Storing Water on the Land: The Waffle® Concept Revisited

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STORING WATER ON THE LAND

THE WAFFLE® CONCEPT REVISITED

JODY RUTLEDGE

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PREFACE

This practicum began as a regional-based graduate design studio project. I explored the Waffle® concept as method to reconnect fragmented landscapes and decrease seasonal flooding and drought in the Assiniboine River Basin (ARB). Although the Waffle® concept faced social and environmental challenges, its goal to detain large amounts of runoff, with little additional infrastructure investment, was intriguing. At the end of the studio project, I wanted to explore further the principles of the Waffle® concept and whether it could be used alongside other water retention options to create a landscape that could mitigate downstream flooding and nutrient export and extends its services to agriculture, recreation, prairie ecology, sustainable water management. In addition, I wanted to explore how these services could be explored through the lens of landscape architecture to educate and create human experience.

The original Waffle® concept was developed to detain spring runoff in the flat landscape conditions found in the Red River Basin and for this practicum, I wanted to explore whether it could be applied to the Assiniboine River Basin and used to manage both spring runoff and large precipitation events throughout the growing season.

OBJECTIVES

- To increase on-site water storage to decrease downstream peak flow and nutrient export.
- To select a site for an exemplary application of methods and techniques discussed which lead to improvements in environmental/ ecological qualities through landscape architecture and design.
- The design proposal captures runoff and creates a landscape that optimizes slow release, reduces runoff impacts of agriculture; and creates opportunities for ecological restoration and recreation.

INTRODUCTION

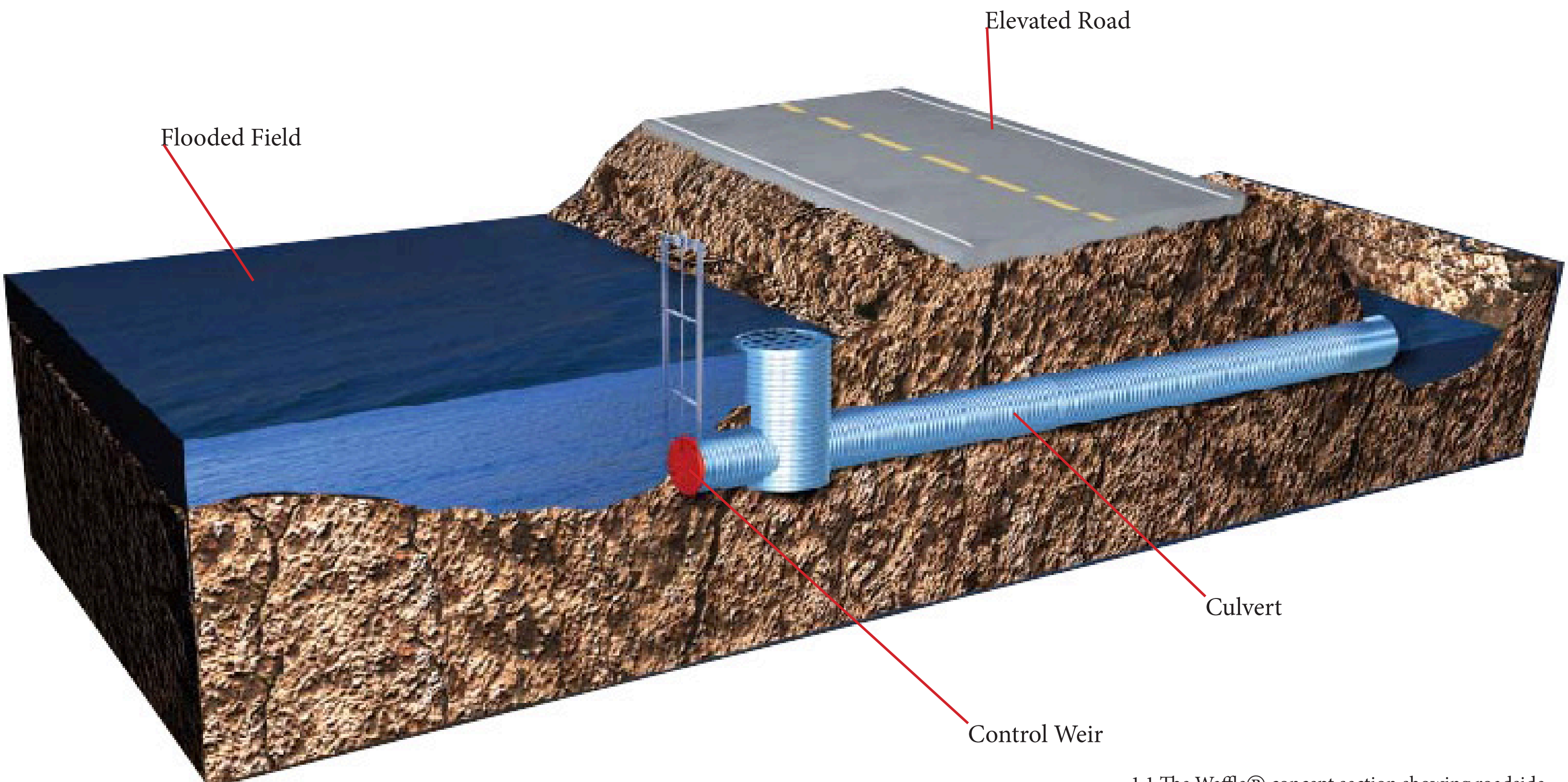
Since the 1960's approximately 70% of Canada's wetlands have been drained or filled. Agricultural drainage networks have further affected the ability of the landscape to slow the flow of water and filter out contaminants.

