fur traders and buffalo hunters. It did not receive its current name until European settlers arrived around 1870.[63]

Another significant feature is the Boyne Marsh, previously known as the Great Marsh. This wetland once occupied land between the Missouri Trail on the west and the Red River on the east. The Rivière aux Îlets-de-Bois and a few other creeks drained into the wetland and caused extensive flooding during the spring melt.[64] The Missouri Trail was a major route for early Indigenous peoples travelling between the convergence of the Red and Assinboine Rivers, and the Missouri River. The trail followed the western edge of the Boyne Marsh and sat to the east of the escarpment. This same pathway was later used by fur traders and buffalo hunters. A river crossing for the Rivière aux Îlets-de-Bois was located about a mile and a half east of Carman.[65]

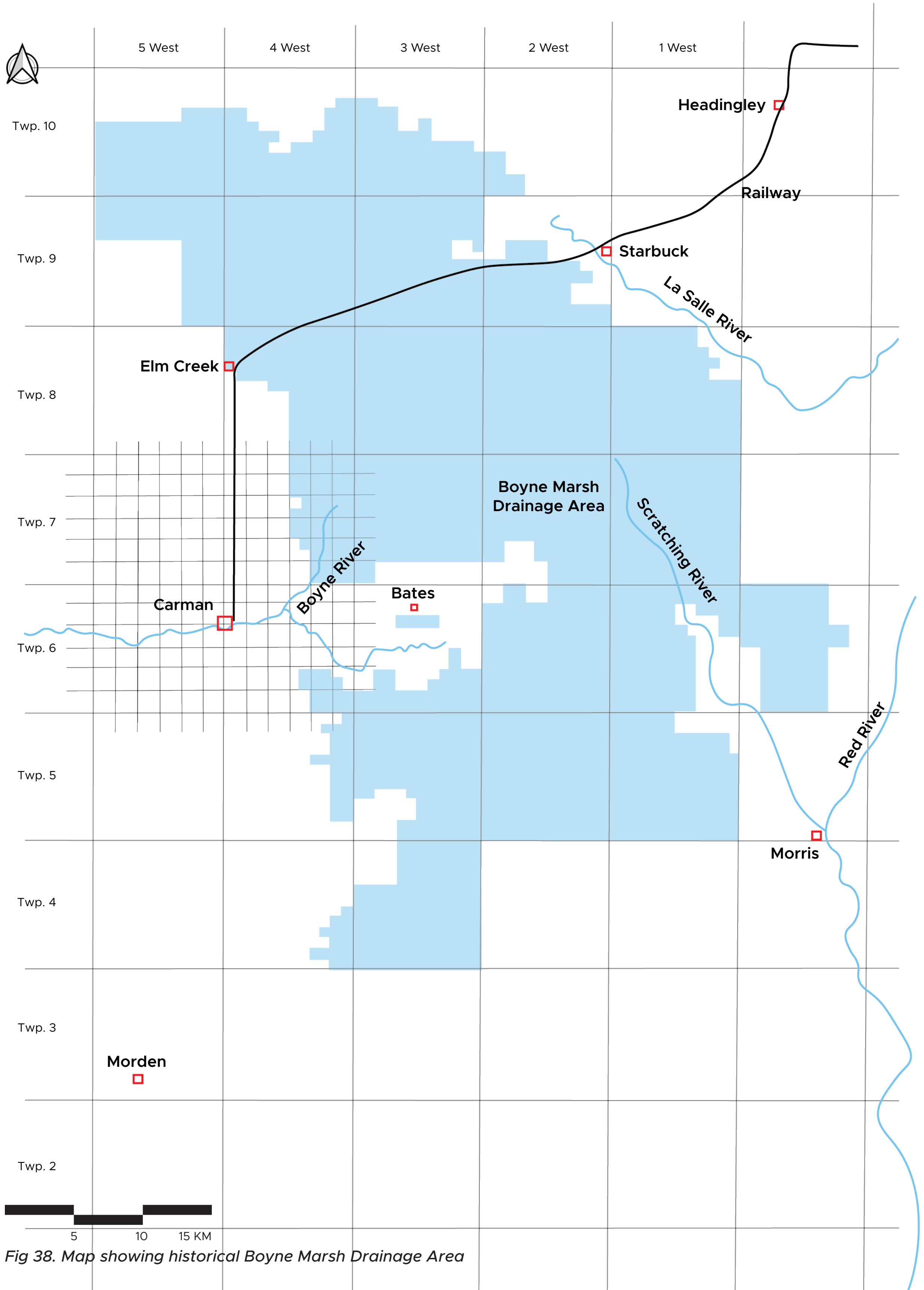


Fig 38. Map showing historical Boyne Marsh Drainage Area

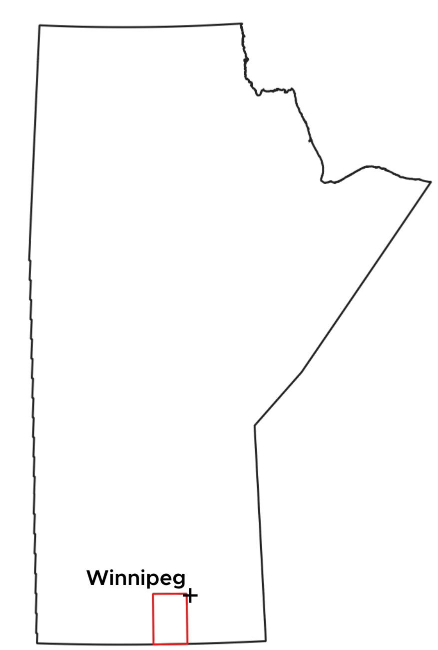


Fig 39. Extent of map over southern Manitoba

After European Settlement

As there were few roads in the area when Manitoba entered Confederation, newcomers from the south and east followed the Missouri trail to find land to settle. Due to tension over landownership with existing Catholic and Metis families, most families who had already lived in the area for several decades prior abandoned it, moving north of St. Daniel. The presence of the railroad network dictated the location and success of early settlements. Settlements that existed within the vicinity of the Norquay Channel, apart from Carman, included Barnsley, Bates, Campbellville, Homewood, and Salterville. Of these communities, only Barnsley and Homewood survived until present with the others shutting down in the first decade of the 20th century.[66] As the Boyne Marsh was drained and new land became available for agriculture, many Mennonite settlers from Russia and post-WWII Dutch came to the area.

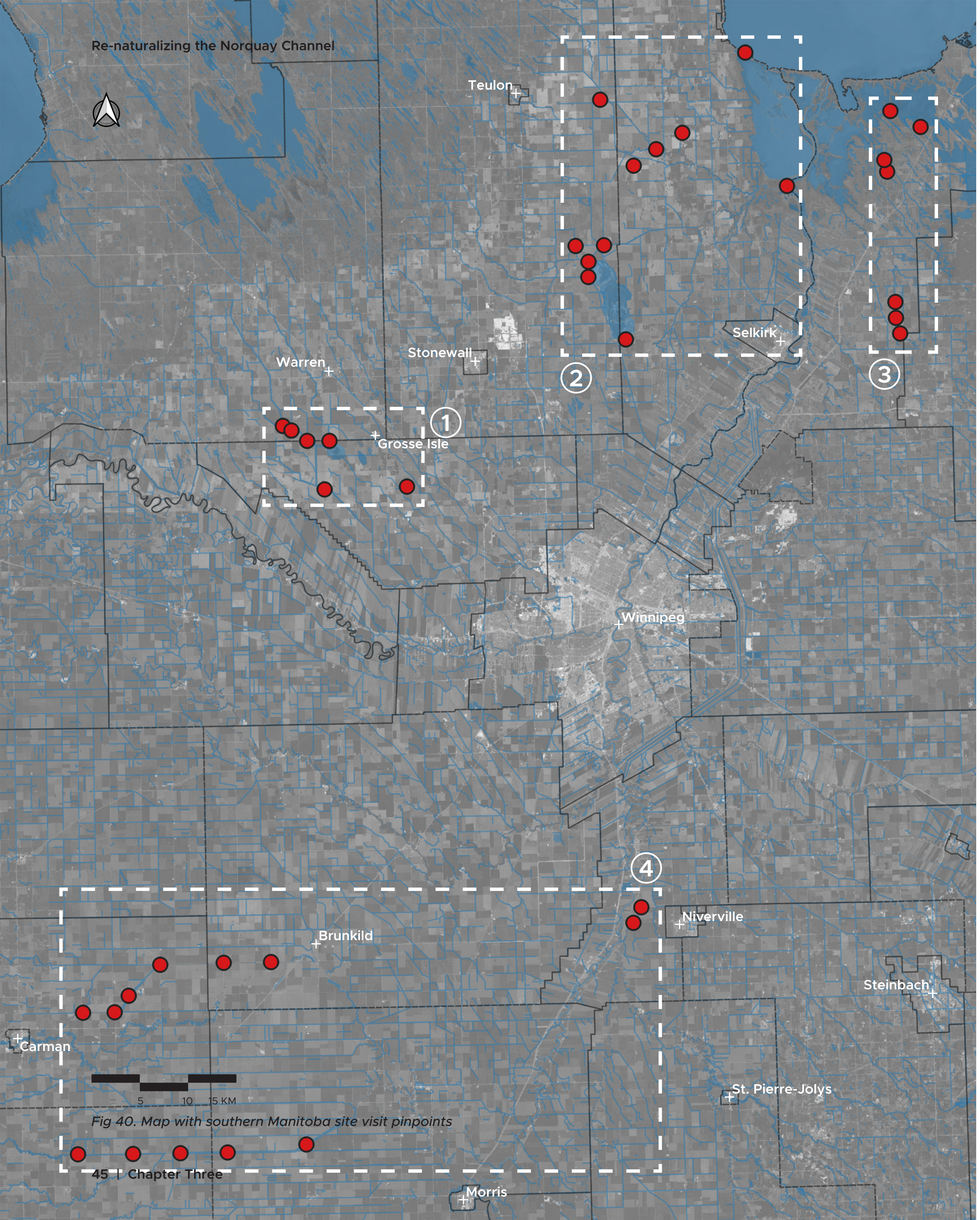


Fig 40. Map with southern Manitoba site visit pinpoints

Site Visits in Southern Manitoba

Several sites were visited in the southern part of province in late Winter 2023 (Figure 40), including Grant's Lake near Grosse Isle, Oak Hammock Marsh, Brokenhead Wetland Interpretative Trail, Netley Creek Provincial Park near Breezy Point, various sites west of Clandeboye, various sites north of Libau, various sites northeast of Selkirk, two spots along Provincial Road 200, the Tobacco Creek Channel, and finally the Norquay Channel. I was most drawn to the Norquay Channel and the Tobacco Creek Channel.

My initial interest in the Norquay Channel arose from the lack of wetland-related projects within the area around Carman. Grant's Lake, Oak Hammock Marsh, the Brokenhead Wetland Trail, and the Netley Creek Provincial Park already provide access to wetlands and wet prairies about an hour drive north of Winnipeg. I continued to visit both the Norquay Channel and Tobacco Creek Channel in March, April, and July 2023.

I picked the Norquay Channel because it has two water quality monitoring sites within the drainage area, which provided data on surface water quality. The Stephenfield Reservoir west of Carman ensures that the channel almost always has water even during all warmer months.[67] This quality seemed ideal for constructing a landscape that supports wetland ecosystems.[68] The area also has more agricultural activity than others.

① March 15, 2023

Grants Lake
Quarry Site
Various Drainage Waterways

② March 20, 2023

Oak Hammock Marsh
Teulon Lagoon
Chalet Beach
Ross Creek
Clandeboye Road
Netley Creek Provincial Park

③ March 22, 2023

Lynx Lane
Road 32 East Drain
Road 78 North Drain
Road 79 North Drain
Road 80 North Drain

④ March 23, 2023

Tobacco Creek
Norquay Channel
Niverville Controller North
Niverville Controller South

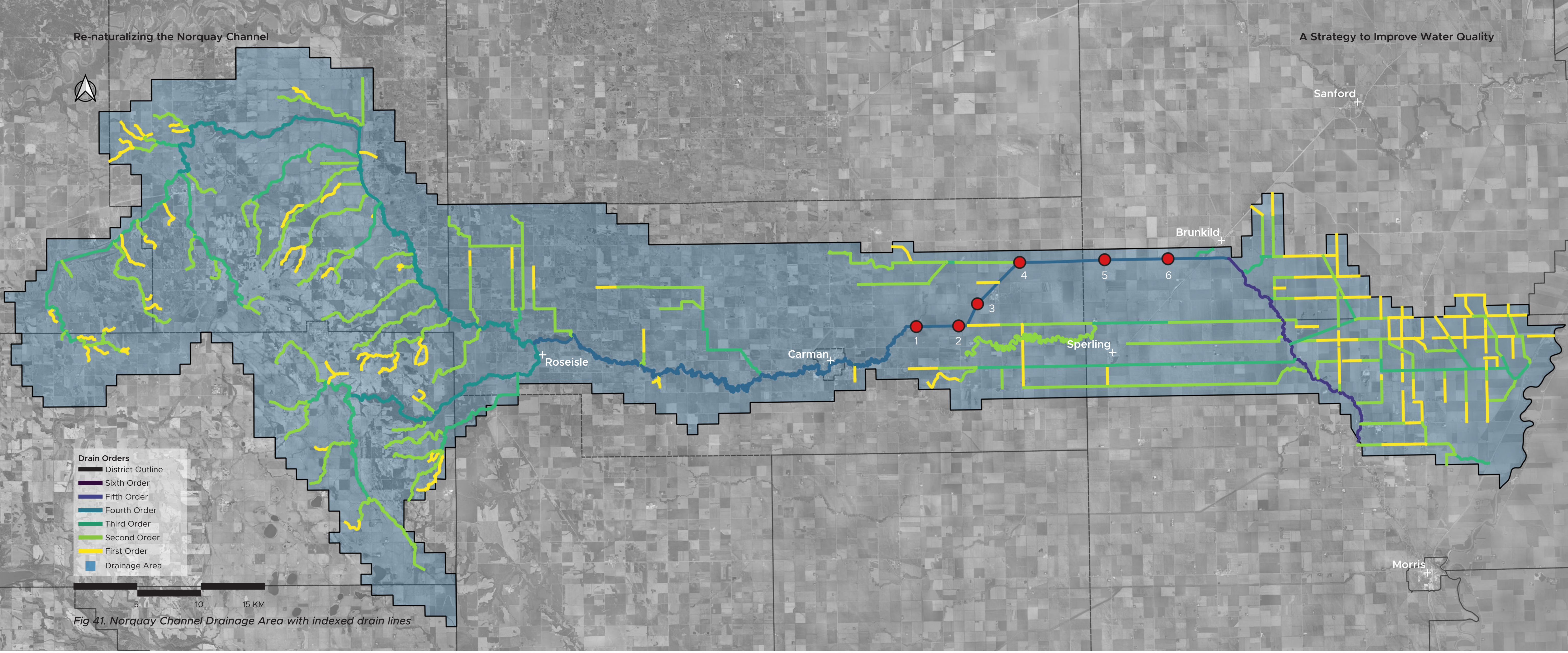


Fig 41. Norquay Channel Drainage Area with indexed drain lines

How the Norquay Channel Fits in the Landscape

The area around the Norquay Channel once consisted of the marsh wetlands of Boyne Marsh. Many historical accounts of the vicinity around the Norquay Channel come from the settlers who came to Carman or passed by it on the trail from Headingley to Missouri. The Boyne Marsh received inflow from the Boyne River, and the Morris River was the outlet for the wetland. The original drainage channel, constructed around the turn of the century to drain the Boyne Marsh and connect the Boyne River to the Morris River, was much smaller. There was no waterway connecting the Boyne and Morris Rivers prior to this intervention. The Norquay Channel, as we know it now, resulted from construction improvements made under the Agricultural Rehabilitation and Development Act (ARDA) in the 1960s. It serves as the main drainage channel for the entirety of the Norquay Channel Drainage District and receives flows from several smaller order tributaries and the Boyne River.

Norquay Channel Drainage District Site Visits

I visited six points along the Norquay Channel in March, April, and July 2023 to better understand the channel, its changing water level, and the changing views of the surrounding landscape. I determined an approximate composition of crops near the channel, which aided in understanding the agricultural practices of the area. Early in September, I visited another six spots where the width of the channel was the greatest to further consider a site for my design work. A final site visit to the original six points was completed in October 2023.

Fig 42. *Norquay Channel seasonal photo comparison at Road 36 North and Road 20 West*

Fig 43. Norquay Channel seasonal photo comparison at Road 36 North and Road 18 West

Fig 44. Norquay Channel seasonal photo comparison at Road 37 North

Six Site Visits Along the Norquay Channel

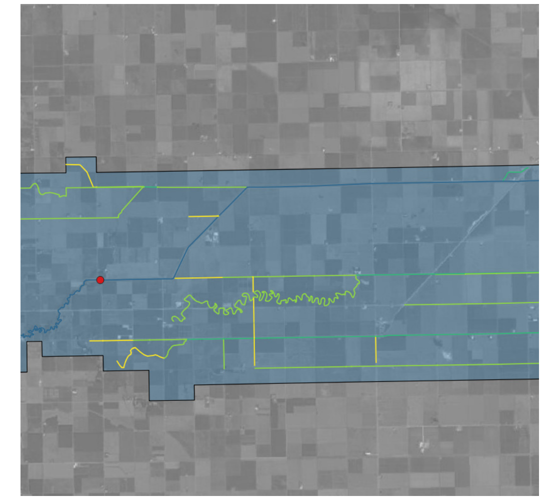


Fig 45. Site One context map

Site One

The first, west-most location, is at a channel crossing where Road 36 North and Road 20 West meet, about four miles east and one mile north of Carman near where the Carman Diversion meets the Norquay Channel. The artificial waterway starts here. What stood out to me most here was the channel width, around twenty-five meters. The density of the emergent vegetation along the lower edge of the water was still very noticeable in the winter and created a winter habitat for animals in the area. Although I did not witness any animals at the time, there were lots of recent tracks left behind by a small mammal.

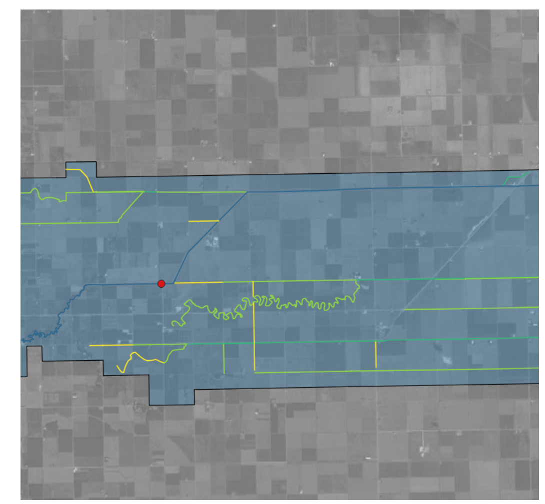


Fig 46. Site Two context map

Site Two

The second location is further east, where Road 36 North crosses Road 18 West, about six miles east and one mile north of Carman. The community of Homewood is a mile and a half due south, and Highway 3 runs east and west another half mile south. The channel width here was significant again; however, further north and east of this point the channel narrows out. The nearly thirty meters of open water and lack of emergent vegetation made it seem much more barren here in the summer and winter, leaving room for intervention involving emergent vegetation and creating habitats.

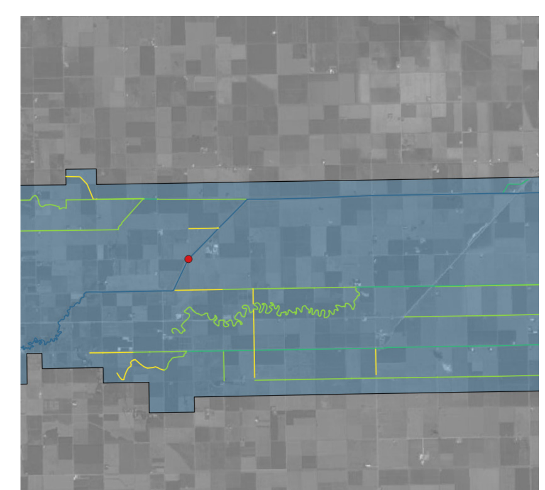


Fig 47. Site Three context map

Site Three

The third location, at a bend in Road 37 North, is just over a half mile from the Blooming Prairie Colony, and seven miles east and two miles north of Carman. There is no crossing here so the channel can only be viewed from one side. Within this area the channel begins to narrow gradually. There are no longer any control structures, but a few rock outcroppings slow the channel's flow.

March April July October

Fig 48. Norquay Channel seasonal photo comparison at Road 39 North and Road 15 West

Fig 49. Norquay Channel seasonal photo comparison at Road 39 North and Provincial Road 336

Fig 50. Norquay Channel seasonal photo comparison at Road 39 North and Road 8 West

Six Site Visits Along the Norquay Channel Continued

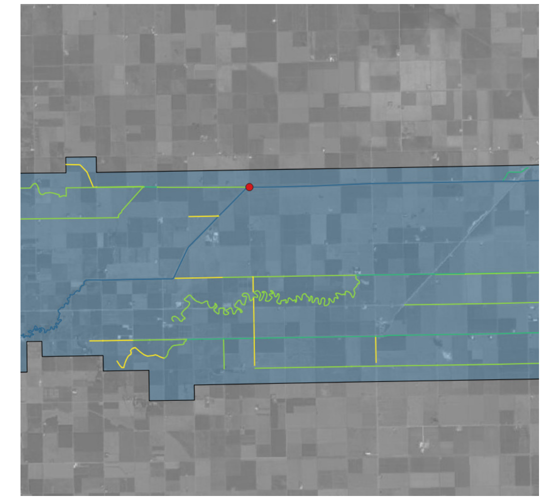


Fig 51. Site Four context map

Site Four

At the fourth location, northeast of the third site, the channel straightens out to the east. Located at the crossing of Road 39 North and Road 15 West, it is nine miles east and four miles north of Carman. The Carrothers Drain is a third-order drain that merges with the Norquay Channel, one of the only significant waterways that combines with the Norquay Channel. The channel continues to narrow further east of this point.

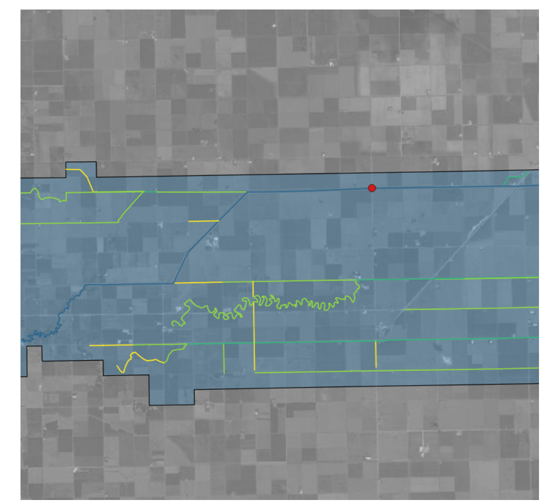


Fig 52. Site Five context map

Site Five

The fifth location at the crossing of Provincial Road 336 and Road 39 Northwest, thirteen miles east and four miles north of Carman, and six miles west and one mile south of Brunkild, is significantly narrower than previous sites. The constricting effect of the channel here causes the water to flow faster, although less volume is held, making spring melt water very prominent and the amount of open water more irregular than at the previous locations, and there is more emergent vegetation. The snow sloping here in the winter took an attractive shape due to the lack of vegetation breaking the flat surface. There was no evidence of the presence of animals.

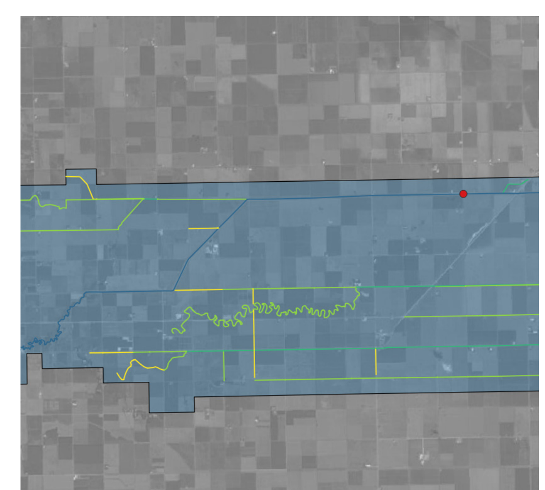


Fig 53. Site Six context map

Site Six

The sixth and final location at the crossing of Road 39 Northwest and Road 8 West, is sixteen miles east and four miles north of Carman, and three miles west and one mile south of Brunkild. The channel is at its narrowest here. As at the fifth site, the spring melt water fills the channel significantly, but the channel water is often scant during the summer. The channel width is much more irregular, with even more emergent vegetation. In the winter, at this portion of the channel, there was no visible vegetation with no evidence of animals.

Fig 54. Algae in channel due to stagnant water and high temps. July 2023

Fig 55. Culvert outlet on the Norquay Channel, April 2023

Fig 56. Foam build up from water turbulence, April 2023

Fig 57. Culvert outlet with dark field runoff on the Norquay Channel, April 2023

Surface Water Quality in the Norquay Channel

One of the major considerations in determining the design site's location was the need for water quality improvement. Two long-term water quality monitoring sites are located within the Norquay Channel Drainage area: one on the Boyne River in Carman in the west, and one on the Morris River at the east end. Samples have been taken from the Boyne River location every quarter since 1973. Samples from the Morris River location have been taken quarterly from 1988 to 1995 and from 2012 onwards.[69]

The water quality data for the Norquay Channel contains values that are both measured and calculated. Measured values consist of data collected straight from the sample, whereas calculated values are typically a combination of two or more measured values. I have included all values accessible to me for transparency to show that my selection was deliberate and that the other values were also reviewed simultaneously.