Large-scale flooding is occurring more frequently with a major economic impact. These flood events result in property damage, soil erosion, sedimentation of crops, rivers and lakes, that have created conditions that negatively impact water quality.

Historically, our response has been to build large structures like the Winnipeg Floodway and the Portage Diversion to divert water from the Red and Assiniboine rivers. These structures have certainly saved the City of Winnipeg and other communities from being inundated by floodwaters. But what they don't do is address water quality. Nitrogen and phosphorus are found in runoff and when deposited into downstream waterbodies ideal conditions are created for algal growth and lake eutrophication. Recently, researchers have begun to explore a variety of ways to hold water on the land. These interventions are often small scale and manage water at its source point. Wetland restoration and the waffle concept are two such interventions and have shown effects on soil erosion, nutrient export and peak flows.

A site near Cardale, Manitoba is used to apply these principles and create a new prairie landscape that reveals the process that detains water and filters nutrients and sediment. The design includes a trail system to bring visitors in close contact with this new prairie hydrology.

This practicum started as a regional-based studio project. The Waffle® concept originally developed for the Red River Basin was explored as a method to reconnect fragmented landscapes and decrease seasonal flooding and drought in the Assiniboine River Basin. This practicum further explores how or if the Waffle concept principles could be used alongside other water retention structures to mitigate flooding and nutrient export and, at the same time, create experience.



1.1 The Waffle® concept section showing roadside control weir and underground culvert. (Image: Kurz et al., 2008)

I. THE WAFFLE CONCEPT


1.2 The Waffle® concept water intake site with protective cage. (Image: Kurz et al., 2008)

The Waffle® concept it is a basin-wide, distributed, temporary storage strategy that uses field spaces to hold water and elevated road infrastructure as levies to control springtime runoff during snowmelt events (Figure 1.1) (Kurz, Wang, de Silva, Hanson, Kurz, Peck, Simonsen & Steadman, 2008, p.xiv). Gates and weirs are installed at road junctions (Figure 1.2) to detain surface water until the main tributary could accommodate the water without overflowing riverbanks and flooding surrounding land. After peak flows have passed, control gates are opened to allow water to flow toward collecting watercourses.

Dr. Gerald Groenwold of the Energy and Environmental Research Centre at the University of North Dakota developed the Waffle® concept after the 1997 Red River Flood. Using fine-grained LiDAR (Light Detection and Ranging) imaging data, sections of land were assessed based on their storage capacity and relative position in the basin. Groenwold's work showed that using the Waffle® concept could have reduced peak flood level by as much as 30% during the 1997 flood.

Figure 1.3 Aerial image of the Waffle® concept showing spring melt pattern and extent of land inundation. (Image: Kurz et al., 2008)

1.2 WATER QUANTITY AND QUALITY IMPACTS OF THE WAFFLE® CONCEPT

The Waffle® concept meets important criteria for practical water management in the region. It has the ability to mitigate flooding and nutrient export, is relatively inexpensive, takes advantage of existing infrastructure, and protects both the urban and rural areas of the basin (Kurz et. al., 2008). Scientific trials conducted verified that the Waffle® approach could affect the overall flood volumes through processes like increased evaporation and infiltration, increase soil moisture and supplementing groundwater reserves "without adversely affecting the environment" (Kurz et. al., 2007, p. xiv).