Measured values that were accessible include Ammonia, Dissolved Ammonia, Dissolved Inorganic Carbon, Dissolved Organic Carbon, True Colour, Conductivity at 25C, Nitrate (NO3-N), Nitrite (NO2-N), Dissolved Nitrogen (NO3 & NO2), Total Kjeldahl Nitrogen (TKN), Total Alkalinity (CACO3), Total Phosphorus, Biochemical Oxygen Demand, Dissolved Oxygen, pH, Dissolved Sulphate, Water Temperature, Total Dissolved Solids, Total Suspended Solids, and Turbidity.[70]

Calculated values include Alkalinity (CO3), Alkalinity (OH), Total Alkalinity (HCO3), Total Dissolved Carbon, Total Inorganic Carbon, Total Organic Carbon, Total Carbon, Total Hardness (CACO3), Acid Hydrolyzable Phosphorus, Total Nitrogen, and Particulate Phosphorus. Total Particulate Phosphorus is determined by subtracting the measured values of Total Phosphorus and Total Dissolved Phosphorus. This is separate from Total Inorganic Phosphorus and Total Reactive Phosphorus measurements.[71]

Although these stations sample general chemistry, nutrients, metals, bacteria, and pesticides, my main concern is nutrients that lead to eutrophication. For this reason, I have chosen to show only the Total Phosphorus, Total Nitrogen, Total Suspended Solids, and Total Dissolved Solids. Since the land within the Boyne-Morris watershed is primarily cropland, the main water quality concerns involve nutrient loading and salinity, which are influenced by fertilizers. The Boyne River was previously listed as a vulnerable water body, due to agricultural activity in the area, in the Nutrient Management Regulation under the Water Protection Act.[72]

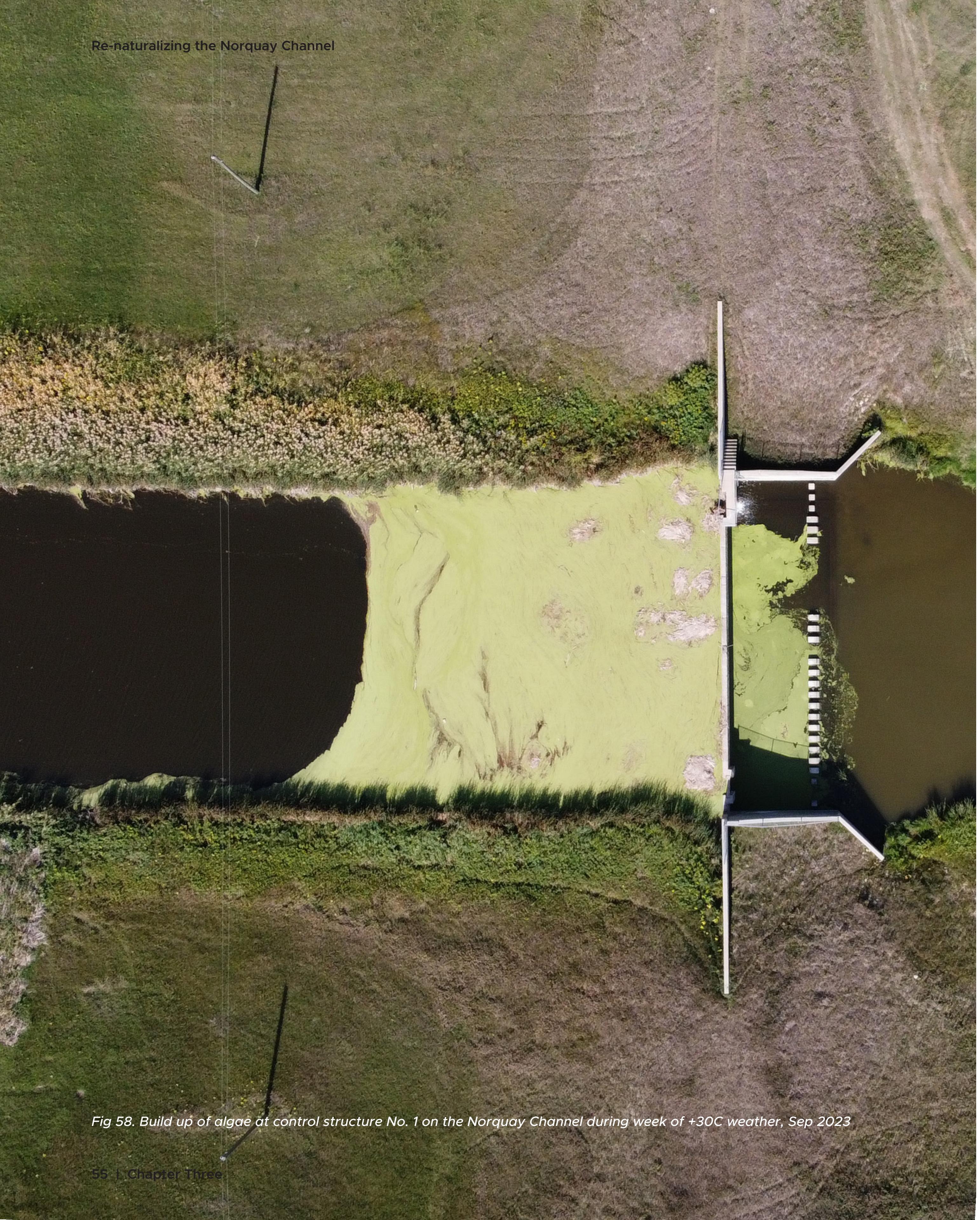


Fig 58. Build up of algae at control structure No. 1 on the Norquay Channel during week of +30C weather, Sep 2023

Water Quality Standards in Manitoba

There are three levels of consideration regarding water quality in Manitoba: Tier I Water Quality Standards, Tier II Water Quality Objectives, and Tier III Water Quality Guidelines. Tier I Water Quality Standards contain minimum standards for common classes of discharges in Manitoba and form the basis for best practices in treatment technologies.[73] Tier II Water Quality Objectives define restrictions for several common pollutants monitored through licensing under The Manitoba Environment Act. When additional restrictions are required to protect ground and surface water beyond what is specified in Tier I Water Quality Standards, these restrictions form the basis for water quality.[74] Tier III Water Quality Guidelines contain three general types of guidance:

1. They define several variables derived by the Canadian Council of Ministers of the Environment (CCME).
2. They contain tissue residue guidelines from Health Canada to protect those who consume fish or other aquatic life.
3. They contain narrative water quality guidelines, as it is unrealistic to provide numerical guidelines for all possible chemical, physical, or biological variables.[75]

Tier III Water Quality Guidelines are used to interpret ambient water quality data. Exceedances and long-term trends in ambient water quality data can be compared directly to the numerical water quality guidelines.[76] The numerical water quality guidelines can identify if ambient water can sustain specific uses, including drinking water, recreational activities, and irrigation.[77] Tier III Narrative Water Quality Guidelines contain values addressing nutrients, nuisance aquatic plants, and toxic algae. The most applicable value to this project is the measurement of total phosphorus to prevent eutrophication.

Tier II Water Quality Objectives provide restrictions for several water quality variables. Total Dissolved Solids and Total Suspended Sediments are the most applicable values to this project. These water quality variables apply to surface and groundwater for irrigation and wildlife.[78] Both Tier II Water Quality Objectives and Tier III Water Quality Guidelines provide values applicable to which I can compare the water quality of the Norquay Channel.

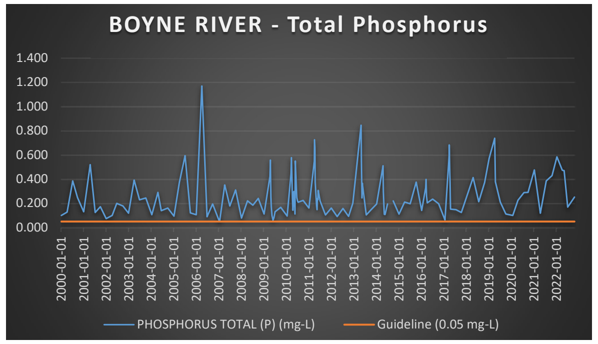


Fig 59. Boyne River Total Phosphorus, 2000 - 2022

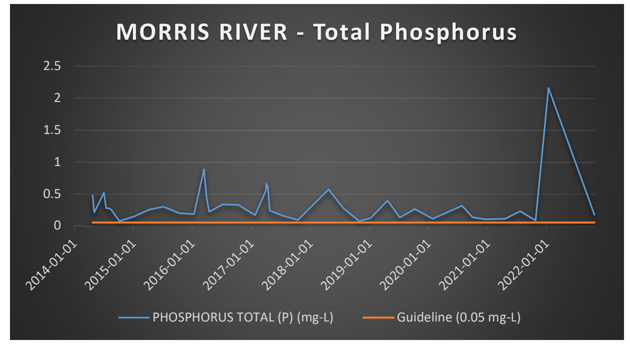


Fig 60. Morris River Total Phosphorus, 2014 - 2022

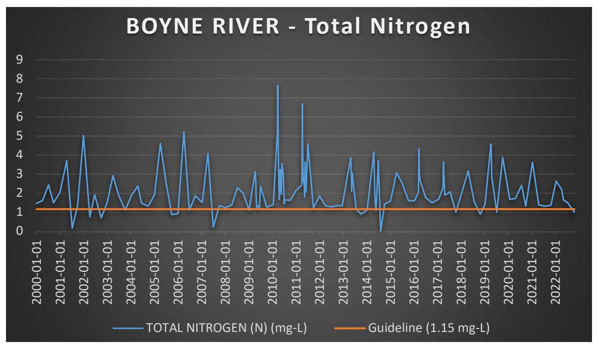


Fig 61. Boyne River Total Nitrogen, 2000 - 2022

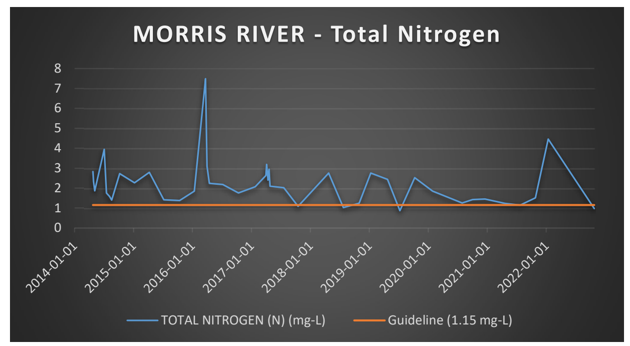


Fig 62. Morris River Total Nitrogen, 2014 - 2022

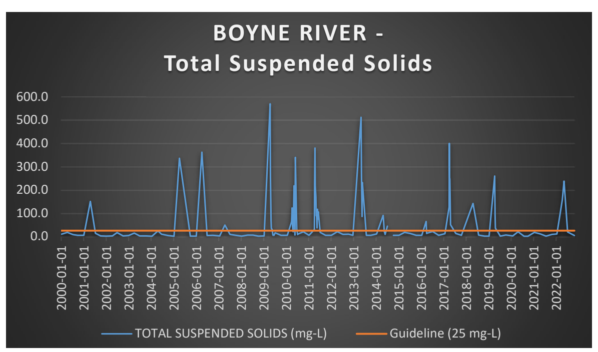


Fig 63. Boyne River Total Suspended Solids, 2000 - 2022

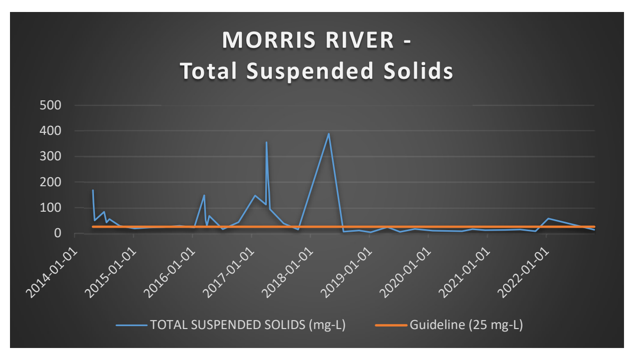


Fig 64. Morris River Total Suspended Solids, 2014 - 2022

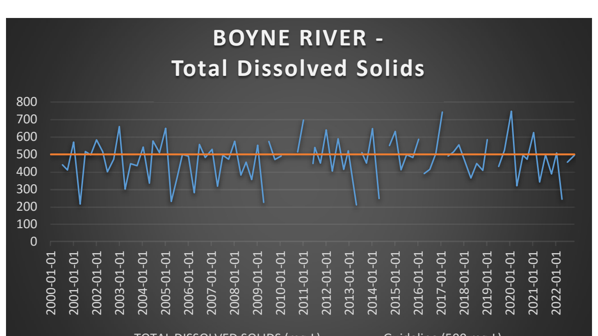


Fig 65. Boyne River Total Dissolved Solids, 2000 - 2022

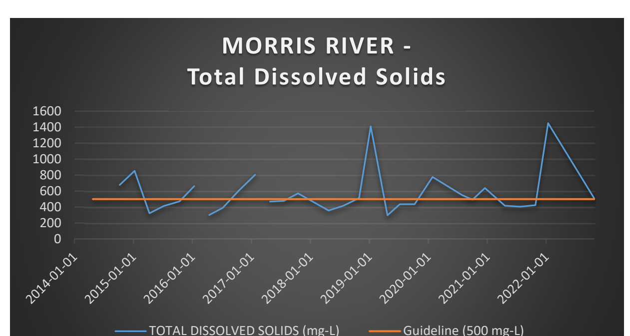


Fig 66. Morris River Total Dissolved Solids, 2014 - 2022

Water Quality Variables Relevant to this Project

As mentioned on Page 22, interannual and intra-annual hydrological variability is demonstrated in Figures 59 - 66. Most peaks observed in all four datasets coincide with spring melts and years with high amounts of precipitation in the summer. Samples that appear to be below the narrative guidelines were years with less snowmelt and precipitation, leading to lower water volumes and, therefore, lower amounts of nutrients. Most streams and rivers in southern Manitoba typically exceed the phosphorus guideline because high amounts of phosphorus naturally occur in adjacent soils, as well as in local human activities and land uses.[83]

Total Phosphorus

The annual mean total phosphorus concentration within the Boyne and Morris Rivers tends to exceed the narrative Manitoba water quality guideline for rivers of 0.05 mg/L. Total Phosphorus was calculated by adding total particulate phosphorus and total dissolved phosphorus.

Total Nitrogen

A nitrogen concentration target of 1.15 mg/L on the Red River has been proposed to lessen Lake Winnipeg's nutrient load. The annual mean total nitrogen concentration within the Boyne and Morris rivers has exceeded the narrative guideline of 1.15 mg/L.[79] Total Nitrogen was calculated by adding dissolved nitrogen (NO3 and NO2) and total Kjeldahl nitrogen (TKN).

Total Suspended Solids

Total Suspended Solids (TSS) refer to waterborne particles exceeding two microns in size; any smaller particles would be called total dissolved solids. TSS may comprise sediments, clay particles, algae, and bacteria.[80] A water body with a more significant amount of TSS may cause plant life and fish to die off as the water tends to be cloudier, blocking light.[81] Similar to the previous two datasets, the TSS is greater upstream in the Boyne River since the slower and stagnant water downstream allows suspended particles to settle.

Total Dissolved Solids

Total Dissolved Solids (TDS) refer to inorganic salts and small amounts of organic matter dissolved in water. TDS may comprise cations calcium, magnesium, sodium, and potassium and anions carbonate, bicarbonate, chloride, sulphate, and nitrate (from groundwater).[82] In drinking water, higher levels of TDS cause excessive hardness, unpalatability, mineral deposition, and even corrosion, whereas lower TDS levels affect water's palatability. TDS and guidelines for TDS depend on the parent material of the soils since some soils may tend to be higher in these minerals, leading to elevated readings.

Fig 67. Drone aerial of water control structure No. 2 on the Norquay Channel looking west

Design Site Selection Criteria

① Proximity to Amenities

The designed landscape should include interpretive qualities so visitors may learn about the wetlands, prairies, agriculture, and drainage during their visit. This site is about an hour drive from downtown Winnipeg and a twenty-minute drive from Carman, Brunkild, and Sperling.

② Accessibility

Located near an existing channel crossing and gravel mile-section roads, the site had to be accessible by vehicle for visitors and maintenance purposes.

③ Open Water

Some portions of the channel have more open water than others. This is due to the width of the channel and water control structures retaining water. Areas with a greater channel width tend to have slower water flow.

④ Existing Vegetation

Although part of the intention is to increase the opportunity for more emergent vegetation to establish, having some existing vegetation is beneficial as that implies there is already potential for animal habitat in the vicinity.

⑤ Evidence of Nutrients

Another intention of the design is to create an environment that mimics conditions found in marsh and fen landscapes with the purpose of treating the water by retaining suspended solids that carry nutrients, so the prolific growth of algae is an indication that the water is fairly nutrient-rich, and stagnant.

⑥ Channel Breadth

A moderate transition happens between portions of the channel with the greatest and least breadth. Locating an ideal spot along the channel where moderate changes in water depth would be observed throughout the year is essential for operating a wetland. During the spring, there should be a high water level, followed by a water level plateau over the summer and a reduction in water level into the fall.

Fig 68. Drone aerial of the Norquay Channel with approximate measurements

The Design Site

The chosen site is within an hour-long drive from downtown Winnipeg and a twenty-minute drive from Carman, Brunkild, and Sperling. It is within several miles of a few communities, meaning it is relatively accessible and close to local amenities. The amount of open water within the channel at the chosen site provides a desirable flow rate for diversion to a wetland. The flow rate and volume are just right, so erosion would be limited. Several tall grass prairie and wet meadow plant species were observed on site. With some existing desirable species, the proposed plant palette will enhance the vegetation on the chosen site. Algae appeared within the channel during multiple site visits, which indicates that nutrients are present in the water at the chosen site. Finally, the chosen site will be located where the channel experiences a transitional breadth. Distinct water levels will be experienced here with the changing seasons, allowing the wetland to operate with natural water level fluctuations.

Fig 69. View of Carrother's Drain facing west with vegetation, Sep 2023

Fig 70. Ditch outlet on the Norquay Channel, Jul 2023

Fig 71. Bale on berm of the Norquay Channel, Sep 2023

Fig 72. Berm of the Norquay Channel used for baling, Sep 2023

Fig 73. Stagnant water at one of the rock outcroppings on the Norquay Channel, Jul 2023

Fig 74. Unidentified egg near the Norquay Channel, Sep 2023

Fig 75. Drone aerial showing different channel widths by rock outcropping transition, Jul 2023

Fig 76. Drone aerial showing the channel convergence of the Carrother's Drain, Sep 2023

Fig 77. Water level difference at rock outcropping on the Norquay Channel, Jul 2023

Fig 78. Blackbirds were the most observed species during all seasons, Sep 2023

Fig 79. Farming equipment passing on the dike of the Norquay Channel, Sep 2023

Fig 80. Wet meadow grasses and mowed channel bank, Sep 2023

Fig 81. Evidence of channel flow on a minimally windy day, Sep 2023

Fig 82. Another bridge variation on the Norquay Channel, Jul 2023

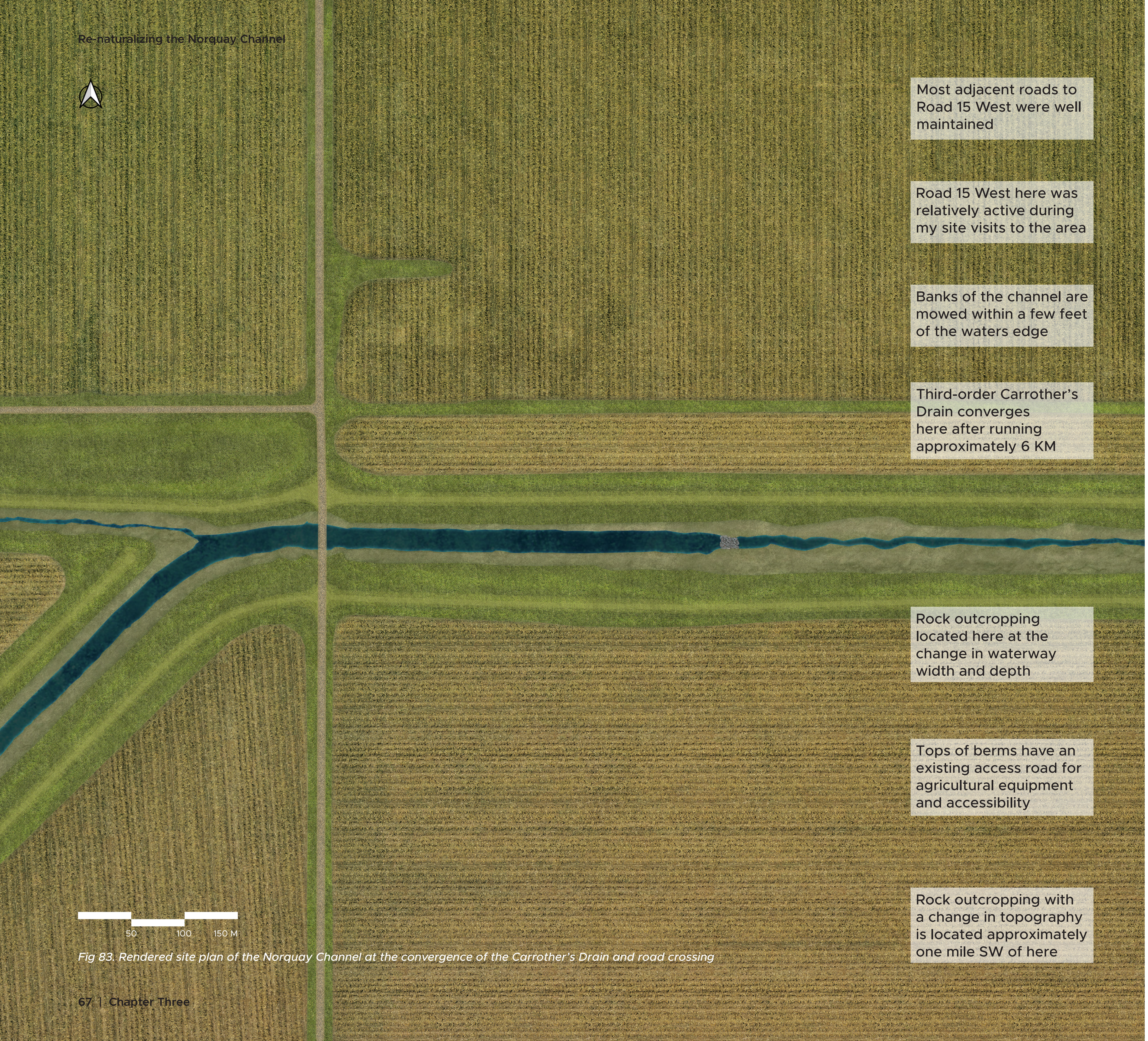


Fig 83. Rendered site plan of the Norquay Channel at the convergence of the Carrother's Drain and road crossing

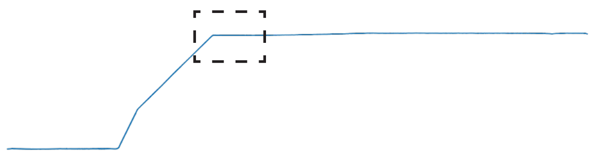
Norquay Channel Design Site

Strengths and Opportunities

This site has ample space with no adjacent residences, meaning minimal to no interference with existing structures is necessary. The topographical change is much more gradual in this area; the gradient control structures are rugged rock outcroppings that retain some water and slow the flow. This site is located within the transitional space between the widest and narrowest points, which allows the site design to show the possibility of the outcome of both conditions. No shelterbelts or tree clusters are within at least a half mile of the site, leaving opportunities for new tree plantings. The lack of additional topographic features means the site benefits from uninterrupted views across agricultural fields and unimpeded views of the sky. This site is relatively accessible from a well-maintained provincial road and from the highway.

Weaknesses and Threats

Some of the work to implement the design may require the road network to be modified around the site, and the present channel crossing used often, so maintaining it would be necessary. A potential threat here is the Carrothers Drain, which converges with the channel as it straightens towards the east. Finding an ideal way to blend it into the site design will be essential.



Existing Site Plant Species Observations

The following plant and animal species were observed during five site visits. The illustrated section below provides an example of the existing channel elevation in relation to the adjacent agricultural land. The vertical scale is exaggerated for the purpose of clearly communicating the difference in height of the channel, berm, and dike.

Fig 84. Agricultural Plants

Emergent Plants

Calamogrotis canadensis (Marsh Reed Grass)
Glyceria grandis (Tall Manna Grass)
Juncus effusus (Rush Grass)
Phragmites australis (Common Reed)
Schoenoplectus spp. (Bulrush)

Fig 85. Emergent Plants

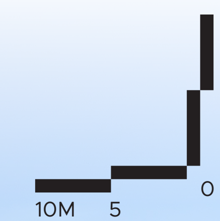
Agricultural Plants

Brassica napus (Canola)
Glycine max (Soybean)
Helianthus annuus (Sunflower)
Hordeum vulgare (Barley)
Pisum sativum (Field peas)
Zea mays (Field Corn)

Fig 87. Upland and Wet Meadow Species

Low Prairie / Upland Plant Zone

Asclepias syriaca (Common Milkweed)
Cirsium arvense (Canada Thistle)
Deschampsia caespitosa (Tufted Hairgrass)
Medicago sativa (Alfalfa)
Melilotus Albus (White Sweet Clover)
Melilotus indicus (Sweet Clover)
Rumex crispus (Curled Dock)
Schizachyrium scoparium (Little Bluestem)
Solidago canadensis (Canadian Goldenrod)
Symphoricarpos occidentalis (Western Snowberry)
Symphyotrichum leave (Smooth Aster)
Veronica serpyllifolia (Thyme-Leaved Speedwell)



Animal Species on Site

Agelaius phoeniceus (Red-winged Blackbird)
Anas platyrhynchos (Mallard Ducks)
Euphagus carolinus (Rusty Blackbird)
Zenaida macroura (Mourning Dove)
Ondatra zibethicus (Muskrat)

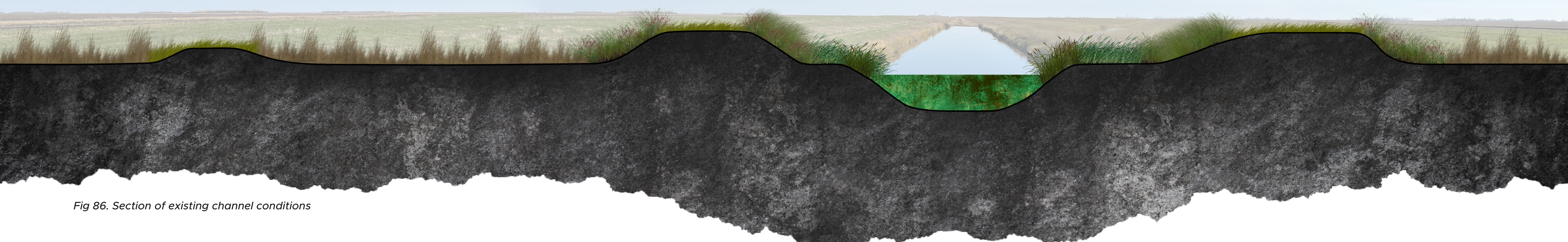


Fig 86. Section of existing channel conditions

Chapter Three Endnotes

60 “Boyne River (rivière aux îlets -de-Bois)” Carman-Dufferin Heritage, accessed November 21, 2023, https://carmandufferinheritage.ca/pdfs/Boyne%20River%20history%20expanded%20version.pdf. 3.
61 “Boyne River (rivière aux îlets -de-Bois)” Carman-Dufferin Heritage. 4.
62 “Boyne River (rivière aux îlets -de-Bois)” Carman-Dufferin Heritage. 3.
63 Carman/Dufferin Municipal Heritage Advisory Committee. “Boyne Marsh.” Local Heritage Special Places, accessed November 21,2023, https://carmandufferinheritage.ca/local%20heritage/special%20places/loc-her-spec-pl.html.
64 Carman/Dufferin Municipal Heritage Advisory Committee. “Boyne Marsh.” Local Heritage Special Places, accessed November 21,2023, https://carmandufferinheritage.ca/local%20heritage/special%20places/loc-her-spec-pl.html.
65 “Boyne River (rivière aux îlets -de-Bois)” Carman-Dufferin Heritage, accessed November 21, 2023, https://carmandufferinheritage.ca/pdfs/Boyne%20River%20history%20expanded%20version.pdf. 5.
66 June M. Watson. The rural municipality of Dufferin, 1880-1980 (Carman, Man.: Council of the Rural Municipality of Dufferin, 1982), 38-40.
67 Cited from Discussion with Daniel Rheault on 15 May 2023.
68 Cited from Discussion with Daniel Rheault on 15 May 2023.
69 Water Quality Management Section, Sustainable Development. “Water Quality Investigations and Routine Monitoring.” Boyne-Morris Watershed Integrated Watershed Management Plan – Water Quality Report, April 2017, https://www.gov.mb.ca/sd/water/watershed/iwmp/boyne/documentation/boynemorris_wq_sub.pdf. 2.
70 Water Quality Management Section – Manitoba Environment and Climate. Boyne and Morris River / General Chemistry and Nutrients, May 29, 2023.
71 Water Quality Management Section – Manitoba Environment and Climate. Boyne and Morris River / General Chemistry and Nutrients, May 29, 2023.
72 Water Quality Management Section, Sustainable Development. “Water Quality Investigations and Routine Monitoring.” Boyne-Morris Watershed Integrated Watershed Management Plan – Water Quality Report, April 2017, https://www.gov.mb.ca/sd/water/watershed/iwmp/boyne/documentation/boynemorris_wq_sub.pdf. 2.
73 Manitoba Water Stewardship. “Tier I - Water Quality Standards.” Manitoba Water Quality Standards, Objectives, and Guidelines, November 28, 2011, https://www.gov.mb.ca/sd/pubs/water/lakes-beaches-rivers/mb_water_quality_standard_final.pdf. 2.
74 Manitoba Water Stewardship. “Tier II - Water Quality Objectives.” Manitoba Water Quality Standards, Objectives, and Guidelines, November 28, 2011, https://www.gov.mb.ca/sd/pubs/water/lakes-beaches-rivers/mb_water_quality_standard_final.pdf. 9.
75 Manitoba Water Stewardship. “Tier III - Water Quality Guidelines.” Manitoba Water Quality Standards, Objectives, and Guidelines, November 28, 2011, https://www.gov.mb.ca/sd/pubs/water/lakes-beaches-rivers/mb_water_quality_standard_final.pdf. 40.
76 Manitoba Water Stewardship. “Tier III - Water Quality Guidelines.” Manitoba Water Quality Standards, Objectives, and Guidelines, November 28, 2011, https://www.gov.mb.ca/sd/pubs/water/lakes-beaches-rivers/mb_water_quality_standard_final.pdf. 40.
77 Manitoba Water Stewardship. “Tier III - Water Quality Guidelines.” Manitoba Water Quality Standards, Objectives, and Guidelines, November 28, 2011, https://www.gov.mb.ca/sd/pubs/water/lakes-beaches-rivers/mb_water_quality_standard_final.pdf. 44.
78 Manitoba Water Stewardship. “Tier II - Water Quality Objectives.” Manitoba Water Quality Standards, Objectives, and Guidelines, November 28, 2011, https://www.gov.mb.ca/sd/pubs/water/lakes-beaches-rivers/mb_water_quality_standard_final.pdf. 27.
79 “Nutrient Concentration and Loading Targets for Lake Winnipeg and its Tributaries.” A Proposed Regulation under the Water Protection Act, Winter 2020. https://www.gov.mb.ca/sd/pubs/water/lakes-beaches-rivers/nutrient_targets_regulation_plain_language_summary_fall_2020.pdf. 7.
80 Campbell, Brian. “What Is Total Suspended Solids (TSS)?” Wastewater Digest, July 12, 2022. https://www.wwdmag.com/utility-management/article/10939708/what-is-total-suspended-solids-tss.
81 “Total Suspended Solids (TSS) and Total Dissolved Solids (TDS).” DataStream, accessed November 21, 2023, https://datastream.org/en-ca/guidebook/total-suspended-solids-tss-and-total-dissolved-solids-tds.
82 Health Canada. “Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Total Dissolved Solids (TDS).” Government of Canada, August 21, 2009. https://www.canada.ca/en/health-canada/services/publications/healthy-living/guidelines-canadian-drinking-water-quality-guideline-technical-document-total-dissolved-solids-tds.html.
83 Water Quality Management Section, Sustainable Development. “Water Quality Investigations and Routine Monitoring.” Boyne-Morris Watershed Integrated Watershed Management Plan – Water Quality Report, April 2017, https://www.gov.mb.ca/sd/water/watershed/iwmp/boyne/documentation/boynemorris_wq_sub.pdf. 4.

Page Left Blank Intentionally

Page Left Blank Intentionally

Chapter Four

Re-naturalizing the Norquay Channel

The primary and secondary design objectives provide an end goal for the design. Design considerations include land ownership, water depths and flow rates, and vegetation hardiness help guide the design process. A few precedents, including Wolverton Creek in Minnesota, Boston's Emerald Necklace in Massachusetts, the Brokenhead Wetland Trail, and the Niverville Lagoon Decommissioning in Manitoba, provide examples of water quality improvements, biodiversity improvements and interpretation that influence my design. Preliminary design work included sketchbook drawings, water flow modelling, and topographic form plans. The final design resulted from many iterations and revisions to achieve the desired result.

Fig 88. Facing the wetland on the south side of the channel

Fig 89. View of boardwalk path, trees, and wet meadow vegetation

Primary Design Objective

Water Quality Improvement

The primary design objective is to improve the Norquay Channel's water quality. This involves manipulating the form of the landscape and devising a plant palette to retain and absorb nutrients that would otherwise later lead to eutrophication. Phosphorus and nitrogen are the primary nutrients that lead to eutrophication in the waterway. Water quality is improved by purposefully diverting and slowing down some of the water, allowing suspended solids to settle in a sedimentation pond, and by increasing the surface area and creating a more gradual slope. Increasing the water-to-bank contact to get more plants to interact with more water.

Secondary Design Objectives

Biodiversity Improvement

Wetlands facilitate the growth of diverse vegetation due to water's changing levels at different times of the year. Diverse vegetation creates a desirable environment for different animal species to inhabit. Although many existing plant species on site will be maintained, additional species will be necessary to enhance the wetland and adjacent spaces. A list of the proposed plant species is provided on Page 106.

Recreational / Interpretative Qualities

A space such as this, offering ecological services and varying plant species, will allow people to visit and learn about the components and functions of the landscape before them. This project would be a significant addition as there are no other constructed wetlands southwest of Winnipeg. Being close to several smaller communities and the population center of Carman, there would be amenities nearby, making it a great recreational spot to visit year-round.

Promoting Irrigation Access

The primary function of the Norquay Channel is to remove excess water from agricultural lands during high precipitation or periods of melt, while simultaneously providing a canal for water to be drawn from for irrigation and stock water. Maintaining water access for irrigation will become increasingly important as climate change continues to create highly variable conditions across the years and seasons.

Design Considerations

Several factors could affect the outcome of the intervention.

Land Ownership

The channel is considered provincial land. The drainage infrastructure, including control structures, berms, and dikes are under provincial control. Agricultural parcels and some mixed individual residential and agricultural land parcels are adjacent to the channel. Since additional land is necessary to construct a wetland, it would be necessary to take land from these adjacent properties. Compensation for utilizing this land might be sorted through the incentives portion of the GROW program.[84] The intention is to use minimal agricultural land to maintain productivity and encourage wider acceptance of the proposal.

Seasonal Maintenance

Currently, the Norquay Channel receives minimal maintenance. Once a year, the channel stages and slopes are mowed and receive a spray for Tier II noxious weeds.[85] The design is intended to further limit maintenance and allowing the environment to maintain itself through fluctuations in water level and a broad plant palette.

Water Level Variance

The Norquay Channel is currently designed to withstand a 1-in-10-year water event. Spring melts usually reach the channel's maximum water flow and volume so the dikes on either side of the channel become necessary.[86] The same occurs during a heavy rain event in the summer. The high water level of the channel is approximately at the same elevation as the surrounding prairie and rarely exceeds it.[87] In the future, it is expected that there may be more weather extremes, therefore, more chances of regional droughts and floods. A waterway made adaptable to flooding and droughts by utilizing topographic water retention and natural control mechanisms is necessary.

Water Flow and Volume

A few different conditions currently exist along the Norquay Channel. To the west is a very wide section, then moving east, a transitional portion, and then significant narrowing for the final eight miles. Where the channel is widest, the flow rate tends to be slower; the constriction of the narrower part leads to a higher flow rate. This same constriction effect was observed during water flow and soil erosion experiments (see page 87 - 88). Controlling the speed will be necessary to prevent unnecessary erosion of the banks and other landforms around the channel.

Plant Palette and Hardiness

The 1961-1990 Canadian plant hardiness map shows the Norquay Channel area as being on the cusp between 3a and 3b.[88] According to the 1981-2010 Canadian plant hardiness map, the area around the Norquay Channel would be classified as somewhere between 3b and 4a.[89] As the climate continues to shift, so does the plant hardiness zone of the region. Preparing for change over the next century plants will be introduced that can adapt to the shifting zones. It is anticipated that some will be lost, but others will take their place.

Change in Form Over Time

The channel has existed in its current form for around sixty years, experiencing minimal change due to erosion. The amount of water expected on the site will vary yearly, meaning the flow rates will also vary. This means that some form of erosion control, such as a geotextile, will be necessary to prevent potential loss of integrity. The proposed sedimentation pond will need to be dredged after a certain period to continue functioning since sediments are expected to build up. The general linear nature of the channel will remain to ensure that it continues to operate as intended, apart from this intervention.

Fig 90. Convergence of the Norquay Channel and Carrother's Drain from Road 15 West bridge crossing looking west

Precedent One: Wolverton Creek Restoration

Minnesota, USA

Like the Norquay Channel, Wolverton Creek was previously cleared and canalized to improve drainage from adjacent agricultural land. Efforts were made to redevelop the creek to address habitat loss, flooding, and erosion. The creek was given an easement and constructed with a meandering form to increase interactions between the water and vegetation and provide habitat. This project was part of an entire watershed improvement initiative to address problematic waterways that are no longer functioning optimally. Many improvements to Wolverton Creek were based on the Mustinka River project, which suffered similar problems. Both waterways are part of the Upper Red River sub-basin in Minnesota.

Fig 91. Aerial view of Wolverton Creek

Size: Approximately 1.7 SQ KM

Wetland Functionalities:

- Flood Mitigation
- Water Filtration

Vegetative Functionalities:

- Corridor Connectivity
- Erosion Control
- Native Plantings

Precedent Two: Niverville Lagoon Decommissioning

Manitoba, CA

The Niverville Lagoon Passive Decommissioning is one of Native Plant Solutions' many projects. The decommissioning of the lagoon was facilitated through bio- or phyto-remediation through a wetland design, one of the first of its kind. Native plant species help remove and break down the contaminants within the soil and water on site. The site has now been tied in as an extension of an existing park and birdwatching area. This project exemplifies how infrastructure may be adapted to become part of a greater wetland ecosystem and habitat through careful plant species selection. (Source)

Fig 92. Decommissioned lagoon cell in Niverville

Size: Approximately 0.86 SQ KM

Wetland Functionalities:

- Flood Mitigation
- Water Retention
- Wildlife Habitat

Vegetative Functionalities:

- Bio-remediation
- Phyto-remediation
- Native Plantings

Precedent Three: Brokenhead Wetland Trail

Manitoba, CA

The Brokenhead Wetland Interpretative Trail preserves an ecologically and culturally significant calcareous fen and cedar bog. To minimize ecosystem disruption, a low-impact boardwalk system on the ground surface allows visitors to traverse the wetland and get close to the ecosystem. Plaques and podiums provide information on the plants and landscape features being showcased along the boardwalk, and rest points allow visitors to sit and enjoy their surroundings. The boardwalk system was also installed over the winter to minimize the disruption that construction during the warmer months could have caused.

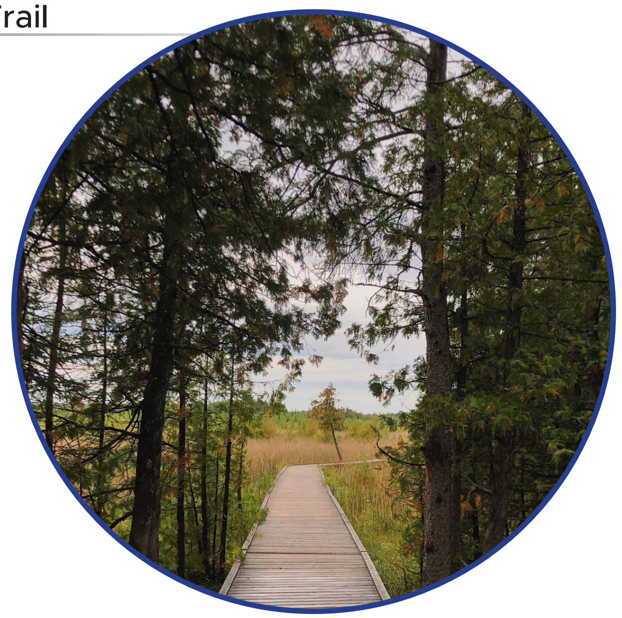


Fig 93. Boardwalk on the Brokenhead Wetland Trail

Size: Approximately 1.3 SQ KM

Wetland Functionalities:

- Water Filtration
- Ground Infiltration
- Carbon Sequestration

Vegetative Functionalities:

- Habitat Preservation
- Erosion Control

Precedent Four: Boston's Emerald Necklace

Massachusetts, USA

Boston's Emerald Necklace is a connected park system that Frederick Law Olmsted designed between the late 1870s and 1890s. The original waterway running through the park system contained hazardous waste and other runoff from adjacent land. The area was also susceptible to flooding, which made it clear that something would have to be done to improve the waterway. The park chain serves as one of the earliest examples of green infrastructure. The primary goal of the park system is to retain and filter stormwater while also providing space for native vegetation and tree species. The collection of parks utilizes organic materials such as stone, soil and plants to filter water and absorb pollutants.

Fig 94. Aerial view of part of Boston's Emerald Necklace

Size: Approximately 4.5 SQ KM

Wetland Functionalities:

- Water Retention
- Water Infiltration

Vegetative Functionalities:

- Permeable Surfaces
- Native Plantings
- Increased Tree Plantings


Fig 95. Decommissioned Niverville Lagoon


Fig 96. Wolverton Creek

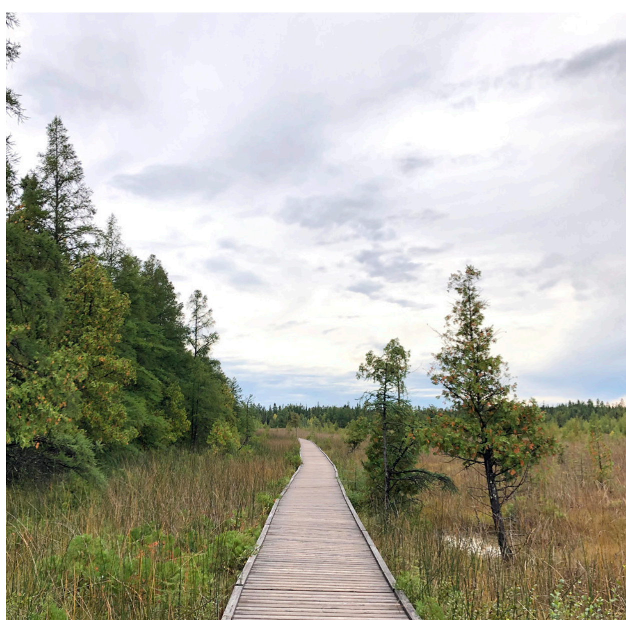


Fig 97. Brokenhead Wetland Trail

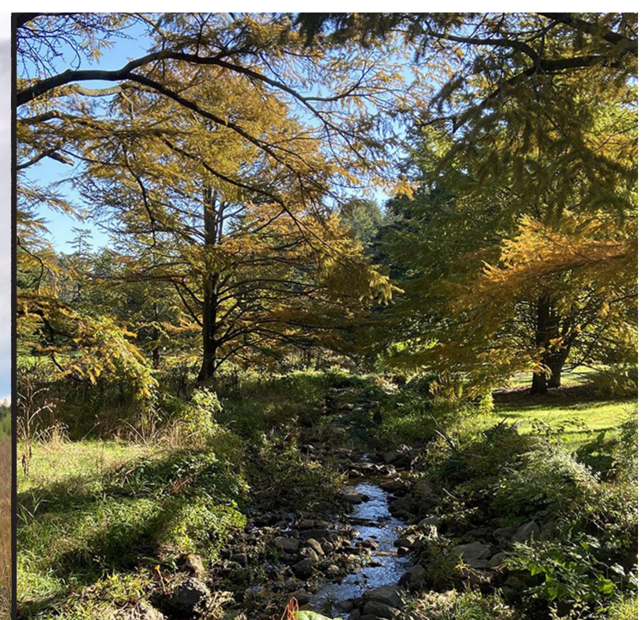


Fig 98. Part of Boston's Emerald Necklace

Reflection on Precedents

Precedents were chosen that could inform both ecological and design decisions. Climates and physical contexts were similar to those of the Norquay Channel site. Each project included features involving one or more of my design objectives. These projects have been indicated as effective in meeting their goal and performing as expected.

As wetland restoration designs, the Wolverton Creek and closely related Mustinka River projects have contexts and objectives similar to my project on the Norquay Channel. Both the Mustinka River and Wolverton Creek were canalized waterways that suffered from erosion and poor water quality. Their design objectives prioritized overland flood reduction, minimal erosion, improved water quality, and improved wildlife habitat by including more native plantings.

The Niverville Lagoon Passive Decommissioning project, located in Manitoba, involves the retirement of a wastewater treatment lagoon through bio- or phyto-remediation and a carefully crafted native plant selection. This project incorporates native plant species to help break down water and soil contaminants. This idea can be applied in the Norquay Channel. The lagoon's form did not change, meaning that plant selection was crucial in removing contaminants from the soil and water on site. The Niverville Lagoon project demonstrates how water-related infrastructure can be adapted and re-naturalized over time.

Regarding recreational and interpretive aspects, I considered the design of the Brokenhead Wetland Interpretive Trail. The trail provides informational plaques and podiums explaining the unique plants and landscape features that can be observed on either of its sides. After visiting the site several times, I have noticed that people always comment on the unique experience of walking through that wetland landscape. This is the sort of experience I intend to facilitate in my site design on the Norquay Channel. The boardwalk's construction provides an example of a system that could be used in parts of my site design, as I wanted to minimize interference on the landscape.

Several parks are connected within the Boston Emerald Necklace and work collectively to maintain water quality and provide visitors with park space. That idea partly inspired a local and regional intervention based on my site design. Multiple sites similar in nature to the one I am designing could be located all along the Norquay Channel and other artificially straightened waterways within the Red River Valley. Collectively, they would address flood mitigation, water quality improvements, and biodiversity improvements and provide visitors with recreational and educational sites.