The Waffle® approach reduces springtime runoff rates and total flood volumes. The results of the field trials showed that an average of 38% of the total stored water volume can be lost to infiltration and evaporation, thereby reducing the total volume of potential water that would have otherwise flowed downstream (Kurz et al., 2007, p.153).

Nutrient export was also examined. There are two main contaminants of agricultural runoff that are taken into account when looking at the efficacy of the Waffle® concept: nitrate and phosphorus levels. In two of three sites, nitrate concentrations decreased between flooded and non-flooded areas. This is likely due to the process in which bacteria convert nitrates to nitrogen gas through denitrification. This typically occurs in anaerobic or low oxygen environments (Kurz et. al., 2007, p.104). Limited changes were seen in phosphorus concentrations between the fall of 2003 and 2004 and again in the late springs/ early summer of 2004/2005. Fall and spring phosphorus concentration in flooded and non-flooded areas on the monitored sites show little change at the study site, phosphorus concentrations remained similar in fall and spring. Where water was stored, there was an increased from 6.0 to 7.5 ppm in average concentrations. There were reductions seen as well in areas with stored water (Kurz et al., 2007, p.102). When it comes to phosphorus, small agricultural losses can cause significant water quality problems as eutrophication can occur at very low concentrations of phosphorus in surface water bodies (20-50 parts per billion) which causes harmful and potentially toxic cyanobacteria blooms.

1.3 FINANCIAL IMPACTS THE WAFFLE® CONCEPT

The estimated net benefits of a Waffle® approach ranged from hundreds of millions of dollars to over $800 million dollars over 50 years. These numbers did not include economic benefits associated with decreased flood damage to smaller communities, agricultural land, rural infrastructure or farmsteads. The Waffle® concept takes advantage of existing infrastructure with minor structural modifications to produce benefits. It can be used in addition to on-channel dams, dikes or diversions that address channel flow rather than overland runoff. Implementation can be small or large depending on the benefits to surrounding landowners, which increases its adaptability and value (Figure 1.3).

Figure 1.4 Aerial view of the extent of springtime flooding.
(Image: Government Relations, 2014)

1.4 APPLICATION OF THE WAFFLE® CONCEPT TO THE ASSINIBOINE RIVER BASIN

In its original form, the Waffle® concept was not evaluated as a means of mitigating summer flooding but only springtime flooding. However, flood events are occurring throughout the growing season in the Assiniboine River Basin (ARB) (Figure 1.4). Timing of these events is important because seeded fields will succumb to water damage after two days and fields that have not yet been seeded may be able to hold water for up to two weeks (Butzen, 2016). In this case, holding water on seeded fields is not economically feasible.

However, others are examining the concept of holding water on the land and as mentioned previously, is the subject matter of the Red Assiniboine Project was conducted in Manitoba by Agriculture and Agri-Food Canada (AAFC), Environment and Climate Change Canada and the Manitoba Government. Policies like the new Surface Water Management Strategy and research by scientists like John Pomeroy at the University of Saskatchewan all suggest that storing water on the land is a viable method for decreasing peak flows and associated flooding and lake eutrophication.

Another approach that has been developed and researched but not yet put into practice is the Waffle® Concept. Weirs are installed at key junctions to control water levels within field sections and once peak flow has passed these gates are systematically opened to release runoff. It was developed in North Dakota after the 1997 Red River Flood. Dr. Gerald Groenwold, along with other research scientists at the University of North Dakota found that it could have reduced peak flood levels by 30%. Estimates showed that benefits from the Waffle® concept ranged from 100 to over 800 million dollars in reduced property damage. Nutrient export was also examined and it showed that reduced phosphorus and nitrate concentrations were found in runoff from flooded fields.

Using existing infrastructure and landforms to reduce flood damage and nutrient export seems like a good idea. But could it applied to the ARB? There are a number of differences though that made the question a challenging one. Topography of the Red River Basin (RRB) is flat and expansive, while the ARB is undulating with a variety of landform patterns. The Waffle® concept examined springtime flood events while flooding in the ARB occurs throughout the growing season.