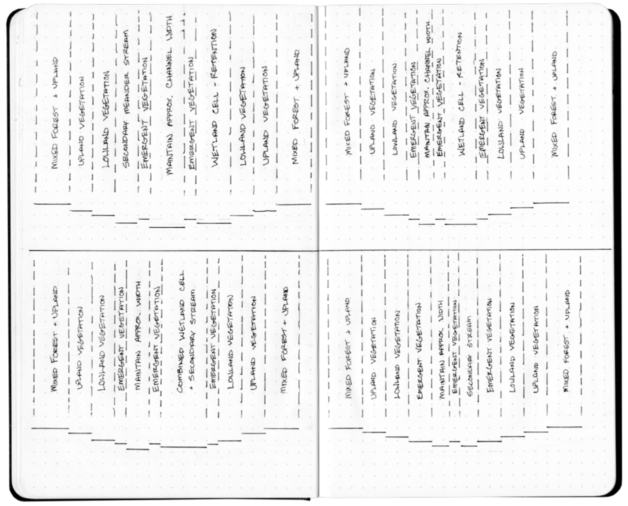


Fig 99. First iteration of zoning proportions

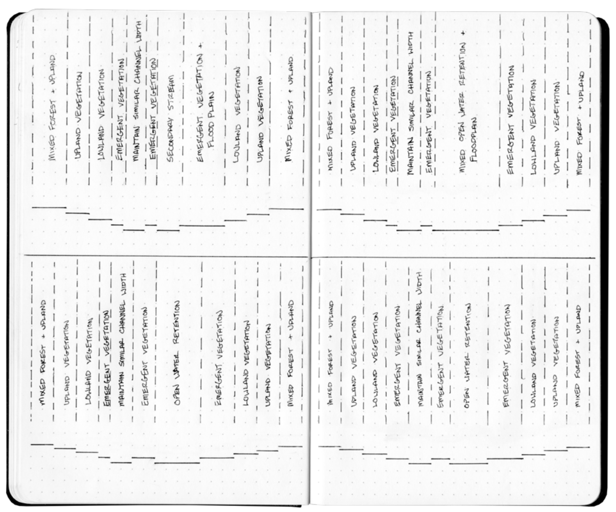


Fig 100. Second iteration of zoning proportions

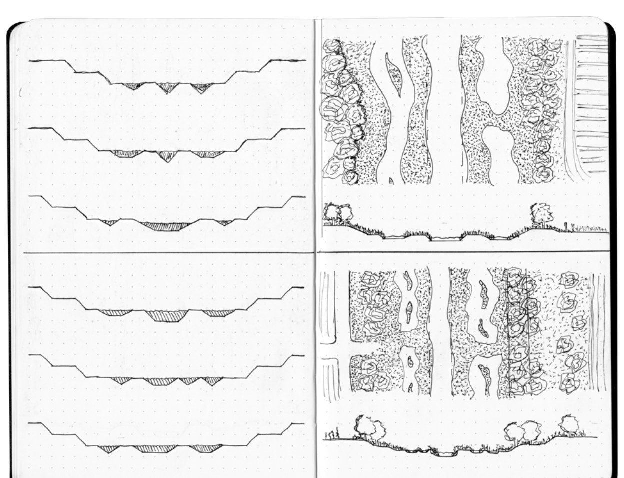


Fig 101. Initial sections prioritizing horizontal proportions

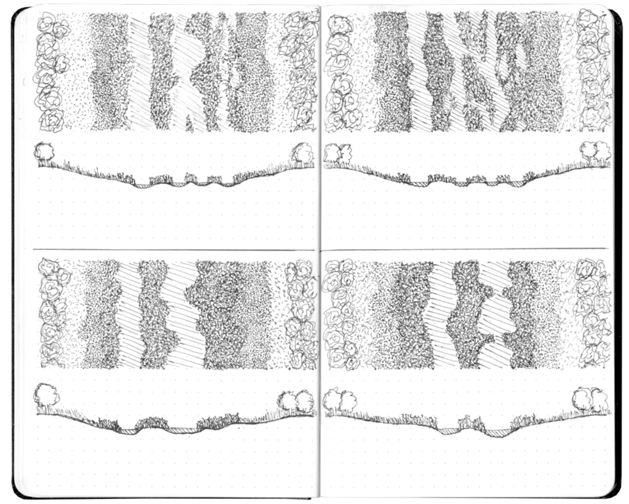


Fig 102. Experimental channel proportions

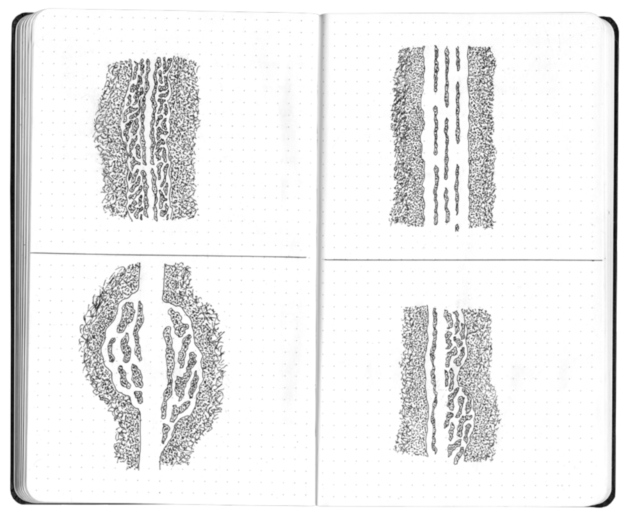


Fig 103. Experimental plans with vegetation "islands"

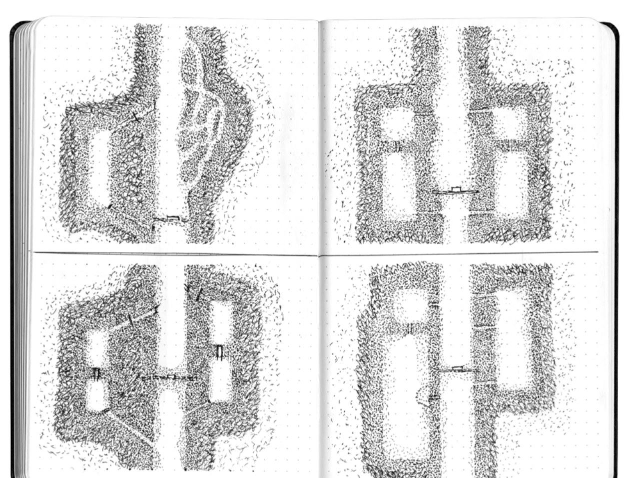


Fig 104. Channel with separate retention ponds

Preliminary Design Work

Analog sketching allowed initial concepts to flow freely and be adjusted with each iteration, while the water flow sandbox model allowed for experimentation of topographic forms and their interactions with water. The water flow sandbox model helped inform the intervention's final topographical form.

Analog Sketches

Early in the design process, hand sketches helped to understand the relationships between the different elevations and vegetation zones of the existing channel and how the intervention may work with this relationship. Sketches were initially done in plan, with sections completed separately to understand the vertical and horizontal relationship of vegetation and seasonal water levels. Initially, the proposed intervention forms were larger, abstract and lacking a ground in reality. These sketches were entirely a drawing experiment with potential forms. A retaining feature with wetland vegetation along its edge was the primary form that took shape. This form would redirect and slow down some water, allowing sediments to settle out before entering the channel again. Variations of this retaining feature were drawn, and the need to test variations of this form with actual water flow and volume arose, which led to a testing sandbox.

Figure 99 (Top Left) shows the first layout of plant and water zone proportions with an emphasis on maintaining the existing channel and creating a lesser secondary stream.
Figure 100 (Middle Left) shows a second layout of planting and water zone proportions with an emphasis on emergent vegetation and semi-permanent wetland flood plains.
Figure 101 (Bottom Left) shows sections that visualize horizontal proportions with water depth, plans include secondary stream and isolated water retention pools.
Figure 102 (Top Right) shows experimental plan proportions of a maintained original channel against a secondary stream and permanent wetland zones to the sides.
Figure 103 (Middle Right) shows plan sketches that test implementing vegetated wetland "islands" into the existing channel to divide and slow down water flow.
Figure 104 (Bottom Right) shows sketches that demonstrate separating channel water during times of high water elevations for retention using weirs and narrow channels. This set of sketches was one of the last iterations that helped inform the final layout.

Sand Form Base No Water	High Water Volume Low Flow Rate	Low Water Volume High Flow Rate

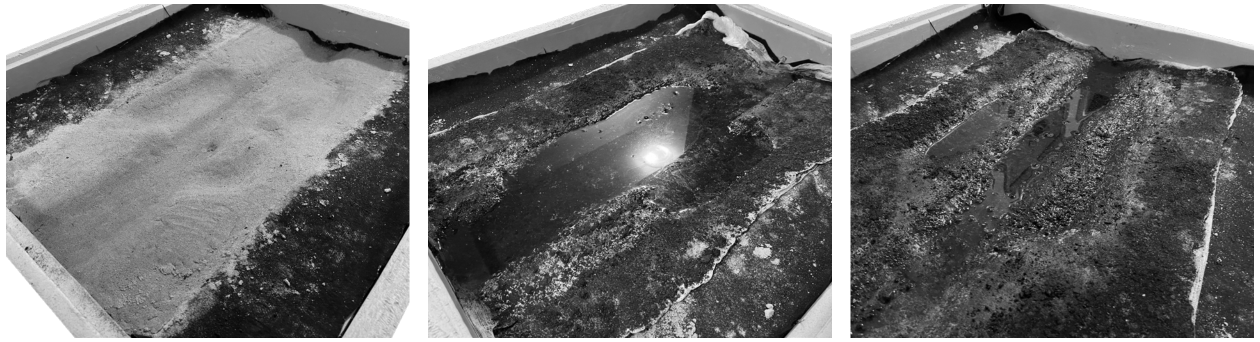


Fig 105. First form of the second iteration of the sandbox model

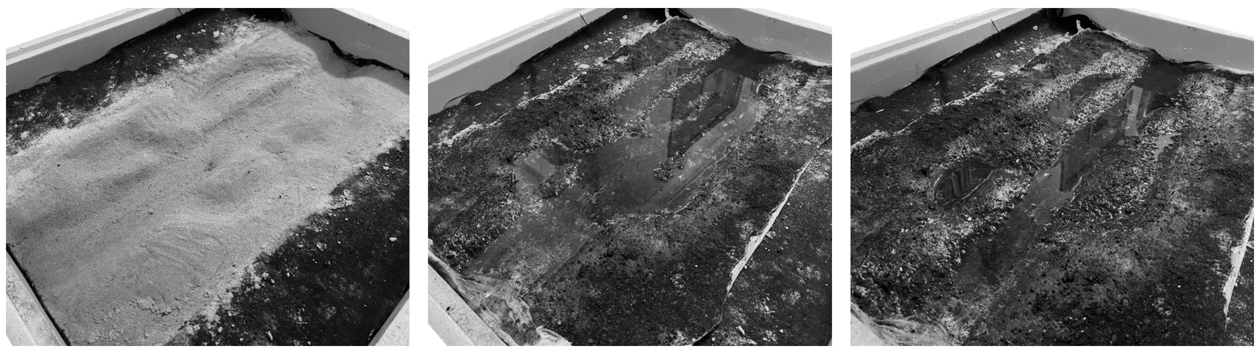


Fig 106. Second form of the second iteration of the sandbox model

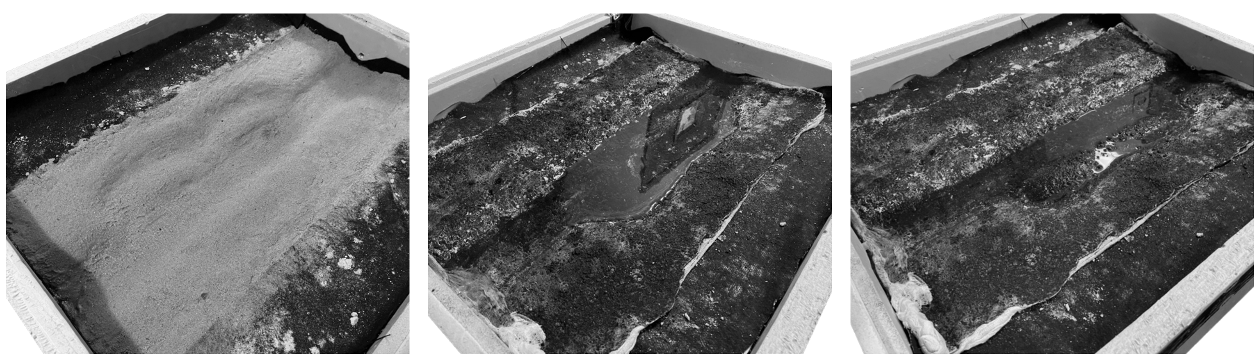


Fig 107. First form of the third iteration of the sandbox model

Fig 108. Second form of the third iteration of the sandbox model

Water Flow Modelling

Three iterations with two forms per iteration were created with a sandbox model. The first iteration was much more experimental than the last two, shown here, which were informed by additional topographic concept plan drawings. The sandbox container was made of 1-1/2 inch rigid foam insulation fastened together with strips of adhesive. A layer of geofabric was laid inside the model to help with waterproofing. An inlet and outlet opening allowed tubing to be positioned for water flow. Sand was used to create an exaggerated topographical form, which was then covered by a sheet of clay-plasticine rolled onto a netted material with soil pressed on. This sheet was then moulded on the sand to fit the topographic form.

The first iteration of forms, not pictured here, was used to understand how water would flow over or around topographic forms implemented within the original channel space. A smaller secondary channel was also introduced adjacent to, but separate from, the original channel.

The second and third iterations tested the interactions between the retention and constructed wetland components. The purpose of testing a retention form was to understand how water may flow as it is being collected, how it may flow within the channel after the retention pool had been filled, and how it would be retained once the depth of the channel had receded. The purpose of testing a constructed wetland component was to understand how the water would flow over it after reaching an estimated spring melt water elevation, how water would flow within it after receding, and how water would flow around it during low water elevation periods. The forms were tested simultaneously and separately to understand potential drawbacks or benefits. Overall, there were no conflicts between the components, and both operated the same individually as when they were together. The tests proved that the forms could be implemented separately or simultaneously along the channel.

Figure 105 (Second Iteration Form One) utilizes a single retention pond component with an opposing constructed wetland form to demonstrate how water would collect in these two spaces when built simultaneously.
Figure 106 (Second Iteration Form Two) maintains the same constructed wetland component as the previous form, but utilizes two retention pond components to demonstrate the effects of having two of these features in series.
Figure 107 (Third Iteration Form One) contains the constructed wetland component individually without featuring any opposing retention ponds.
Figure 108 (Third Iteration Form Two) contains dual retention pond components without an opposing constructed wetland component.

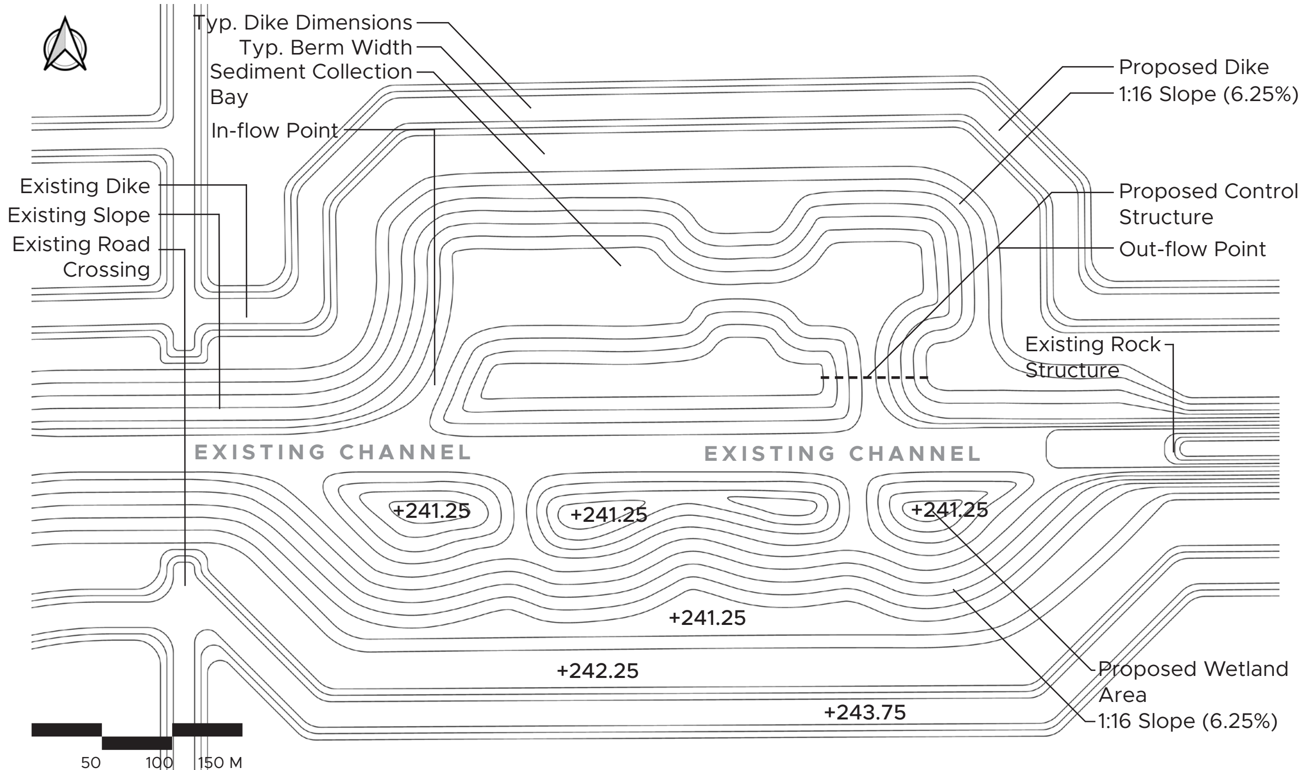


Fig 109. Seventh iteration of the topographical site plan

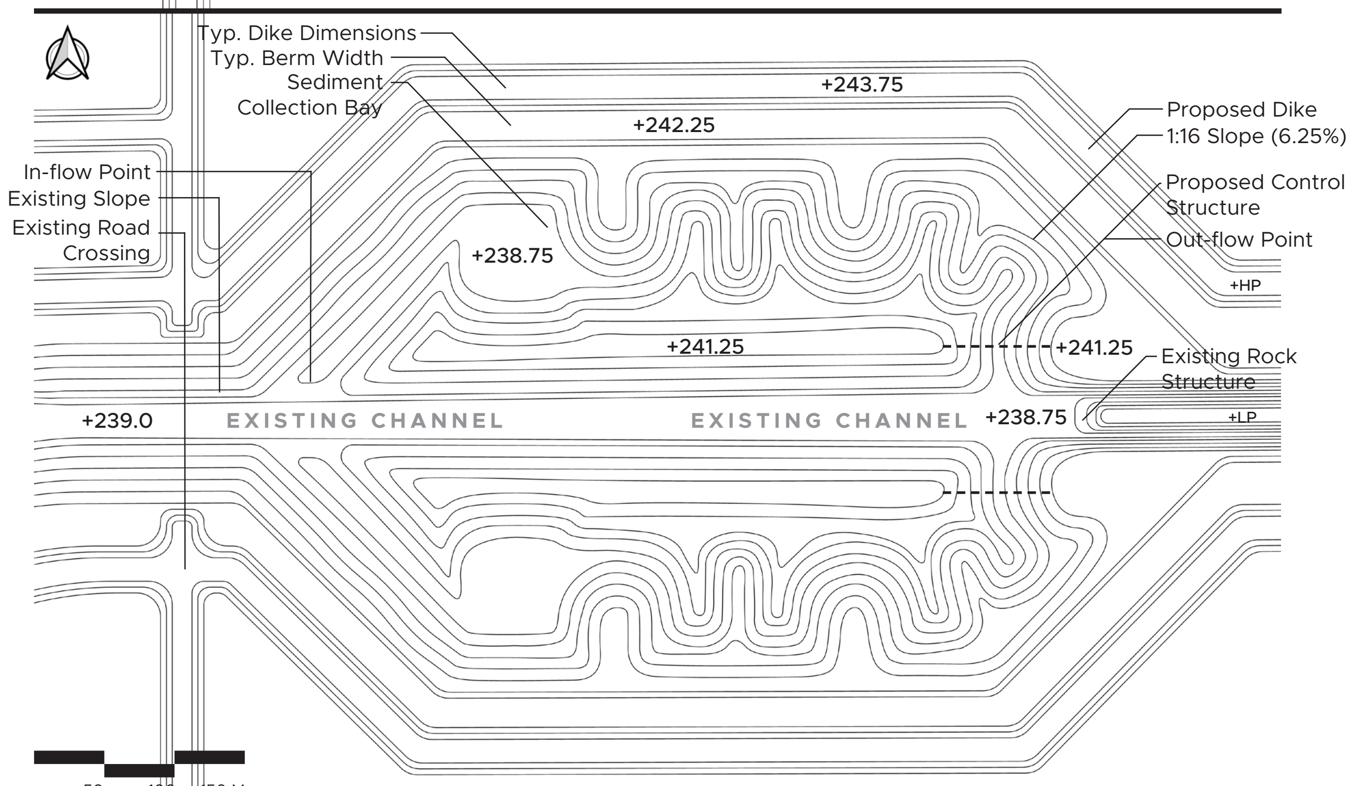


Fig 110. Eighth iteration of the topographical site plan

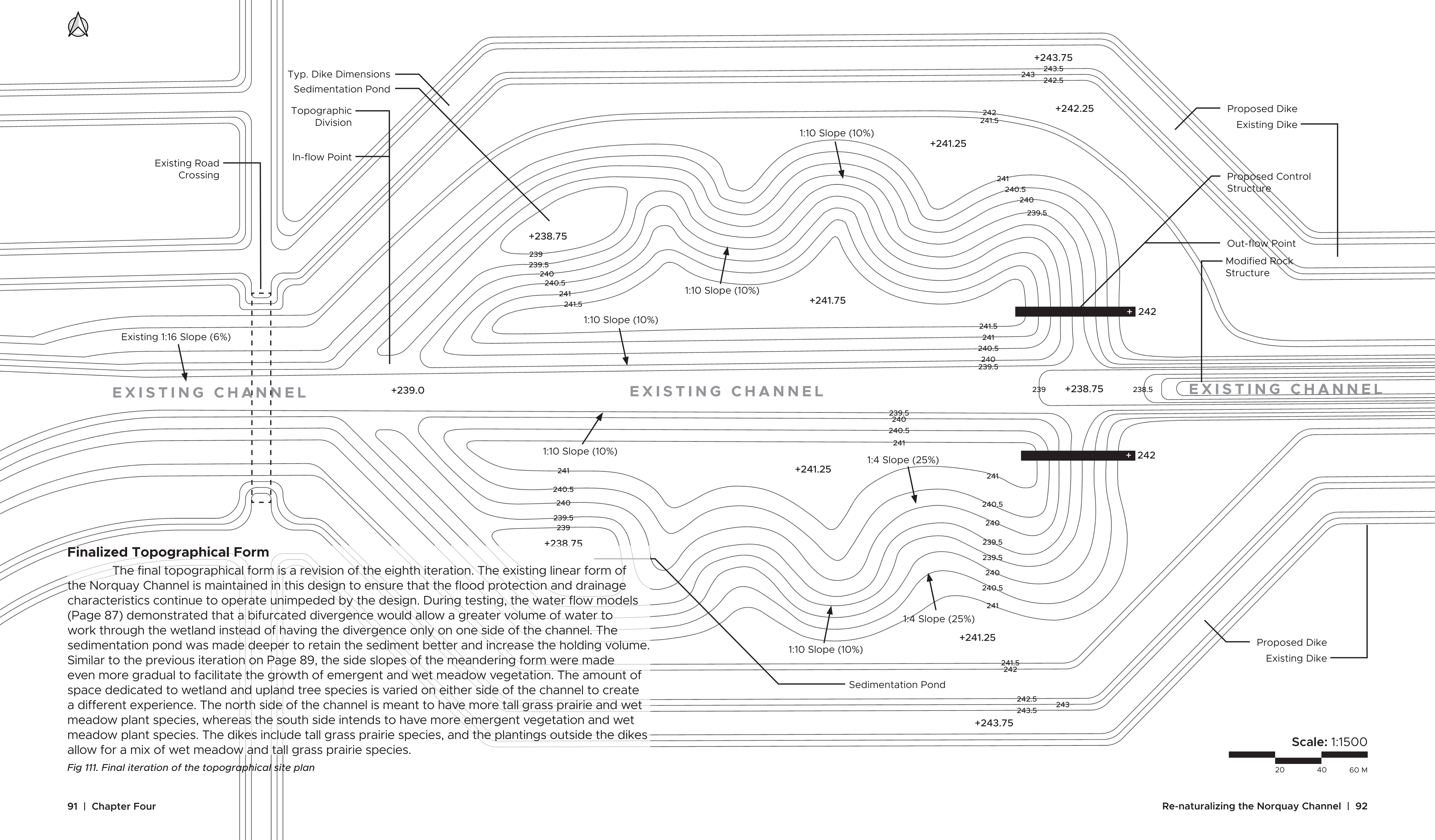
Topographical Design Plans

Several iterations of topographical plans were made to reflect the forms I made within the sandbox model. They started with a sedimentation pond form on one side and a free-flowing constructed wetland form on the other. After several revisions of this combination and further research on wetland restoration and design, an entirely different form was proposed, shown in Figure 110. This revision included a sedimentation pond and a wide, meandering form that would replicate that of a naturalized waterway. The intention behind this iteration to assemble a combination of a sedimentation pond at the start to allow sediments to settle out, increasing the amount of plant growth along the water's edge by making a gradual slope with shallower water and increasing the contact between the water and wetland vegetation. These were the dimensional variables that were adjusted further for the final iteration.

A few existing features within the site justify its boundary. To the west, the rock outcropping, which acts as a dam, designates a drop in water elevation and change in topography. The channel narrows, and water volume decreases after this point. To the east, the channel curves to the southwest and meets with the Carrothers Drain. Although the width of the channel is constant through this curve, the Carrothers Drain is narrower and would complicate the inlet of the wetland form. The existing road crossing also creates an edge-like condition and provides a way to cross the channel. On the north side of the channel, there is a raised portion of land which acts as an access road to the fields. This raised land is approximately 150 meters north of the channel and provides a northern boundary. This measurement was reflected on the other side of the channel to minimize the amount of agricultural land taken for this proposed project.

Figure 109. features a sedimentation pond and a constructed wetland feature separate across the channel from each other. This duality was the foundation for several earlier iterations of the design. However, it was determined based on further research that this separation of features was not an optimal configuration for meeting the proposed design objectives.

Figure 110. combines the sedimentation pond and constructed wetland features. The entire intervention allows for water retention, but the sedimentation pond at the inlet would hold the most water while also allowing the sediment to settle out. The meandering form with a gradual slope allows emergent vegetation and wet meadow species to grow over a greater area. This increases the contact between the water and the vegetation, meaning there would be a greater positive impact on water quality. The proposed water control structure at the outlet would hold some water back while gradually allowing it back into the channel. For simplicity, the intervention was mirrored on either side of the channel at this stage. However, the form was changed in later iterations to promote different experiences on either side of the channel.



Finalized Topographical Form

The final topographical form is a revision of the eighth iteration. The existing linear form of the Norquay Channel is maintained in this design to ensure that the flood protection and drainage characteristics continue to operate unimpeded by the design. During testing, the water flow models (Page 87) demonstrated that a bifurcated divergence would allow a greater volume of water to work through the wetland instead of having the divergence only on one side of the channel. The sedimentation pond was made deeper to retain the sediment better and increase the holding volume. Similar to the previous iteration on Page 89, the side slopes of the meandering form were made even more gradual to facilitate the growth of emergent and wet meadow vegetation. The amount of space dedicated to wetland and upland tree species is varied on either side of the channel to create a different experience. The north side of the channel is meant to have more tall grass prairie and wet meadow plant species, whereas the south side intends to have more emergent vegetation and wet meadow plant species. The dikes include tall grass prairie species, and the plantings outside the dikes allow for a mix of wet meadow and tall grass prairie species.

Fig 111. Final iteration of the topographical site plan

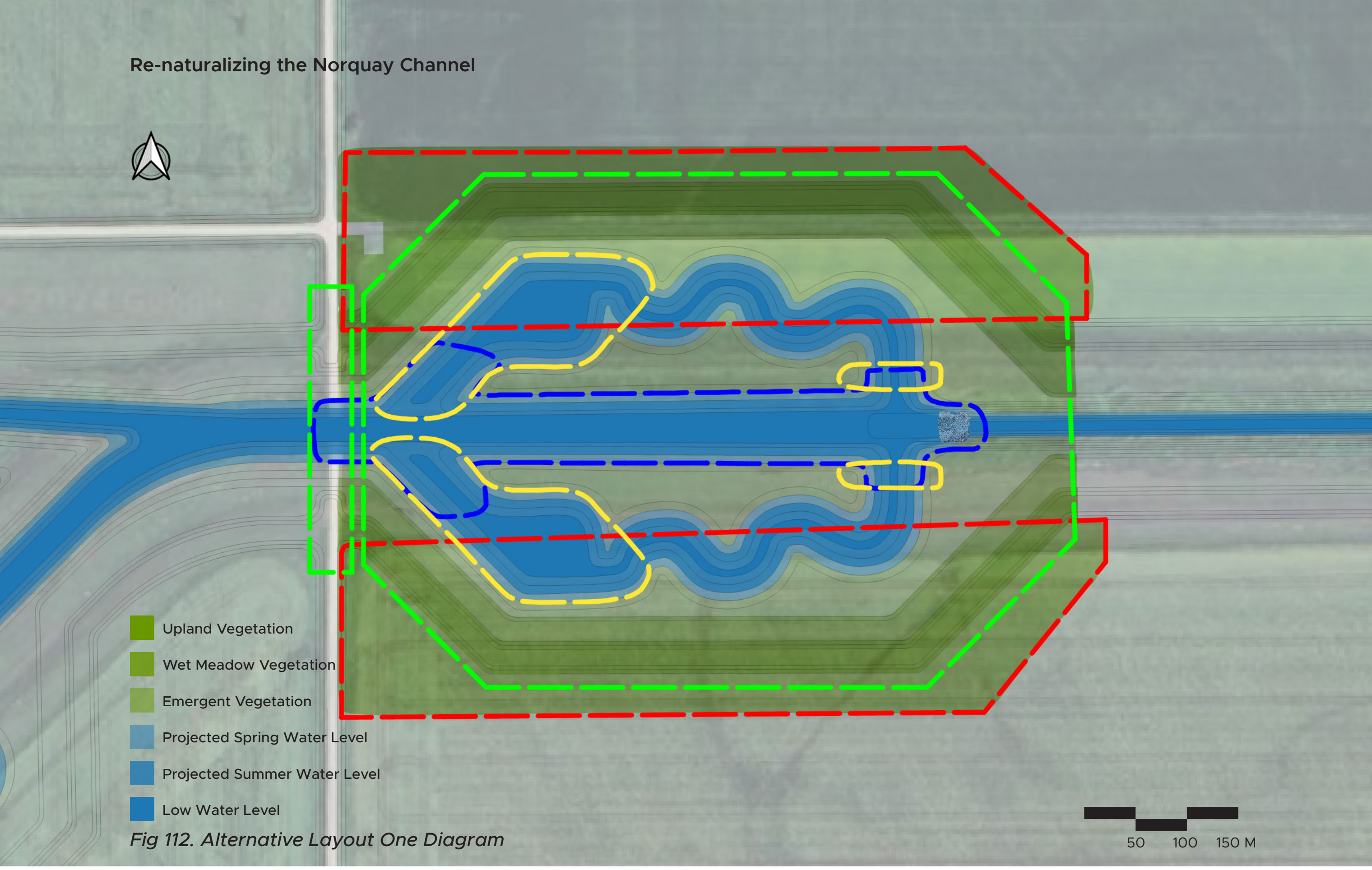


Fig 112. Alternative Layout One Diagram

Design Alternatives

While working on the various iterations of the proposed site design, certain design aspects required further study and reasoning. I created two alternative layouts for comparison. The first factor is the amount of land that each layout needs. One design consideration was land ownership and minimizing the amount of agricultural land needed for the design. This factor is the most important as it sets the foundation for the rest of the design. Next, the accessibility and views present for each potential site needs to be considered. Creating a desirable space for individuals to visit is crucial to the project's success. Operational costs, in terms of energy and finances, are also significant as this factor takes into account the long-term operation of the design. Finally, construction costs, in terms of energy and finances, are considered between the two layouts. This factor is considered last, as either project will have construction costs, but the fulfillment of the first three considerations matters most.

Considering the factors described, alternative one is preferred over alternative two as it achieves a similar design with less space, allows for better access and better views across the site, and requires less extensive maintenance. Although the construction requirements may be more extensive for the chosen design layout, the other factors outweigh this concern.

Spatial Extent

Alternative one in Figure 112 uses less land than alternative two in Figure 113. Alternative one fits within a space 150 meters away from the center line of the existing channel. In contrast, alternative two fits within a space 200 meters away from the center line of the existing channel. Alternative one uses approximately 95,500 square meters, whereas alternative two uses approximately 160,700 square meters for a difference of over 65,000 square meters. Therefore, alternative one benefits in terms of spatial extent. Only two agricultural parcels are affected in either layout.

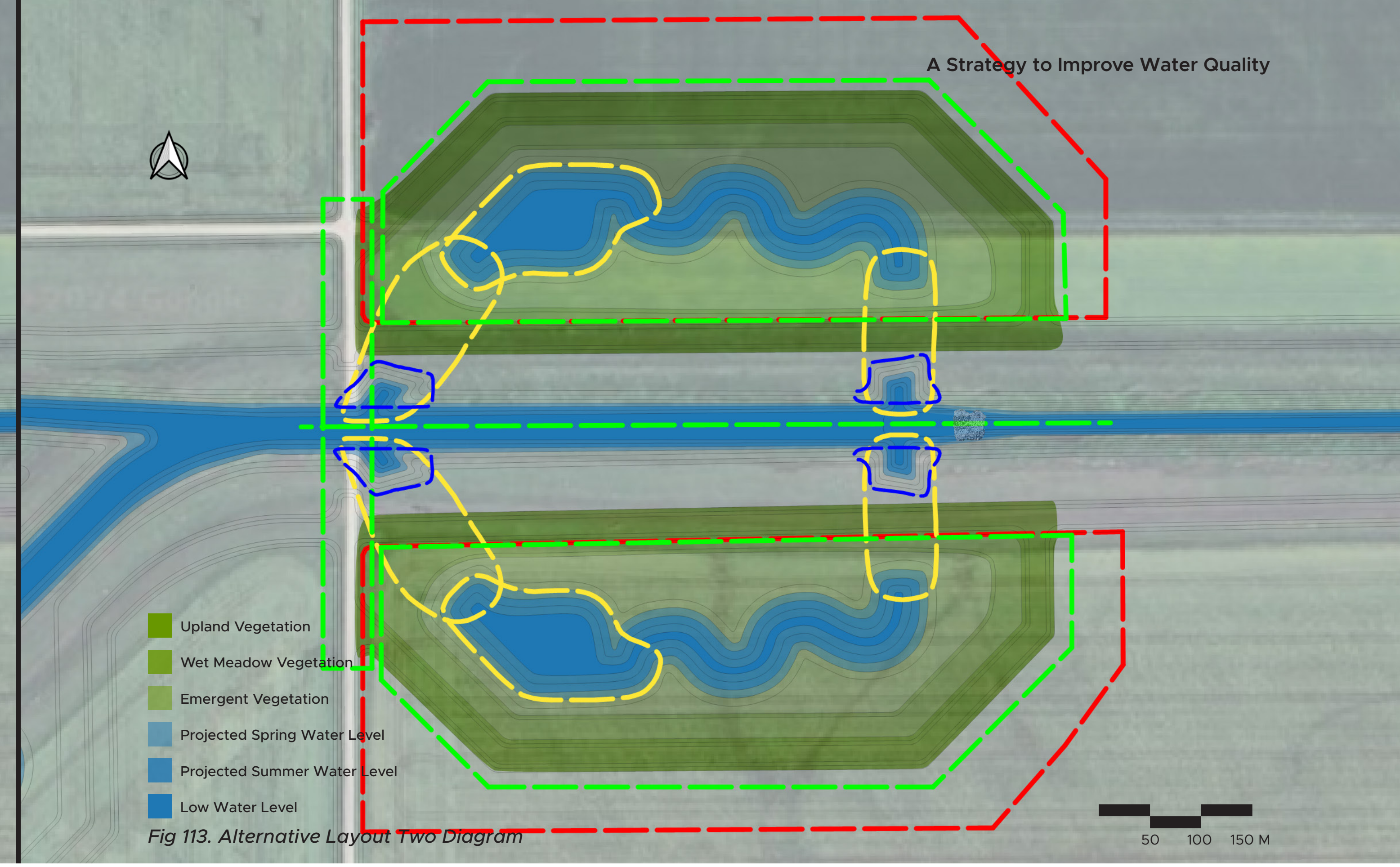


Fig 113. Alternative Layout Two Diagram

Accessibility and Views

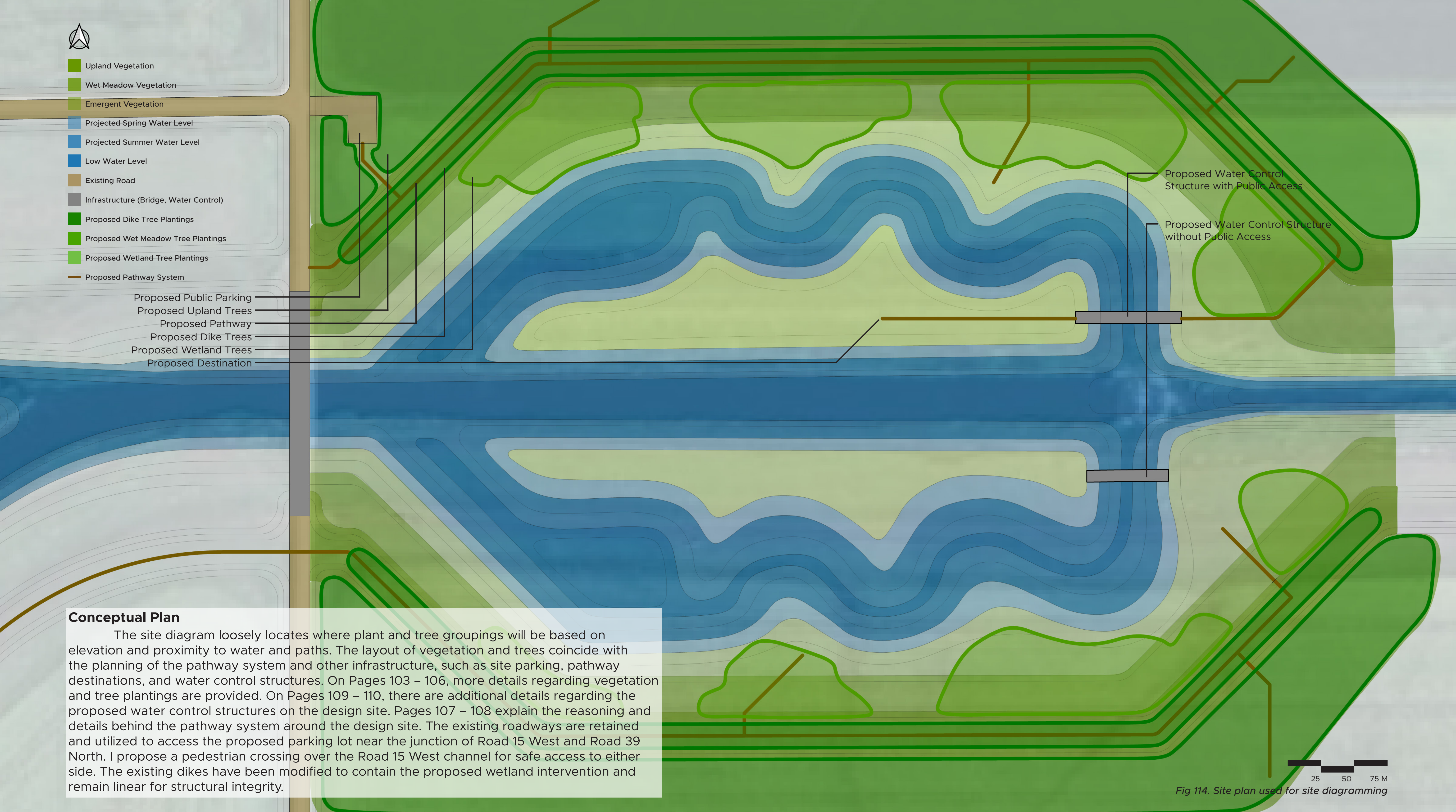
Alternative one in Figure 112 exists as a whole unit with the channel running through the middle, compared to alternative two in Figure 113, which is divided into two units by the existing channel and remaining dikes. Alternative two is cut off from surface water access to the existing channel. A person kayaking or canoeing along the channel would have access to the wetland area in alternative one. View lines are cut short across alternative two by the remaining dike, whereas they would be continuous in alternative one.

Operational Requirements

Dredging and mowing would be required for both layouts. Alternative one in Figure 112 would require dredging primarily at the inlets, within the sedimentation pond, and at the outlet around the water control structure. Alternative two in Figure 113 would require more extensive maintenance on the culverts and corresponding water control structures, as they would be susceptible to blockages. Therefore, the operational energy needed to maintain alternative one is expected to be lower than that of alternative two.

Construction Requirements

Alternative one would disrupt the existing channel far more than alternative two in Figure 113. Alternative two requires the installation of two sets of culverts to connect the wetland to the existing channel under the remaining dikes. Alternative one would require the removal of the existing dikes and creating an inlet and outlet. Although the energy put into excavating the channel and wetland would be higher for alternative one, I am willing to accept this, considering that the operational energy would be lower in the long run.



Conceptual Plan

The site diagram loosely locates where plant and tree groupings will be based on elevation and proximity to water and paths. The layout of vegetation and trees coincide with the planning of the pathway system and other infrastructure, such as site parking, pathway destinations, and water control structures. On Pages 103 – 106, more details regarding vegetation and tree plantings are provided. On Pages 109 – 110, there are additional details regarding the proposed water control structures on the design site. Pages 107 – 108 explain the reasoning and details behind the pathway system around the design site. The existing roadways are retained and utilized to access the proposed parking lot near the junction of Road 15 West and Road 39 North. I propose a pedestrian crossing over the Road 15 West channel for safe access to either side. The existing dikes have been modified to contain the proposed wetland intervention and remain linear for structural integrity.

Fig 114. Site plan used for site diagramming

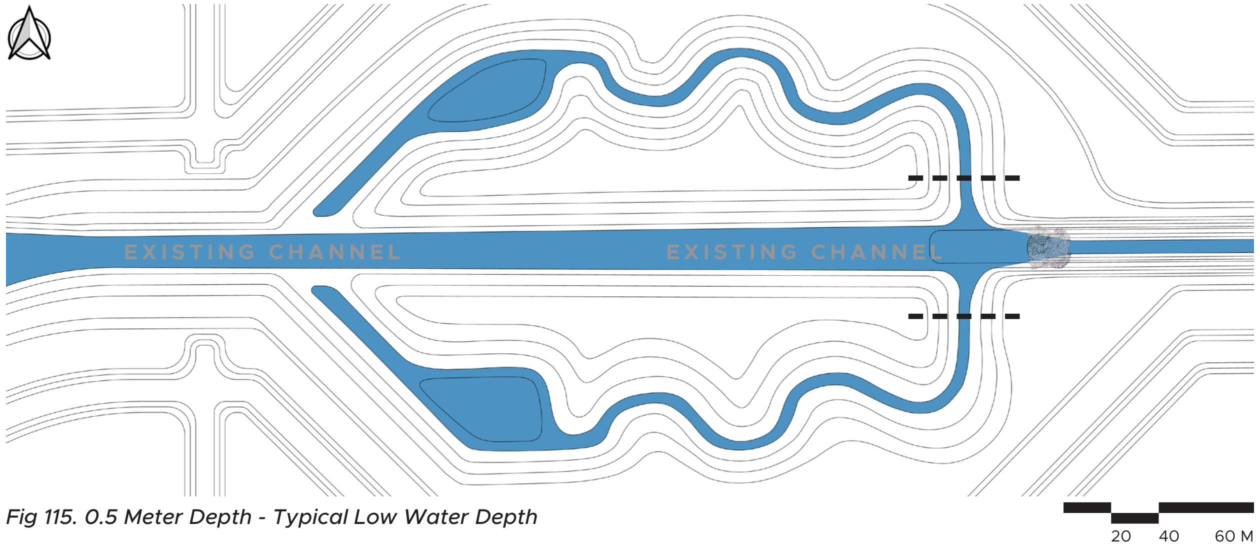


Fig 115. 0.5 Meter Depth - Typical Low Water Depth

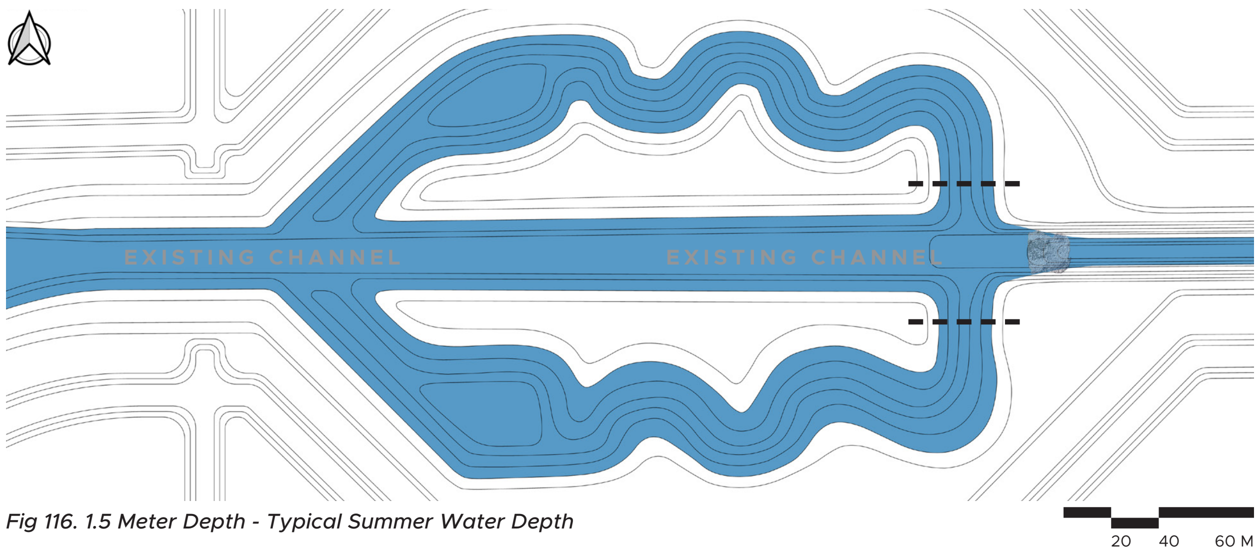


Fig 116. 1.5 Meter Depth - Typical Summer Water Depth

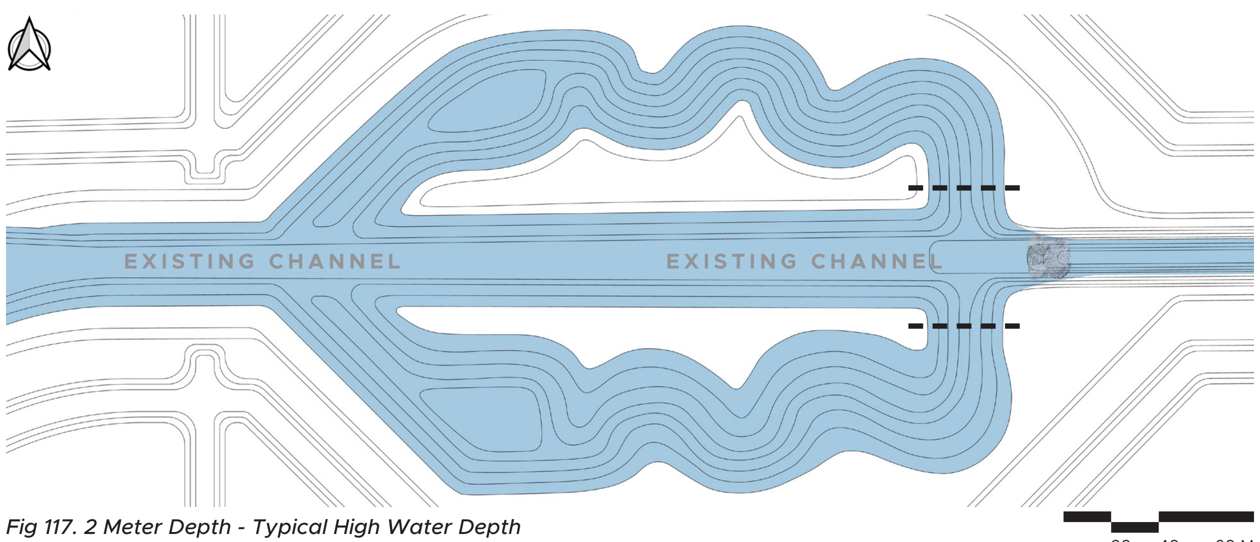


Fig 117. 2 Meter Depth - Typical High Water Depth

Water Elevations in the Design Site

There are three main water depths illustrated across several of these plans. These depths were integral in determining topographic forms, vegetation distribution, and tree layout. The lowest depth is a projected low water elevation of 0.5 meters. An example of this water depth would be a year with low winter precipitation, resulting in a limited spring freshet and summer precipitation. As mentioned previously, the Stephenfield Reservoir would help maintain some water flow through the channel and wetland intervention. This water depth is an example of when that would take effect. The following water depth is a projected summer average of 1.5 meters. This depth is an example of a year with moderate winter and summer precipitation. The highest water depth is a projected spring water level of 2 meters. This would be an example of a year with more significant winter precipitation resulting in a larger spring freshet.

These water depths are only projections and are expected to vary significantly, especially when considering the effects of climate change. The fluctuation of water depths also means that locations of different plant species would fluctuate along the banks of the channel and wetland features.

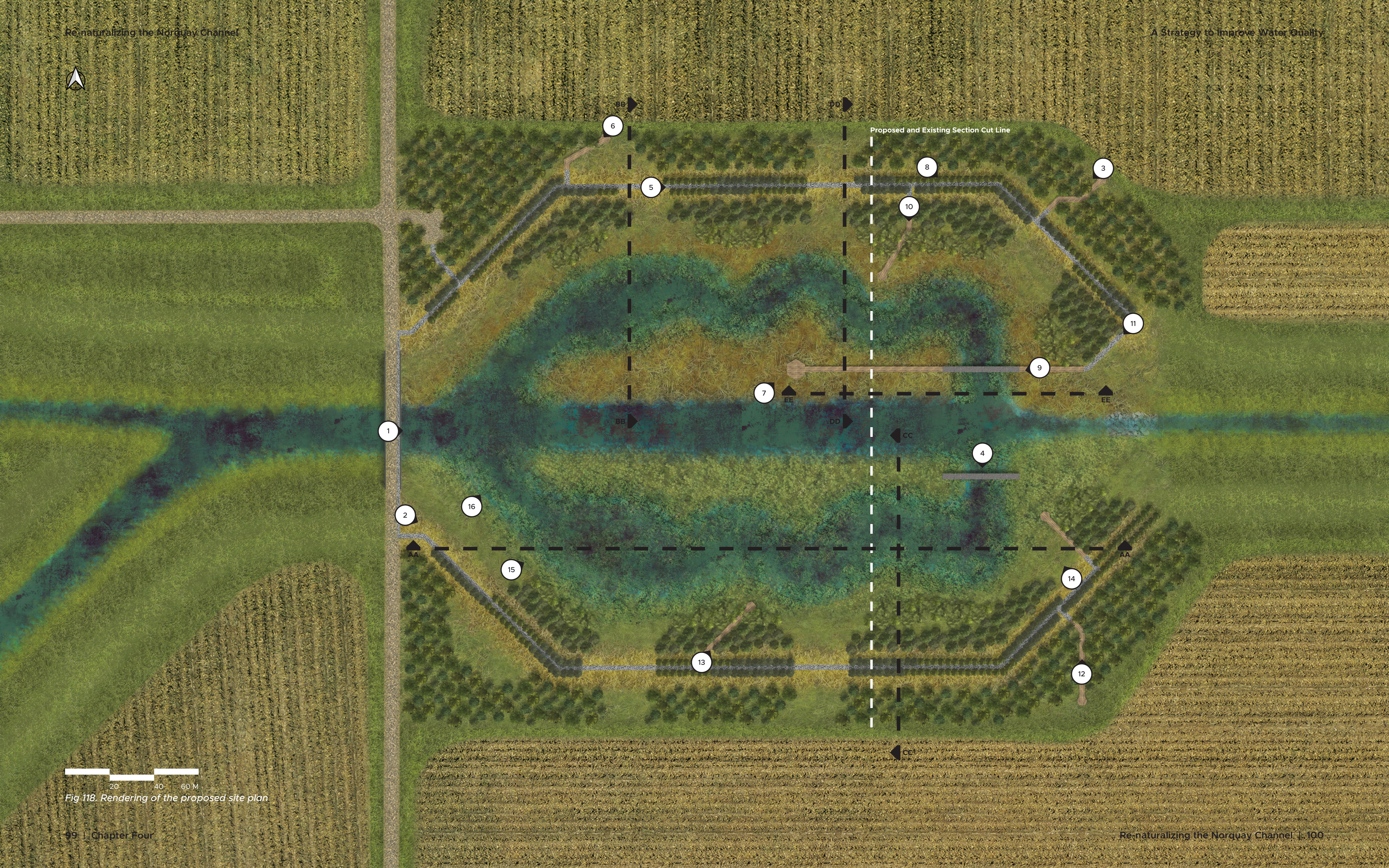


Fig 118. Rendering of the proposed site plan

Fig 119. Section AA - East to west section cut facing north on the south side of the channel wetland

Fig 120. Section BB - Section cut through the sedimentation pond on the north side of the channel

Fig 121. Section CC - Section cut through the meandering portion of the wetland on the south side of the channel

Fig 122. Section DD - Section cut through the meandering portion of the wetland on the north side of the channel

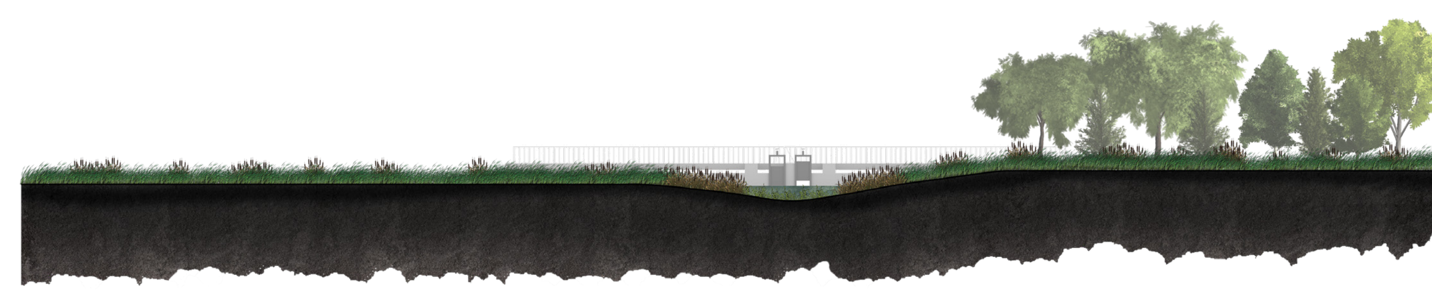


Fig 123. Section EE - Section cut facing the water control structure on the north side of the channel

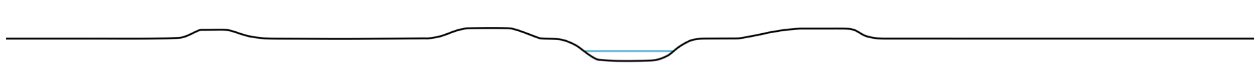


Fig 124. Existing line section cut - north to south

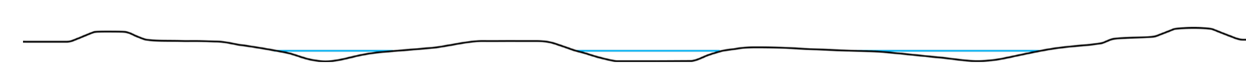


Fig 125. Proposed line section cut - north to south

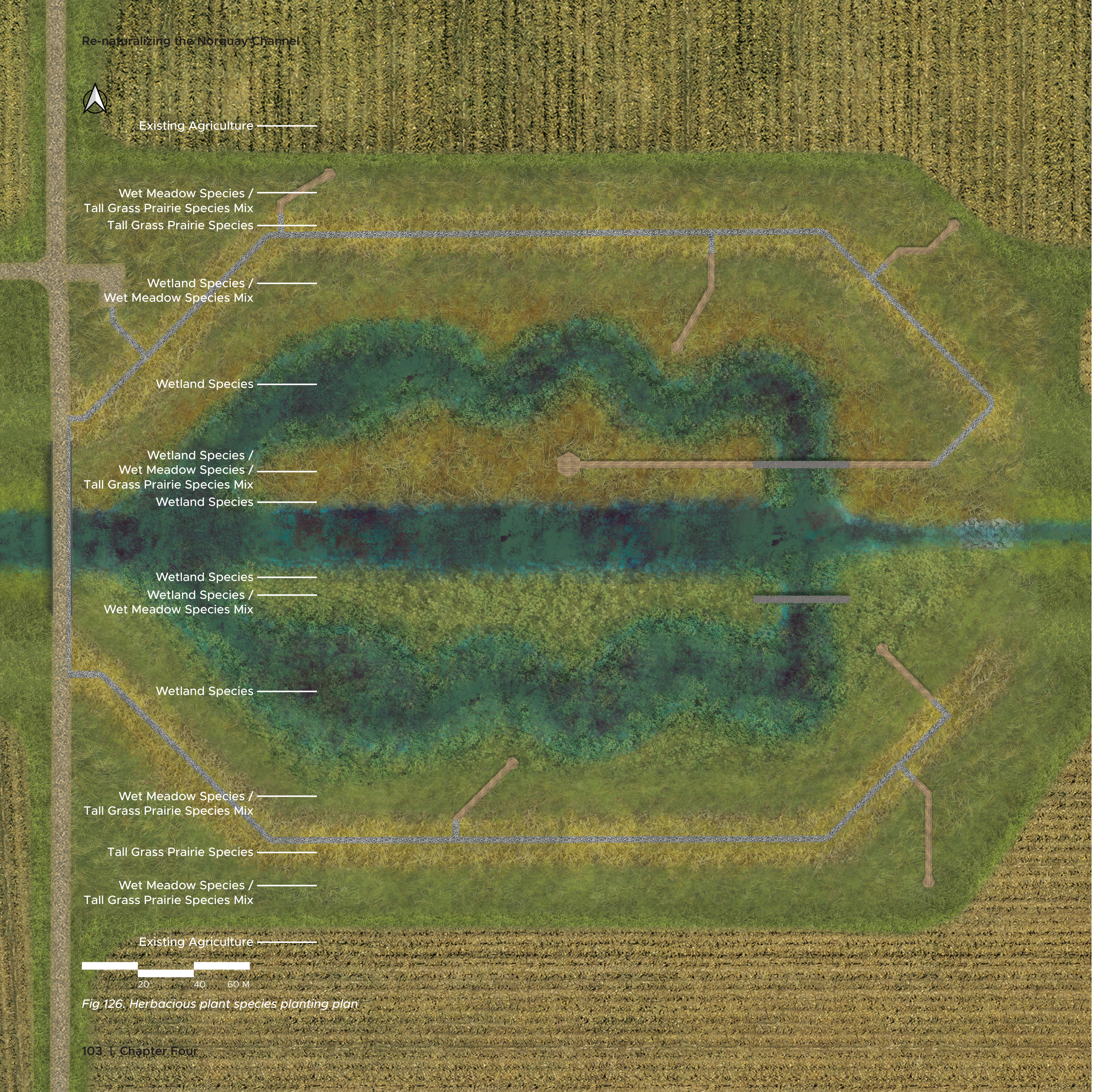


Fig 126. Herbacious plant species planting plan

Proposed Plant Species

Three main categories of plant species were chosen based on anticipated soil saturation and its duration. The three categories are not exclusive; two or more are expected to mix in some areas. Mixing species would also be beneficial when there is a fluctuation in water levels. The tall grass prairie species are located at higher elevations, further away from the wetland. The wet meadow species are expected to have moderate soil saturation and are situated between the higher and lower elevations. The wetland/emergent plant species are located adjacent to and within the water at the projected summer depth and would be temporarily submerged during high projected spring water depths. All species listed fall within hardiness Zones 2 to 4.

The tall grass prairie plant species would need to be reintroduced to the design site as they are native to the area but are not currently prominent on the site. All proposed wet meadow plant species currently exist on-site in varying quantities, but additional plantings would be done in specific areas to achieve the expected mixture of species. All proposed wetland/emergent plant species would need to be introduced to the design site as there was no current evidence of these species there. These wetland/emergent plant species were selected for their ability to facilitate nutrient uptake from the water and soil.

Seeding for the first season will be required, followed by the next year with plugs of species that are more rare or that did not take root. A yearly harvest of most wetland/emergent species would be required to encourage the plants to uptake nitrogen and phosphorus. Mowing may be necessary for the wet meadow and tall grass prairie plants.

Proposed Wetland Plant Species

Beckmannia syzigachne (Sloughgrass)
Juncus effusus (Soft Rush)
Panicum virgatum (Switchgrass)
Sagittaria lancifolia (Arrowhead)
Typha latifolia (Broadleaf Cattail)

Proposed Wet Meadow Plant Species

Melilotus albus (White Sweet Clover)
Melilotus indicus (Sweet Clover)
Solidago canadensis (Canadian Goldenrod)
Symphoricarpos occidentalis (Snowberry)
Veronica serpyllifolia (Speedwell)

Proposed Tall Grass Prairie Species

Andropogon gerardii (Big Bluestem)
Hesperostipa spartea (Needlegrass)
Schizachyrium scoparium (Little Bluestem)
Spartina pectinata (Prairie Cord Grass)
Sporobolus heterolepis (Prairie Dropseed)

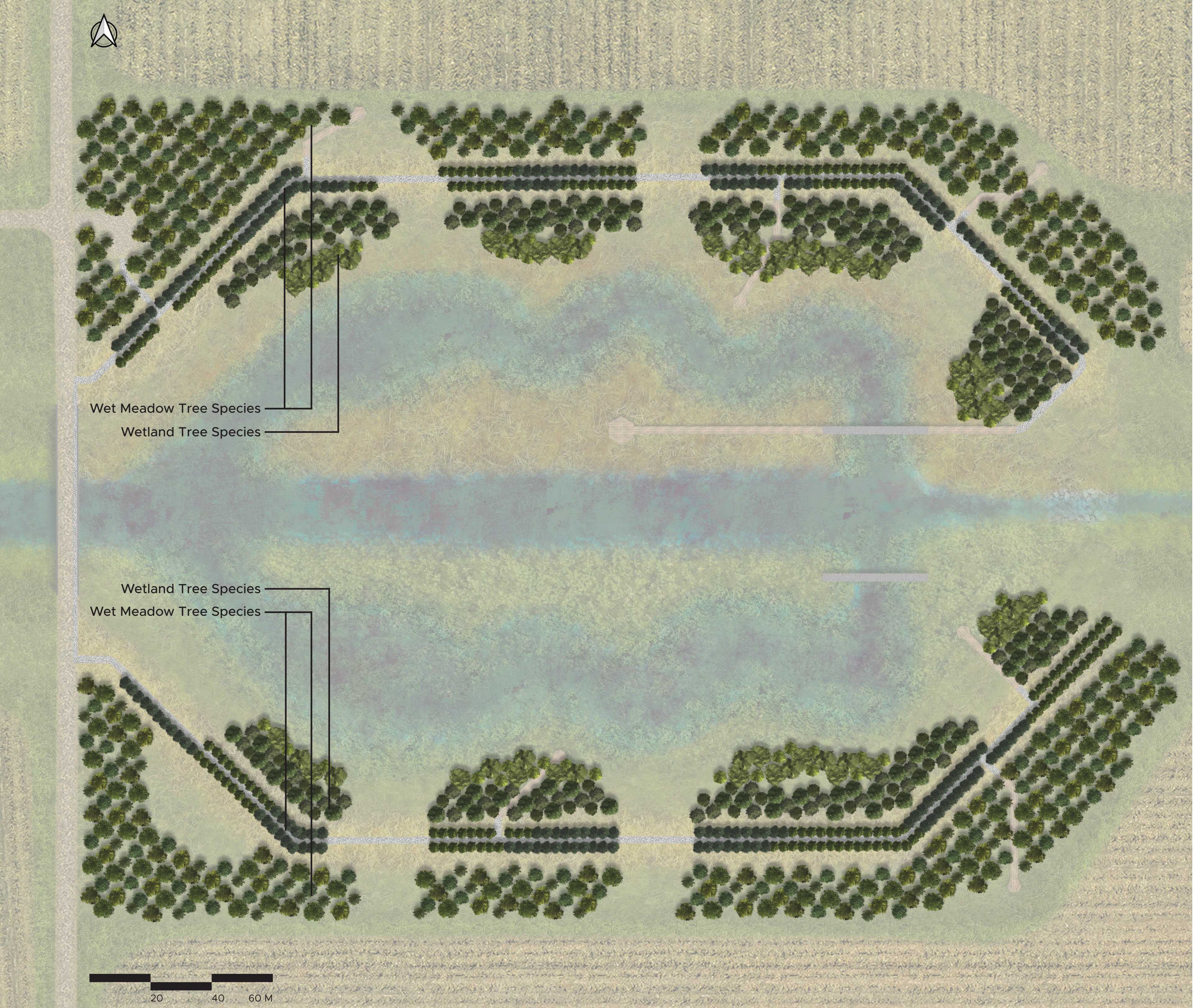


Fig 127. Tree species planting plan

Proposed Tree Species

Two categories of tree species were chosen for this design based on anticipated soil saturation, duration of saturation, and proximity to the wetland. Wetland species may experience 30 to 120 days of saturated soil yearly, whereas wet meadow species can survive up to 30 days in saturated soils.[90] The coniferous species were chosen to add winter interest and protection to the site. Similarly, Ohio Buckeye, Golden Willow, and American Larch were selected for their autumn seasonal interest. The trees planted with the primarily wet meadow plant species tend to fare better during high water. These species include Silver Maple, Red Maple, River Birch, and Eastern Cottonwood.[91] Northern Catalpa, Black Tupelo, and Golden Willows are planted closer to the water as they can withstand moderate to highly saturated soil for longer.[92] Since hardiness zones are expected to change from Zone 2 to 4 and beyond due to climate change, additional species were included for added diversity.

As no trees are currently on the existing design site, all proposed tree species will have to be introduced to the site. Trees may be planted in five- to ten-gallon pots. A watering and pruning schedule would need to be made for each species, as required attention may vary. All drawings will present trees at their expected mature size.

Proposed Wet Meadow Tree Species

Acer rubrum (Red Maple)
Acer saccharinum (Silver Maple)
Aesculus glabra (Ohio Buckeye)
Tilia americana (American Linden)
Picea glauca (White Spruce)
Picea mariana (Black Spruce)

Proposed Wetland Tree Species

Betula nigra (River Birch)
Catalpa speciosa (Northern Catalpa)
Larix laricina (American Larch)
Nyssa sylvatica (Black Tupelo)
Populus deltoides (Eastern Cottonwood)
Salix alba (Golden Willow)

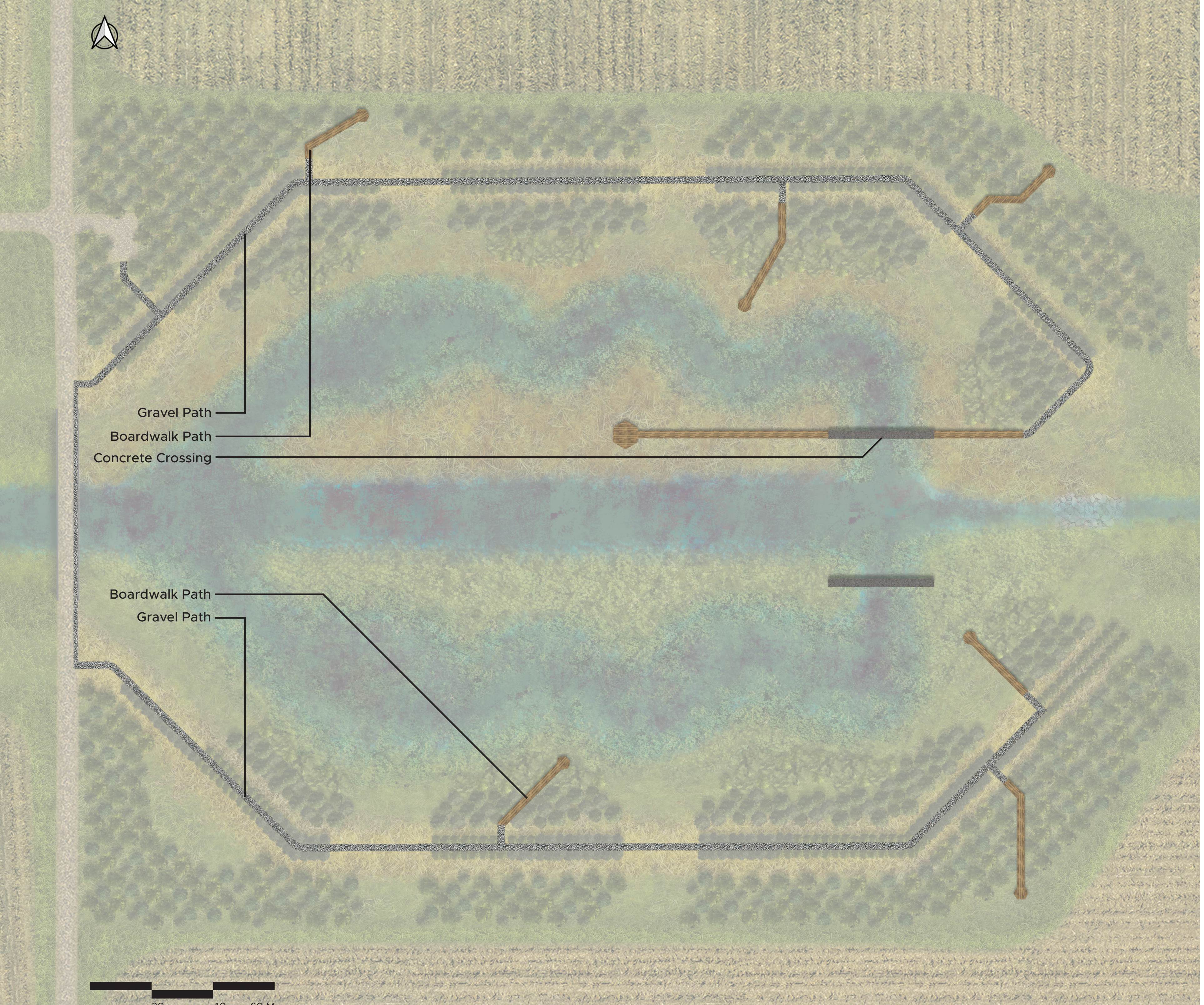


Fig 128. Pathway network plan

The Pathway System

The main pathway follows the top of the dike on either side of the design site. The existing vehicular bridge will be adapted to allow a pedestrian path to one side so visitors can cross the channel safely. The pathway system is composed of two materials. Paths on higher ground are made of rolled gravel, whereas paths in the lower areas are made from constructed boardwalk sections, fastened together, sitting on a float on the ground surface. Secondary paths towards the inside and outside of the site take visitors to a point where they can observe their surroundings and rest. Information plaques on the interior viewing and rest points are attached to the deck, explaining wetland functions, vegetation, or hydrology. In total, the pathway system is approximately 1,615 meters in length.

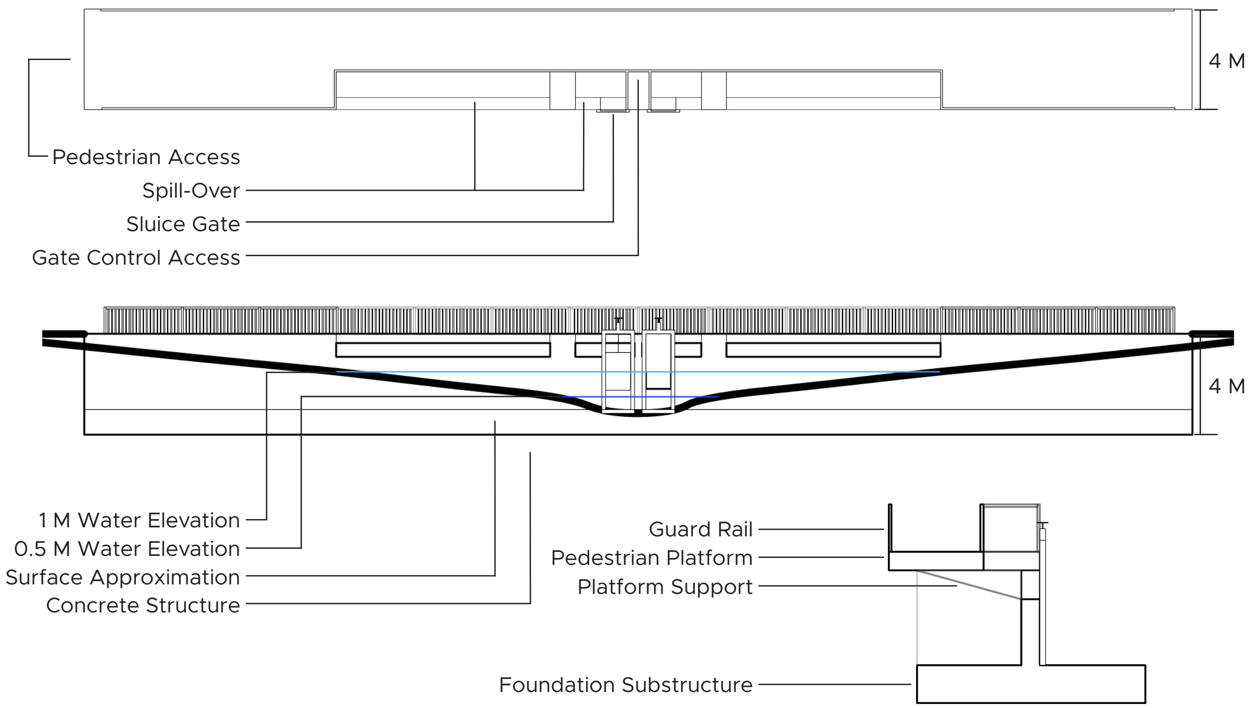
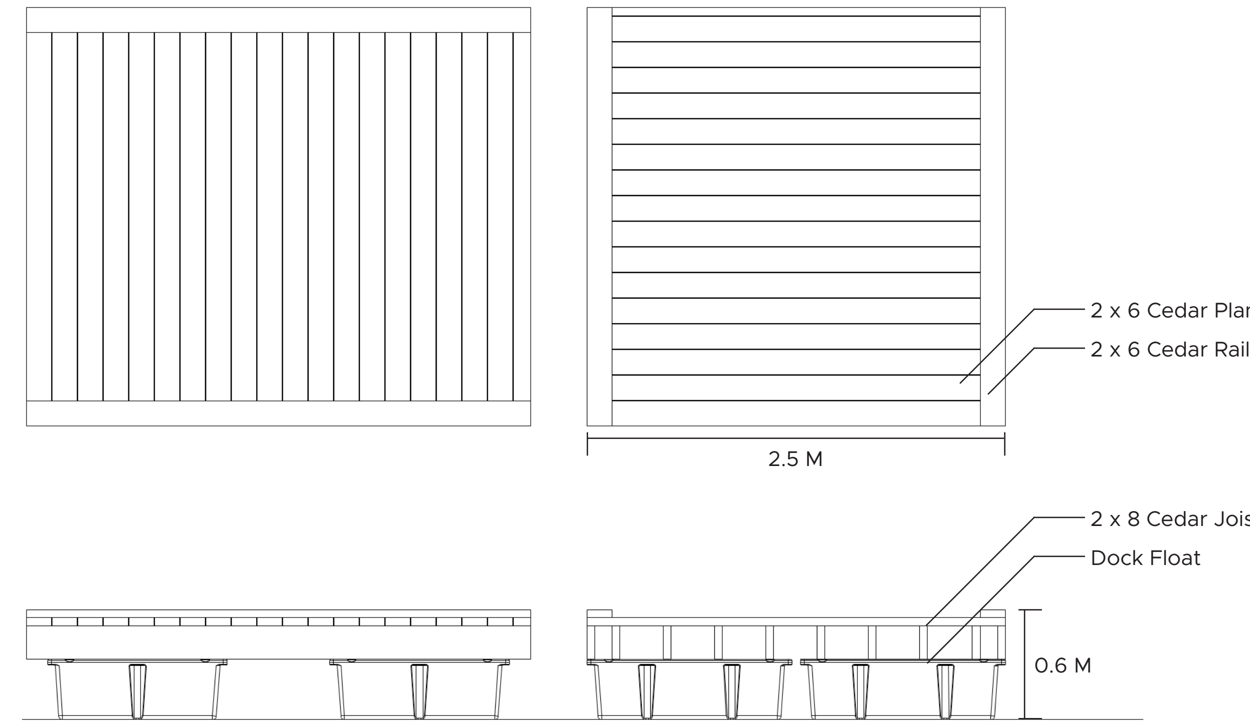


Fig 129. Water control structure diagrams

Fig 130. Rendering of the proposed and photos of the existing water control structure on the Norquay channel at different times of the year

The Water Control Structure

The proposed water control structure combines the water control structures now found along the Norquay Channel with a sluice gate. The current water control structure on the channel crosses the channel with stairs at either end, ascending to an upper platform to view the channel and the gate mechanism. A concrete gate at either side may be raised and lowered to allow or block water flow. During the spring freshet, the water tends to spill over the top of the lower structure, where concrete bollards protrude from the bottom of the channel to capture any large debris flowing down the channel. This water control structure allows for pedestrian access across the top, with guard rails to offer security. Visitors may observe the status of the sluice gate and the water elevation at any given time.



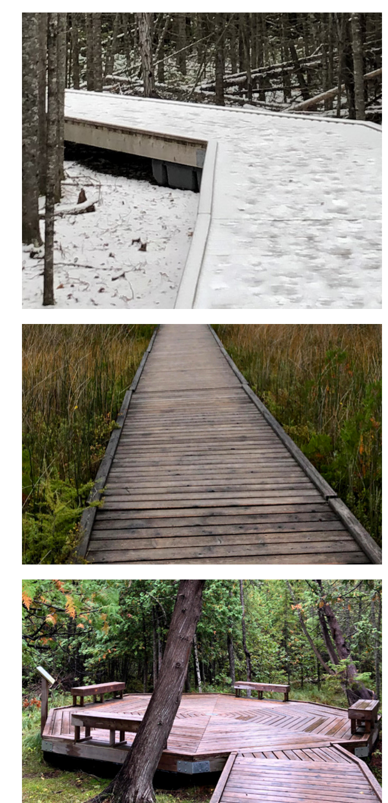


Fig 131. Boardwalk structure diagrams

Fig 132. Photos of the Brokenhead Wetland Boardwalk at different times of the year

The Boardwalk Structure

The site's pathway system consists of rolled gravel and a boardwalk. This boardwalk portion utilizes the same technique as the Brokenhead Wetland Interpretive Trail. The deck portions are fastened to modular dock floats that sit on top of the ground, minimizing the impact of the structure on the landscape. The deck is constructed from cedar dimensional lumber, primarily 2" x 6" planks, and hot dipped galvanized fasteners. The deck material is expected to weather over time, and individual deck boards may be easily replaced if necessary. Since the boardwalk is less than 60 centimeters from the ground, it does not require any railing.

Winter Activities

During the site visits in late spring 2023, there was evidence of snowmobiles and people walking in and along the Norquay Channel. The design proposal supports the use of the site during the winter months. In addition to snowmobiling, cross-country skiing, snowshoeing, and skating are encouraged. The pathway system and design site would still be accessible in winter. Coniferous trees along the dikes and adjacent to the agricultural fields would help break the northwestern winds and guide snow build-up on site.

Fig 133. Seasonal rendering from 3D model

Fig 134. View facing seating destination

Fig 136. View from off the dike path, looking at the Ohio Buckeye allee

Fig 135. Boardwalk destination in the middle of the wetland on the north side of the channel

Fig 137. View over the water control structure on the north side of the channel

Fig 138. View walking through wet meadow and wetland trees

Fig 140. View of boardwalk path through the wet meadow forest, outside of the dikes

Fig 139. Boardwalk path with water control structure in the background

Fig 141. Approach to one of the boardwalk destinations

Chapter Four Endnotes

84 The Growing Outcomes in Watersheds (GROW) Program originates from Manitoba's Climate and Green Plan to encourage the development and delivery of ecological goods and services. GROW focuses on conserving and restoring natural landscapes that provide ecological goods and services on agricultural land. Projects are developed with farms that work alongside their operations to address the watershed's health. Reducing flooding and drought vulnerability and improving water quality and nutrient management are the goals behind GROW projects in Manitoba. (The Manitoba Habitat Heritage Corporation. "Growing Outcomes in Watersheds." GROW: Growing Outcomes in Watersheds - Guide, 2021, https://www.gov.mb.ca/sd/water/pubs/water/watershed/grow-guidebook-2021.pdf. 4.)
There are two types of incentives for landowners participating in the GROW program: Infrastructure establishment costs and annual payments. Establishment costs cover projects that enhance or provide new ecological goods and services. Annual incentive payments apply to the number of acres covered in a Local GROW Program. Guiding values to determine the rate of incentive payments include assessed land value, agricultural capability, and local demand. (The Manitoba Habitat Heritage Corporation. "Incentives." GROW: Growing Outcomes in Watersheds - Guide, 2021, https://www.gov.mb.ca/sd/water/pubs/water/watershed/grow-guidebook-2021.pdf. 12-3.)

85 Cited from Discussion with Leo Duval on 20 September 2023.

86 Cited from Discussion with Leo Duval on 20 September 2023.

87 Cited from Discussion with Leo Duval on 20 September 2023.

88 "Plant Hardiness Zone Maps." Natural Resources Canada - Government of Canada. Accessed March 2, 2024. http://planthardiness.gc.ca/?m=1.

89 "Plant Hardiness Zone Maps." Natural Resources Canada - Government of Canada. Accessed March 2, 2024. http://planthardiness.gc.ca/?m=1.

90 Tree Canada. "How Flooding Affects Trees: Water in Moderation." Tree Canada, January 5, 2023. https://treecanada.ca/article/how-flooding-affects-trees-water-in-moderation/.

91 Tree Canada. "How Flooding Affects Trees: Water in Moderation." Tree Canada, January 5, 2023. https://treecanada.ca/article/how-flooding-affects-trees-water-in-moderation/.

92 Tree Canada. "How Flooding Affects Trees: Water in Moderation." Tree Canada, January 5, 2023. https://treecanada.ca/article/how-flooding-affects-trees-water-in-moderation/.

Page Left Blank Intentionally

Page Left Blank Intentionally

Page Left Blank Intentionally

Chapter Five

Reflection, Evaluation, and Potential Extensions

The design objectives laid out at the start of Chapter Four were addressed through purposeful design choices. The wetland is shaped such that it balances water volume with exposure to emergent vegetation. It creates an ideal condition for wetland vegetation to grow, and increases the diversity of vegetation that could grow on site due to the fluctuating water levels. My intention from the beginning was to allow public access and provide an educational experience so that people may understand and appreciate the operation of the wetlands. At the same time, I wanted to maintain a connection to the adjacent agriculture through clearings and view lines for visitors. With the primary design objective being to improve water quality, I wanted to estimate the impact of the individual site on the water quality of the channel. Estimates were made based on empirical formulas and available data. It was understood from the start that an individual site would have a limited impact on the greater well-being of Lake Winnipeg, which is why a local and regional intervention is proposed.

Fig 142. View from the dike path, looking at the south water control structure

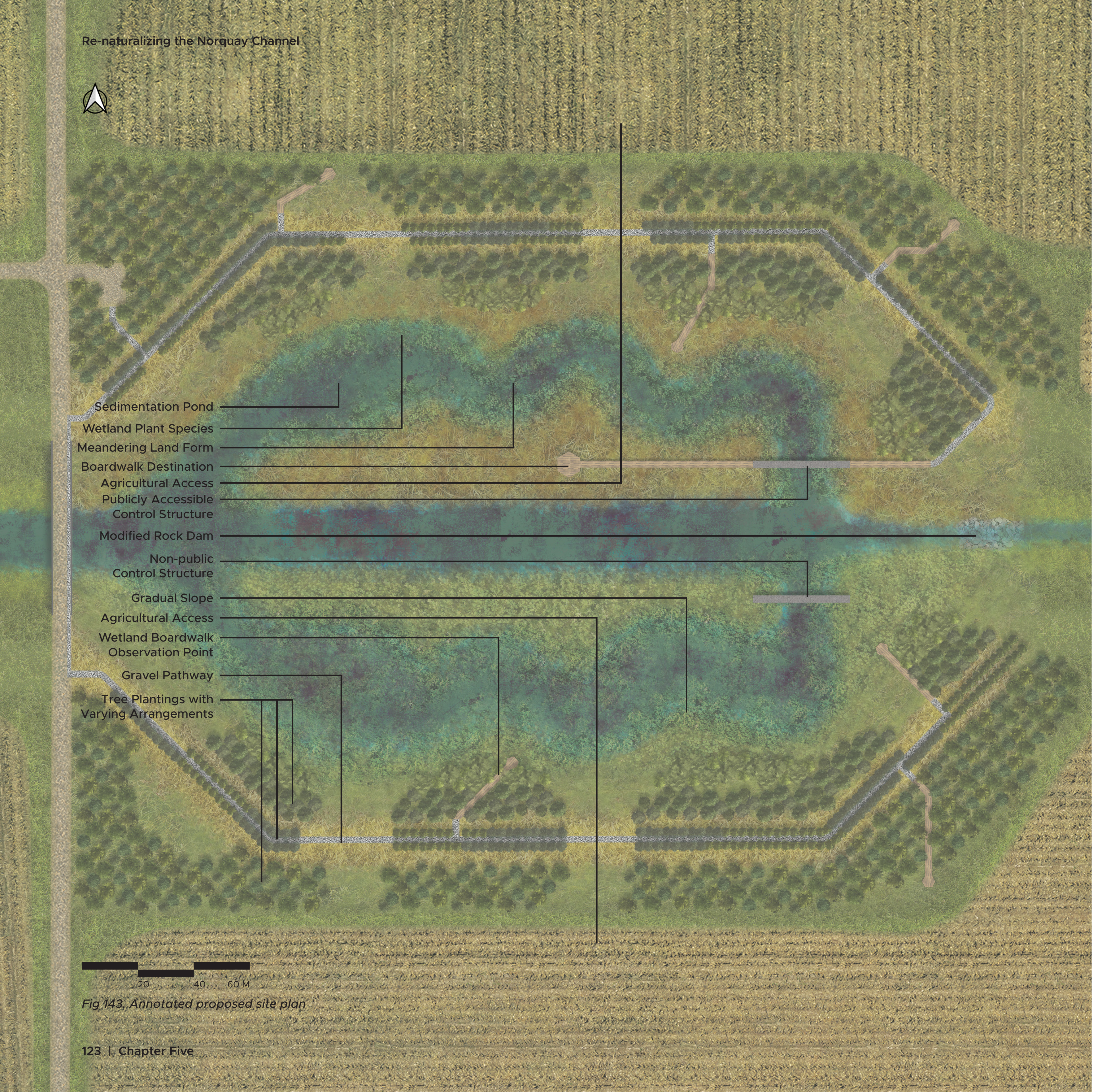


Fig 143. Annotated proposed site plan

How have the Design Objectives been Addressed?

The Primary Design Objective

Improving water quality has been addressed in several ways. The wetland intervention slows down some water flowing down the channel. The water entering the wetland passes through a sedimentation pond, allowing suspended solids to settle. Throughout the wetland, emergent vegetation slows down the water and facilitates nutrient uptake through biofilm on the rootstock and roots from nutrients deposited to the soil. The wetland's meandering form helps further slow the water and increases surface area contact between the water and wetland vegetation. These features help retain some nutrient content that would otherwise continue through the unimpeded channel. Although it is not possible to retain all of the water that passes through the channel or retain all of the excess nutrients, a series of sites down the channel would have a collective positive impact on the water quality as it enters the Morris River to the east.

Secondary Design Objectives

Biodiversity improvement has been addressed by introducing the wetland. Wetlands provide incredible biodiversity due to their fluctuating water levels, allowing a variety of plants to flourish. Increased vegetative biodiversity should help increase animal biodiversity since new habitats would be created. Recreation quality is addressed through the pathway system which provides water-based site access. The pathway system, which consists of gravel paths and boardwalks, features information based on the wetland functions and vegetation found on site which addresses the interpretation quality. One of the two water control structures is publicly accessible, allowing visitors to understand the process of controlling water during the different seasons. Connectivity with the existing channel is provided, allowing visitors to kayak or canoe into the wetland. In the winter, the site is accessible for snowshoeing, cross-country skiing, and snowmobiling. Irrigation access to adjacent agricultural land is addressed by maintaining a clearing with access to the agricultural land. These clearings act as an access point to the wetland for harvesting plant material during mowing and the water for pumping.

Fig 144. View of the sedimentation pond on the south side of the channel

Estimated Impacts on Water Quality within the Design Site

Different variables influence the wetland's ability to reduce excess nutrients in the channel. If the nutrient load at any given time is higher, the wetland will retain fewer nutrients, as the system will be overloaded. This factor is essential to consider during the spring when inflow rates are higher, nutrient concentrations are higher, and plants may remain dormant. During times of lower nutrient loads, when the inflow rate is lower, and therefore the nutrient load is lower, the wetland should operate more effectively.

Mitsch's research provides data on the average retention rates of constructed wetlands. These averages are based on a study of constructed wetlands that receive a low concentration of nutrients originating from non-point sources.[93] For Surface-Flow constructed wetlands, when there is a load of 277 g m^{-2} yr^{-1} of nitrogen, 126 g m^{-2} yr^{-1} of nitrogen is retained for 45.6%. When there is a load of 4.7 to 56 g m^{-2} yr^{-1} of phosphorus, 2.1 to 45 g m^{-2} yr^{-1} of phosphorus is retained for 46 to 80%. When there is a load of 107 to 6,520 g m^{-2} yr^{-1} of suspended solids, 65 to 5,570 g m^{-2} yr^{-1} of suspended solids are retained for 61 to 98%.[94] This data comes from constructed wetlands in warm and cold climates. No information on dissolved solids is provided in this source.

To estimate the impact of this wetland intervention in an ideal scenario, Mitsch provides empirical equations to estimate the outflow concentrations based on inflow concentrations and hydraulic retention times.[95]

Suspended Solids – Surface-flow Wetlands: $\boldsymbol{Co = 5.1 + 0.158Ci}$
Total Nitrogen – Surface-flow Marshes: $\boldsymbol{Co = 0.409Ci + 0.122q}$
Total Phosphorus – Surface-flow Marshes: $\boldsymbol{Co = 0.195Ci^{0.91}q^{0.53}}$

where
Co = outflow concentration (g m^{-3})
Ci = inflow concentration (g m^{-3})
q = hydraulic retention time (HRT) (hours)
and HRT[96] = Volume / Inflow Rate

The following data was collected in 2022 and is used here as it is the last complete set available. The peak monthly average inflow rate was in May 2022 at 19.9 m^3 s^{-1}. The median monthly average inflow rate was in July 2022 at 2.19 m^3 s^{-1}. The lowest monthly average inflow rate was in October 2022 at 0.166 m^3 s^{-1}.[97] In terms of volume, the wetland on the north side of the channel is around 25,000 m^3 at a high-water elevation and nearly halving at a 0.5-meter drop in water elevation for 12,500 m^3. The wetland on the south side of the channel is around 30,000 m^3 at a high-water elevation and halving at a 0.5-meter drop in water elevation for 15,000 m^3. Since the inflow rate uses the units of cubic meters per second, we must convert the remaining seconds to hours by dividing by 3600.

During May, July, and October 2022, we see inflow concentrations of nitrogen of 1.63 g m^{-3}, 1.51 g m^{-3}, and 0.99 g m^{-3}, respectively.[98] During the same period, we see inflow concentrations of phosphorus of 0.47 g m^{-3}, 0.17 g m^{-3}, and 0.25 g m^{-3}, respectively.[99] Finally, during the same period, we see inflow concentrations of Total Suspended Solids of 238 g m^{-3}, 19.1 g m^{-3}, and 4.6 g m^{-3}, respectively.[100] With the calculated volumes and HRT, outflow concentrations of nitrogen decrease to 0.71 g m^{-3}, 0.81 g m^{-3}, and 0.01 g m^{-3}. Similarly, outflow concentrations of phosphorus decrease to 0.06 g m^{-3}, 0.05 g m^{-3}, and 0.19 g m^{-3}. Finally, outflow concentrations of Total Suspended Solids decrease to 42.7 g m^{-3}, 8.1 g m^{-3} and 0.01 g m^{-3}. It is worth noting that the 0.01 g m^{-3} represents negligible changes in concentration.

It is important to reiterate that this is just an estimation based on averages determined by rates demonstrated in other constructed wetlands. Only water that enters the wetland is being treated; most of the water will continue to flow through the original channel. These estimates also assume the constructed wetland operates at peak performance and ignores potential climatic influences.

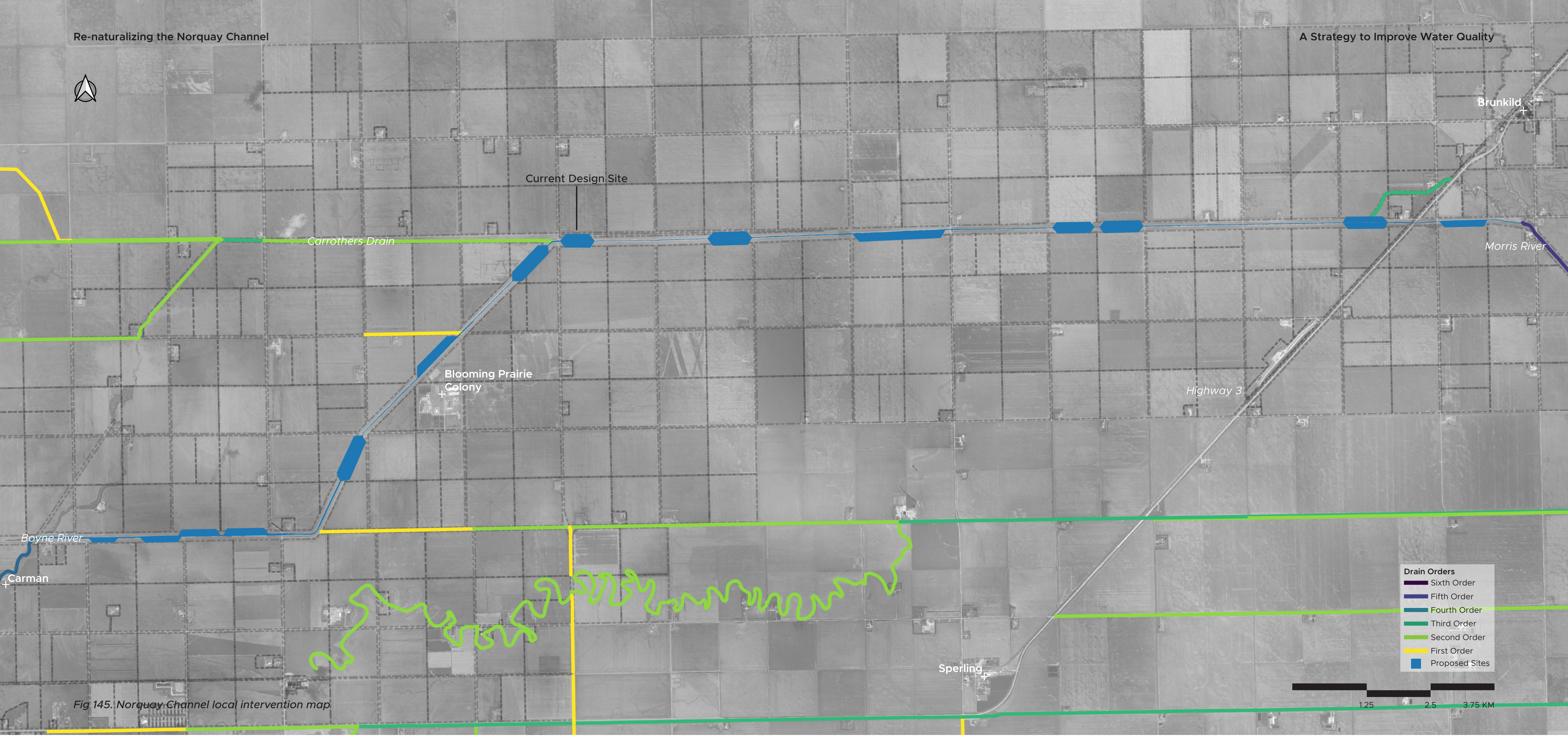


Fig 145. Norquay Channel local intervention map

Potential Intervention Sites along the Norquay Channel

Although the proposed site design will positively impact water quality, its contribution to lowering Lake Winnipeg's nutrient loading is like a drop in the bucket. Therefore, within the Norquay Channel designated drainage area, I propose other sites along the channel where interventions are possible. These sites are similar to my proposed site design, although water depths and land available for the intervention will vary. In total, approximately twenty quarter sections would be affected by the proposed layout in Figure 145.

These proposed sites were chosen because they minimize the amount of agricultural land being taken, do not require demolition or moving of existing structures, and are close to existing road infrastructure, so that there is access to the sites for maintenance and public access. As suggested before, these sites' designs may vary from that I have proposed. Sites may extend perpendicular to the channel, be narrower, or extend for longer distances parallel to the channel. There is a wide array of possibilities. Given that each quarter section is 160 acres, twenty quarter sections would add up to 3,200 acres. The total area of the proposed intervention would compose approximately 400 acres.

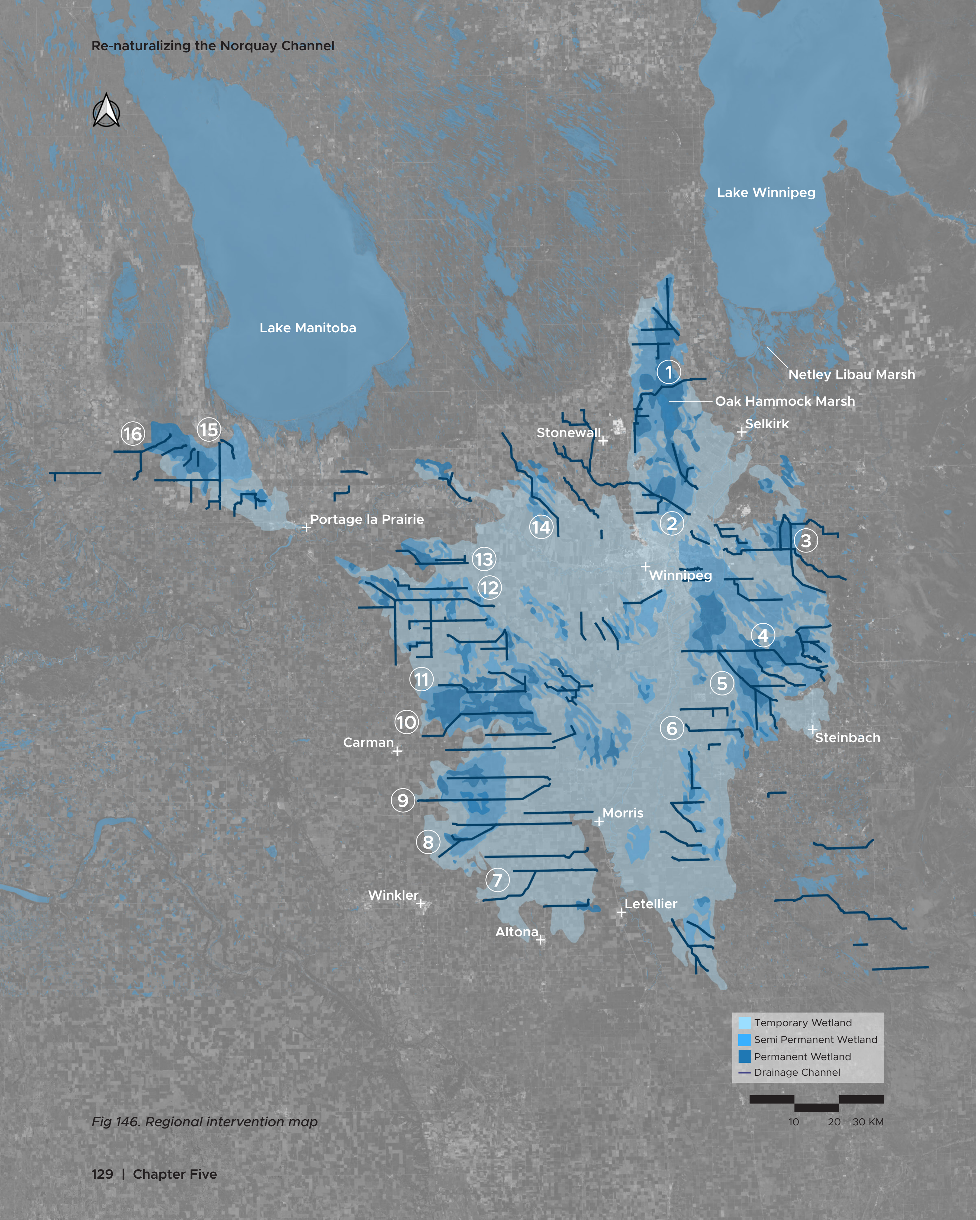


Fig 146. Regional intervention map

1. **Wavey Creek (Fourth Order)**
   Original Wetland: **Balmoral Marsh**
2. **Grassmere Creek Drain (Fifth Order)**
   Original Wetland: **St Andrews Bog**
3. **Cooks Creek (Fourth Order)**
   Original Wetland: **St Anne Bog**
4. **Seine River Diversion (Fourth Order)**
   Original Wetland: **St Anne Bog**
5. **Manning Canal (Fifth Order)**
   Original Wetland: **St Anne Bog**
6. **Tourond Creek (Fourth Order)**
   Original Wetland: **St Anne Bog**
7. **Deadhorse Creek (Fifth Order)**
   Original Wetland: **Tobacco Creek Swamp**
8. **Shannon Creek (Fifth Order)**
   Original Wetland: **Tobacco Creek Swamp**
9. **Tobacco Creek (Fifth Order)**
   Original Wetland: **Tobacco Creek Swamp**
10. **Norquay Channel (Fifth Order)**
    Original Wetland: **Boyne Marsh**
11. **11-A Drain (Fourth Order)**
    Original Wetland: **Boyne Marsh**
12. **Elm Creek Channel (Fifth Order)**
    Original Wetland: **Elm Creek Swamp**
13. **Elm River (Fourth Order)**
    Original Wetland: **Elm Creek Swamp**
14. **Sturgeon Creek (Fourth Order)**
    Original Wetland: **St Andrews Bog**
15. **Westbourne Drain (Fifth Order)**
    Original Wetland: **Westbourne Bog**
16. **Pine Creek (Fifth Order)**
    Original Wetland: **Westbourne Bog**

Interventions at a Regional Scale

The Norquay Channel is just one of many Fifth-Order drains within southern Manitoba. Approximately twelve miles south of the Norquay Channel is the Tobacco Creek Channel. Shannon Creek is three and a half miles south of the Tobacco Creek Channel. Three miles north of the Norquay Channel is the 11-A Drain. These are just a few examples of other substantial drains near the Norquay Channel. Each of these drains offers similar potentials as the Norquay Channel does. As shown in Figure 146, many of these channels overlap with the previously existing wetlands. When selecting waterways here, I prioritized third-, fourth--, fifth-- and Sixth-Order waterways that appear artificial or have semi-artificial portions. These waterways would be similar in scale to the Norquay Channel and be expected to handle a similar volume of water during peak times. The best place to restore wetlands is where they used to exist. Although each waterway's conditions may vary and need to be adequately evaluated, I propose that wetland interventions should be considered along all viable waterways shown in Figure 146.

The site design I proposed in this document would have a positive local impact, but minimally, on Lake Winnipeg. The effect of the design becomes greater when several sites are located in series along the Norquay Channel, and the idea is expanded to other significant waterways in the Red River Valley. These agricultural waterways provide a means of reanimating the wetlands that once existed in the same area. Draining the original wetlands was a large-scale effort over a short period, and now, the same ambition should be applied to recover the wetlands. This effort is done to address climate change in general, as well as the eutrophication of Lake Winnipeg. Manitoba has a history of managing water, but now, it is for a different purpose.

Personal Reflections

Southern Manitoba used to contain multiple marsh and bog wetlands. I first mapped these wetlands in GIS in my regional graduate studio in fall of 2021, and immediately, I was intrigued by them. These wetlands covered such a large area, yet only a fraction of them remain. This disappearance made me want to know more about their fate and relationship to present land uses. Draining over 6,500 square kilometres of wetlands changed the fate of our province, creating accessible agricultural land that attracted so many individuals from near or far. This wave of immigration after the draining of the wetlands included some of my ancestors, who settled in Manitoba due to its agricultural prominence. I believe I understand the importance of agriculture in our province, which is why I have been interested in finding a way to reintroduce wetlands in the agricultural landscape so that they may work together instead of in opposition. This design is just one possibility of many. I feel that is why I found it challenging to begin the design process; you could do almost anything within reason. I have done my best to create a design that considers everything I have learned over the last several years of my undergraduate and graduate degrees. There may be more optimal layouts regarding land use or water treatment, but I am content knowing an honest effort was made to understand the water, land, and vegetation that went into the site design.

Fig 147. View looking from the wetland on the south side of the channel, looking north

Chapter Five Endnotes

93 William Mitsch and James Gosselink, Wetlands, (Hoboken, NJ: Wiley, 2007), 449.
94 William Mitsch, Wetlands, 450.
95 William Mitsch, Wetlands, 453.
96 Frankel, Tom. “What Is Hydraulic Retention Time and How to Optimize for Better Efficiency.” SSI Aeration, December 27, 2023. https://www.ssiaeration.com/how-to-optimize-hydraulic-retention-time/.
97 “Monthly Discharge Graph for BOYNE RIVER NEAR CARMAN (05OF003) [MB].” Water Level and Flow - Environment Canada, March 20, 2024. https://wateroffice.ec.gc.ca/report/historical_e.html?stn=05OF003&dataType=Monthly&parameterType=Flow&first_year=2001&last_year=2022&mode=Graph.
98 Water Quality Management Section – Manitoba Environment and Climate. “Total Nitrogen.” Boyne and Morris River / General Chemistry and Nutrients, May 29, 2023.
99 Water Quality Management Section – Manitoba Environment and Climate. “Total Phosphorus.” Boyne and Morris River / General Chemistry and Nutrients, May 29, 2023.
100 Water Quality Management Section – Manitoba Environment and Climate. “Total Suspended Solids.” Boyne and Morris River / General Chemistry and Nutrients, May 29, 2023.

Page Left Blank Intentionally

Page Left Blank Intentionally

Page Left Blank Intentionally

References

List of Figures, Metadata, and Bibliography

List of Figures

Note:
Photographs and drawings have been produced by author, unless otherwise stated.

List of Images:

List of Figures Continued

List of Figures Continued

Metadata

1:20 000 Water Bodies
Originator: Manitoba Department of Conservation
Publication: March, 2002
Title: WaterBodies
Edition: 1.0
Geospatial_Data_Presentation_Form: vector digital data
Online_Linkage: https://mli2.gov.mb.ca/t20k/meta_files/hyd_bas_20k_py.htm
Abstract: The 1:20 000 scale Topographic Base Map series are digital map layers that show lakes, rivers, streams, marshes, contours, and elevations of surrounding land. Additional features such as classified roads, railway lines, towns, villages and buildings are also shown. This data was collected photogrammetrically from 1:60 000 aerial photography.

2016 Census - Provinces/Territories, Cartographic Boundary File
Originator: Government of Canada; Statistics Canada; Statistical Registers and Geography Division
Publication:
Title: lpr_000b16a_e
Edition: 10.2
Geospatial_Data_Presentation_Form: Vector digital data
Online_Linkage: https://open.canada.ca/data/en/dataset/a883eb14-0c0e-45c4-b8c4-b54c4a819edb/resource/12c03de6-c3f7-4f5f-bb5c-d479f2332842
Abstract: 'Province' and 'territory' refer to the major political units of Canada. From a statistical point of view, province and territory are basic areas for which data are tabulated. Canada is divided into 10 provinces and 3 territories. Statistics Canada uses standard codes and abbreviations to represent provinces and territories. The two-digit code that uniquely identifies each province/territory is based on the Standard Geographical Classification (SGC). The code is assigned from east to west. The first digit represents the geographical region of Canada in which the province/territory is located and the second digit denotes one of the 10 provinces and 3 territories.

2018 Cartographic Boundary File, Current State and Equivalent for United States, 1:5,000,000
Originator: U.S. Department of Commerce, U.S. Census Bureau, Geography Division/Cartographic Products and Services Branch
Publication: May 2019
Title: cb_2018_us_state_5m
Edition: N/A
Geospatial_Data_Presentation_Form: Vector digital data
Online_Linkage: https://www2.census.gov/geo/tiger/GENZ2018/shp/cb_2018_us_state_5m.zip
Abstract: The 2018 cartographic boundary shapefiles are simplified representations of selected geographic areas from the U.S. Census Bureau's Master Address File / Topologically Integrated Geographic Encoding and Referencing (MAF/TIGER) Database (MTDB). These boundary files are specifically designed for small-scale thematic mapping. When possible, generalization is performed with the intent to maintain the hierarchical relationships among geographies and to maintain the alignment of geographies within a file set for a given year. Geographic areas may not align with the same areas from another year.

ArcGIS REST Server World Imagery
Originator: Esri Media
Publication: May 2019
Title: High Resolution 30cm Imagery
Edition: N/A
Geospatial_Data_Presentation_Form: Feature Layer
Online_Linkage: https://services.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer/3 Abstract: World Imagery provides one meter or better satellite and aerial imagery in many parts of the world and lower resolution satellite imagery worldwide. The map includes 15m TerraColor imagery at small and mid-scales (~1:591M down to ~1:288k) for the world. The map features Maxar imagery at 0.3m resolution for select metropolitan areas around the world, 0.5m resolution across the United States and parts of Western Europe, and 1m resolution imagery across the rest of the world. In addition to commercial sources, the World Imagery map features high-resolution aerial photography contributed by the GIS User Community. This imagery ranges from 0.3m to 0.03m resolution (down to ~1:280 in select communities). For more information on this map, including the terms of use, visit us online at http://goto.arcgisonline.com/maps/World_Imagery

Current Drainage Districts
Originator: Government of Manitoba - Manitoba Land Initiative
Publication: N/A
Title: des_
Edition: N/A
Geospatial_Data_Presentation_Form: Vector digital data
Online_Linkage: https://mli.gov.mb.ca/water_resources/des_drain_index.html
Abstract: The Drain Data Sets provide a digital version of Manitoba's drainage system in the agricultural portion of the province as documented by the Water Resources Branch's designations of drains maps. The drainage system is, for the most part, an inter-connected network of channels utilized to convey surface water from the landscape to Manitoba's major lakes. Some drains are natural waterways, some are man made. Large natural waterways, in their original location, typically comprise the trunk or receiving downstream drains. Most drains in hilly or high relief areas are also in their natural location. Where there is less relief, however, and particularly in areas intensively developed for agriculture, most drains are man-made, and many have been relocated to road allowances. Some drains convey their water to wetlands or small lakes, which are in turn connected to the system by channel.

Manitoba Land Use - Agriculture
Originator: Government of Manitoba - Manitoba Land Initiative
Publication: N/A
Title: land_use_agriculture_wp
Edition: N/A
Geospatial_Data_Presentation_Form: Vector digital data
Online_Linkage: https://mli.gov.mb.ca/landuse/index.html
Abstract: Agricultural land use extracted from the general land use files that are provided for Birtle, Brandon, Cedar Lake, Dauphin, Gypsumville, Lac du Bonnet, Minnedosa, Ponton, Riverton, Selkirk, Swan River, Virden, Winnipeg, and Woodridge.

Metadata Continued

Manitoba Municipal Boundaries
Originator: Government of Manitoba
Publication: N/A
Title: MG_MUNICIPALITY_POLY
Edition: N/A
Geospatial_Data_Presentation_Form:
Online_Linkage: https://www.arcgis.com/apps/mapviewer/index.html?layers=c6a9c6e1bb824b40981ebebaf7d733cc&layerId=0
Abstract: This dataset is comprised of boundary geometry for all of the incorporated municipalities and Northern Affairs Communities within the Province of Manitoba. The boundaries in this dataset represent the descriptions set forth in the Municipal Status and Boundaries Regulation (567/88R) and subsequent amendments, and regulations under The Northern Affairs Act. The geospatial referencing of the Municipal Boundaries is based on the best available land parcel data for each municipality and Northern Affairs Community. Where available, cadastral data based on registered survey plans was used. Otherwise, the Manitoba Property Assessment Information dataset produced by Manitoba Municipal Relations was used. The delineation of the boundaries was established according to the regulation establishing or amending the boundary of a municipality or Northern Affairs Community.

Manitoba Provincial Boundary
Originator: GeoManitoba, Manitoba Sustainable Development
Publication: December 2016
Title: bdy_province_py_shp
Edition: N/A
Geospatial_Data_Presentation_Form:
Online_Linkage: https://geoportal.gov.mb.ca/datasets/manitoba::manitoba-provincial-boundary/
Abstract: Manitoba provincial boundary originally accessed through Manitoba Land Initiative website: https://mli.gov.mb.ca/adminbnd/index.html. A feature layer of Manitoba's provincial boundaries:Manitoba/Ontario boundary,Manitoba/Saskatchewan boundary,Manitoba/Nunavut boundary,International boundary.Excluding the International Boundary, the graphical data was computed from original boundary survey measurements published in respective official boundary commission reports using least squares adjustment software "Manor". The adjustments were constrained to known NAD83 [nmip94 adj.] federal/provincial boundary marker positions. For the International Boundary, the graphics were created by converting the official published NAD27 marker positions for the boundary into NAD83 using datum conversion software NTv2 and interconnecting the plotted marker positions with straight lines using CARIS map software.

Manitoba Watershed Districts
Originator: Government of Manitoba, Manitoba Sustainable Development
Publication: Jan 2020
Title: watershed_districts_mb
Edition: N/A
Geospatial_Data_Presentation_Form: Vector digital data
Online_Linkage: https://geoportal.gov.mb.ca/datasets/manitoba::watershed-districts/explore?location=51.309699%2C-98.721188%2C7.59
Abstract: The purpose of this dataset is to provide the public with the areal extents of the 14 watershed districts in Manitoba.

Norquay Channel Drainage District 18
Originator: Government of Manitoba
Publication: N/A
Title: des018_shp
Edition: N/A
Geospatial_Data_Presentation_Form: Vector digital data
Online_Linkage: https://mli.gov.mb.ca/water_resources/des_drain_index.html
Abstract: The Drain Data Sets provide a digital version of Manitoba's drainage system in the agricultural portion of the province as documented by the Water Resources Branch's designations of drains maps. The drainage system is, for the most part, an inter-connected network of channels utilized to convey surface water from the landscape to Manitoba's major lakes. Some drains are natural waterways, some are man made. Large natural waterways, in their original location, typically comprise the trunk or receiving downstream drains. Most drains in hilly or high relief areas are also in their natural location. Where there is less relief, however, and particularly in areas intensively developed for agriculture, most drains are man-made, and many have been relocated to road allowances. Some drains convey their water to wetlands or small lakes, which are in turn connected to the system by channel.

Soil Inventory - 1:1,000,000
Originator: Government of Manitoba
Publication: N/A
Title: soils_shp
Edition: N/A
Geospatial_Data_Presentation_Form: Vector digital data
Online Linkage: http://mli2.gov.mb.ca/adminbnd/index.html
Abstract: This dataset contains Manitoba Agriculture soil survey data at various scales ranging from highly detailed to broader reconnaissance level information.

Southern Manitoba Historical Drainage Districts
Originator: Fall 2023 - Benjamin Boswick
Publication: 2011 (November 2023)
Title: historical_drainage_districts
Edition: N/A
Geospatial_Data_Presentation_Form: Vector digital data
Online_Linkage: N/A
Abstract: Map data adapted from Figure 4 (Drainage districts in Manitoba, 1933) Shannon Studen-Bower. Wet Prairie: People, Land, and Water in Agricultural Manitoba. (Vancouver, B.C.: University of British Columbia Press, 2011), 34. Original map adapted from Adapted from Archives of Manitoba, Manitoba Department of Mines and Natural Resources, Surveys Branch, Map of Manitoba, Southern Portion, 1933; the Drainage Districts, map, in J.H. Ellis, The Soils of Manitoba (Winnipeg, Manitoba: Economic Survey Board, 1938), 29.

Metadata Continued

Watersheds of North America
Originator: Government of Canada, Natural Resources Canada, Mapping Information Branch, The Atlas of Canada
Publication: 2010
Title: North American Atlas – Basin Watersheds
Edition: N/A
Geospatial_Data_Presentation_Form: Vector digital data
Online_Linkage: http://geogratis.gc.ca/download/frameworkdata/North_America_Atlas10M/watersheds/
Abstract: The North American Atlas – Basin Watersheds data set shows watersheds in North America at 1:10,000,000. A watershed is an area encompassing part or all of a surface drainage basin, a combination of drainage basins, or a distinct hydrologic feature. Watersheds are mapped in a hierarchical system, with the largest units encompassing the entire drainage areas of major rivers or river systems, or encompassing seaboard areas. Within these large units, subsequently smaller units encompass the drainage areas of smaller rivers and streams. Watersheds are classified differently in Canada, Mexico and the United States; the data set includes a continental classification (the North American Watershed, or NAW level), as well as the classification unique to each country. This data set was compiled from each country's watershed file and adjustments were made to the data to resolve misalignments and mismatches across international borders.

Wet Prairie Zones of the Winnipeg Region Prior to Drainage
Originator: LARC 7340 Fall 2021 - Regional Studio - Benjamin Boswick
Publication_Date: 1974 (Digitized September 2021)
Title: (PermanentWetland OR SemiPermanentWetland OR TempWetland)
Edition: 1.0
Geospatial_Data_Presentation_Form: Vector digital data
Publisher: N/A
Online_Linkage: N/A
Abstract: Developed by Benjamin Boswick in the Fall 2021 LARC 7340 Regional Studio for the purpose
of mapping wetlands that existed prior to drainage around Winnipeg. Data is based on map sourced
from Manitoba historical map, Wet Prairie Zones of the Winnipeg Region Before Settlement and Drainage
from 1974. Original document is accessible at https://www.flickr.com/photos/manitobamaps/2326505715.
The provided information is given; Bossenmaier, E. F. and C. G. Vogel. Wet Prairie Zones of the Winnipeg Region showing Temporary, Semi-permanent and Permanent Wetlands before Settlement and Drainage. Scale not given. In: Resources Planning, Manitoba Dept. of Mines, Resources and
Environmental Management. Wildlife and Wildlife Habitat in the Winnipeg Region. Winnipeg: 1974. Shows Temporary, Semi-permanent and Permanent Wetlands before Settlement and Drainage.
Purpose: To detail the original wet prairie zones that existed in the Winnipeg region prior to European settlement and organized drainage.

Page Left Blank Intentionally

Bibliography

An, Shuqing, and Verhoeven, Jos. Wetlands: Ecosystem services, restoration and wise use. Cham, Switzerland: Springer Nature Switzerland AG, 2019.

"Berm." Merriam-Webster. Accessed March 25, 2024. https://www.merriam-webster.com/dictionary/berm.

"Boyne River (rivière aux îlets -de-Bois)" Carman-Dufferin Heritage, accessed November 21, 2023, https://carmandufferinheritage.ca/pdfs/Boyne%20River%20history%20expanded%20version.pdf.

"Brokenhead Wetland Interpretive Trail." Manitoba Trails Project. Accessed March 25, 2024. http://www.manitobatrailsproject.ca/trail-list/brokenhead-wetland-interpretive-trail/.

Campbell, Brian. "What Is Total Suspended Solids (TSS)?" Wastewater Digest, July 12, 2022. https://www.wwdmag.com/utility-management/article/10939708/what-is-total-suspended-solids-tss.

Carman/Dufferin Municipal Heritage Advisory Committee. "Boyne Marsh." Local Heritage Special Places, accessed November 21,2023, https://carmandufferinheritage.ca/local%20heritage/special%20places/loc-her-spec-pl.html.

"Channel." Merriam-Webster. Accessed March 25, 2024. https://www.merriam-webster.com/dictionary/channel.

"Constructed Wetlands." US EPA. August 24, 2023. https://www.epa.gov/wetlands/constructed-wetlands.

"Culvert." Merriam-Webster. Accessed March 25, 2024. https://www.merriam-webster.com/dictionary/culvert.

"Dike." Merriam-Webster. Accessed March 25, 2024. https://www.merriam-webster.com/dictionary/dike.

"Ditch." Merriam-Webster. Accessed March 25, 2024. https://www.merriam-webster.com/dictionary/ditch.

Ducks Unlimited Canada. "Wetland Classes." Manitoba Prairie Wetland Classification Guide, accessed November 21,2023, https://www.ducks.ca/assets/2020/05/Ducks-Unlimited-Canada_Landowners-Guide.pdf.

"Emerald Necklace." Olmsted Network, July 6, 2023. https://olmsted.org/sites/emerald-necklace/.

Environment and Climate Change. "Drainage & Water Control." Government of Manitoba. Accessed March 25, 2024. https://www.gov.mb.ca/sd/water/water-rights/drainage-and-water-control/index.html.

Environment and Climate Change Canada, Manitoba Agriculture and Resource Development. "Nutrient Loading." State of Lake Winnipeg – Second Edition, March 2020, https://www.gov.mb.ca/sd/pubs/water/lakes-beaches-rivers/state_lake_wpg_report_tech.pdf.

Frankel, Tom. "What Is Hydraulic Retention Time and How to Optimize for Better Efficiency." SSI Aeration, December 27, 2023. https://www.ssiaeration.com/how-to-optimize-hydraulic-retention-time/.

Health Canada. "Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Total Dissolved Solids (TDS)." Government of Canada, August 21, 2009. https://www.canada.ca/en/health-canada/services/publications/healthy-living/guidelines-canadian-drinking-water-quality-guideline-technical-document-total-dissolved-solids-tds.html.

Hoffbeck, Dr. Steve. "The Wondrous Soil of the Red River Valley." Prairie Public Broadcasting. Accessed March 25, 2024. https://news.prairiepublic.org/show/dakota-datebook-archive/2022-06-04/the-wondrous-soil-of-the-red-river-valley.

Kadlec, Robert H., and Scott D. Wallace. Treatment wetlands. Boca Raton, FL: CRC Press, 2009.

La Salle Redboine Conservation District. "Section 5.0 – Water Resources." La Salle River Watershed: State of the Watershed Report, accessed November 21, 2023, https://www.gov.mb.ca/sd/water/watershed/iwmp/la_salle_river/documentation/summary_lasalle.pdf.

Manitoba Agriculture, Food and Rural Initiatives. Soil Series Descriptions, March 2010, https://agrimaps.gov.mb.ca/agrimaps/extras/info/Soil_Series_Descriptions.pdf.

Manitoba Drainage Standards Document. Provided by Ron Kaatz, Technical Services Engineer, Water Infrastructure, September 21, 2023.

Manitoba Water Stewardship. "Manitoba Water Quality Standards, Objectives, and Guidelines". November 28, 2011, https://www.gov.mb.ca/sd/pubs/water/lakes-beaches-rivers/mb_water_quality_standard_final.pdf.

Margaret Morton Fahrni and W. L. Morton. Third crossing: A history of the first quarter century of the town and district of gladstone in the Province of Manitoba (Winnipeg, Man.: M. Morton and W.L. Morton, 1946), http://www.mb1870.org/localhistory/024%20-%20Third%20Crossing.pdf.

Mitsch, William J., and James G. Gosselink. Wetlands. Hoboken, NJ: Wiley, 2007.

"Monthly Discharge Graph for BOYNE RIVER NEAR CARMAN (05OF003) [MB]." Water Level and Flow - Environment Canada, March 20, 2024. https://wateroffice.ec.gc.ca/report/historical_e.html?stn=05OF003&dataType=Monthly&parameterType=Flow&first_year=2001&last_year=2022&mode=Graph.

Bibliography Continued

"Niverville Lagoon System." Native Plant Solutions, November 25, 2020. https://www.nativeplantsolutions.ca/our-work/niverville-lagoon-system/.

"Nutrient Concentration and Loading Targets for Lake Winnipeg and its Tributaries." A Proposed Regulation under the Water Protection Act, Winter 2020. https://www.gov.mb.ca/sd/pubs/water/lakes-beaches-rivers/nutrient_targets_regulation_plain_language_summary_fall_2020.pdf.

"Plant Hardiness Zone Maps." Natural Resources Canada - Government of Canada. Accessed March 2, 2024. http://planthardiness.gc.ca/?m=1.

Rattan, K.J., E.A. Blukacz-Richards, A.G. Yates, J.M. Culp, and P.A. Chambers. "Hydrological Variability Affects Particulate Nitrogen and Phosphorus in Streams of the Northern Great Plains." Journal of Hydrology: Regional Studies 21 (February 2019): 110–25. https://doi.org/10.1016/j.ejrh.2018.12.008.

Studen-Bower, Shannon. Wet Prairie: People, Land, and Water in Agricultural Manitoba. Vancouver, B.C.: University of British Columbia Press, 2011.

The Manitoba Habitat Heritage Corporation. "Growing Outcomes in Watersheds." GROW: Growing Outcomes in Watersheds - Guide, 2021, https://www.gov.mb.ca/sd/water/pubs/water/watershed/grow-guidebook-2021.pdf.

"Total Suspended Solids (TSS) and Total Dissolved Solids (TDS)." DataStream, accessed November 21, 2023, https://datastream.org/en-ca/guidebook/total-suspended-solids-tss-and-total-dissolved-solids-tds.

Tree Canada. "How Flooding Affects Trees: Water in Moderation." Tree Canada, January 5, 2023. https://treecanada.ca/article/how-flooding-affects-trees-water-in-moderation/.

Warner, Barry G., and Rubec C D A. The Canadian Wetland Classification System. Waterloo, Ont.: Wetlands Research Branch, University of Waterloo, 1997.

Water Quality Management Section – Manitoba Environment and Climate. Boyne and Morris River / General Chemistry and Nutrients, May 29, 2023.

Water Quality Management Section, Sustainable Development. "Water Quality Investigations and Routine Monitoring." Boyne-Morris Watershed Integrated Watershed Management Plan – Water Quality Report, April 2017, https://www.gov.mb.ca/sd/water/watershed/iwmp/boyne/documentation/boynemorris_wq_sub.pdf.

"Watersheds." Freshwater Inflows. Accessed May 6, 2024. https://www.freshwaterinflow.org/watersheds/.

Watson, June M. The rural municipality of Dufferin, 1880-1980. Carman, Man.: Council of the Rural Municipality of Dufferin, 1982.

"What Is a Wetland?" US EPA. May 4, 2023. https://www.epa.gov/wetlands/what-wetland.

"Wolverton Creek Restoration: Buffalo-Red River Watershed District." Buffalo-Red River Watershed District. Accessed March 25, 2024. https://www.brrwd.org/wolverton-creek-restoration.

Adobe Inc. InDesign. V. 19.1.6. Adobe Inc. PC. 2024.

Adobe Inc. Illustrator. V. 28.1 x64. Adobe Inc. PC. 2024.

Adobe Inc. Photoshop. V. 25.3.1 x64. Adobe Inc. PC. 2024.

Epic Games Inc. TwinMotion. V. 2023.2.3, CE. Epic Games Inc. PC. 2024.

QGIS Development Team. QGIS Geographic Information System. V. 3.26.3-Buenos Aires. QGIS Development Team. PC. 2024.

Page Left Blank Intentionally

“Forsitan hoc memorans fiet aliqua die voluptas.”