Figure 2.1 Aerial view of agricultural field showing extent of drainage channels. (Image: Jeope Wolfe; 2014).

2. BACKGROUND AND CURRENT ISSUES

Flood events affect landscapes and people in many ways. The water itself has consequences for property and communities but causes even greater damage to human and natural environments from associated nutrients and sediment that are carried downstream. Understanding the economic, social, and environmental impacts of these flood events can help to develop a sustainable solution that addresses political, industry, community and environmental needs.

2.1 ECONOMIC AND SOCIAL CONSIDERATIONS

Understanding the current economic, social and environmental impacts of flooding and degraded water quality is important to develop a more comprehensive, sustainable solution.

Economic issues include directs costs like flood damage to communities and infrastructure; lost revenue from flooded crops and loss of production; and production of flood infrastructure and maintenance. It is costly to build and maintain Manitoba's current flood infrastructure (Manitoba Infrastructure and Transportation, 2013, p. 14), and requires an intensive maintenance schedule. Minimizing the need for long-term maintenance decreases costs and is an important factor in sustainability. Hydrological engineering and design has often focused on minimal flow area, which doesn't account for extreme events. This strategy sometimes means maintenance is a secondary consideration and results in drains that are expensive to maintain (AECOM, 2010, p.8). As new structures are built, the initial cost and the long-term maintenance investment are equally important to factor into the overall efficiency of each structure.

Smaller retention structures that are constructed, in part, by landowners are a key component to sustainable flood infrastructure. These smaller interventions are also built to mitigate basin-wide flooding but also consider water quality, habitat and other environmental implications (AECOM, 2010, p.1).

Indirect costs include degraded ecosystems caused by eutrophication; loss of shoreline or private property from increased water levels; fishery affects due to fish kills and vulnerability to invasive species.

Social Impact

Policies that support community involvement, education and economic incentive have a greater chance of acceptance in the agricultural community. However, development of drainage policies and agricultural practices has, in fact, contributed to flooding. The book Wet Prairie: People, Land, and Water in Agricultural Manitoba (2011) discuss the history and precedents for draining water from the prairie landscape. Over time, these historical drainage practices have created networks that move excess surface water off cropland. Drains and channels have been dug to increase channel efficiency (Bower, 2011, p. 26). Over time, these channels have created a large, regional network. This efficiency has removed the landscape's ability to slow the flow of runoff and filter nutrients out of the water column. A 2007 document written by the Lake Winnipeg Stewardship Board recommended that watershed managers explore the feasibility of reducing the velocity of flow in agricultural drains in order to allow particulate nutrients an opportunity to settle out (Lake Winnipeg Stewardship Board, 2007, p. 14). Since that time, research has shown (Woltemade, 2000) (Paul, 2003)

2.2 Southwest shoreline of Lake Winnipeg showing extent of late season algal bloom. (Image: Lake Winnipeg Foundation, 2014)

that a variety of structures and their strategic location within the landscape support decreased velocities and have the ability to retain a significant amount of nutrients. These structures include reconstructed and natural wetlands and other settling basins.

In 2013, the Manitoba Government introduced its new Surface Water Management Strategy. The strategy's goal was to "identify actions that would improve the landscape." This required a framework where drainage and water retention are considered as cooperative factors and create benefits that include flood mitigation and nutrient management. The document describes "No Net Loss of Wetland Benefits" that includes wetland restoration and mitigation when drainage is deemed necessary (Water Stewardship Division, 2012, p. 3).

Agricultural Beneficial Management Practices are farm-site activities that reduce negative environmental impacts and have been studied by the International Institute for Sustainable Development and AAFC to determine their performance on a watershed scale (Agriculture and Agri-Food Canada, (2013a). Forage conversion and small dams were found to positively affect water quality, amount of runoff, sedimentation and nutrient loading. AAFC is looking at different types of small-scale water retention structures including small dams, wetlands and sediment control structures and how they can address specific and unique challenges on individual farm sites.

2.2 ENVIRONMENTAL CONSIDERATIONS

Environmental impacts of flooding include topsoil erosion, downstream sediment deposition, changes in water flow velocity and direction, biochemical changes to downstream waterbodies. Fast-flowing runoff removes topsoil and carries it downstream. Sediment deposition on river bottoms affect breeding grounds and fish habitat, and influence flood severity by changing channel roughness and conveyance (Houlden & Collell, 2016).

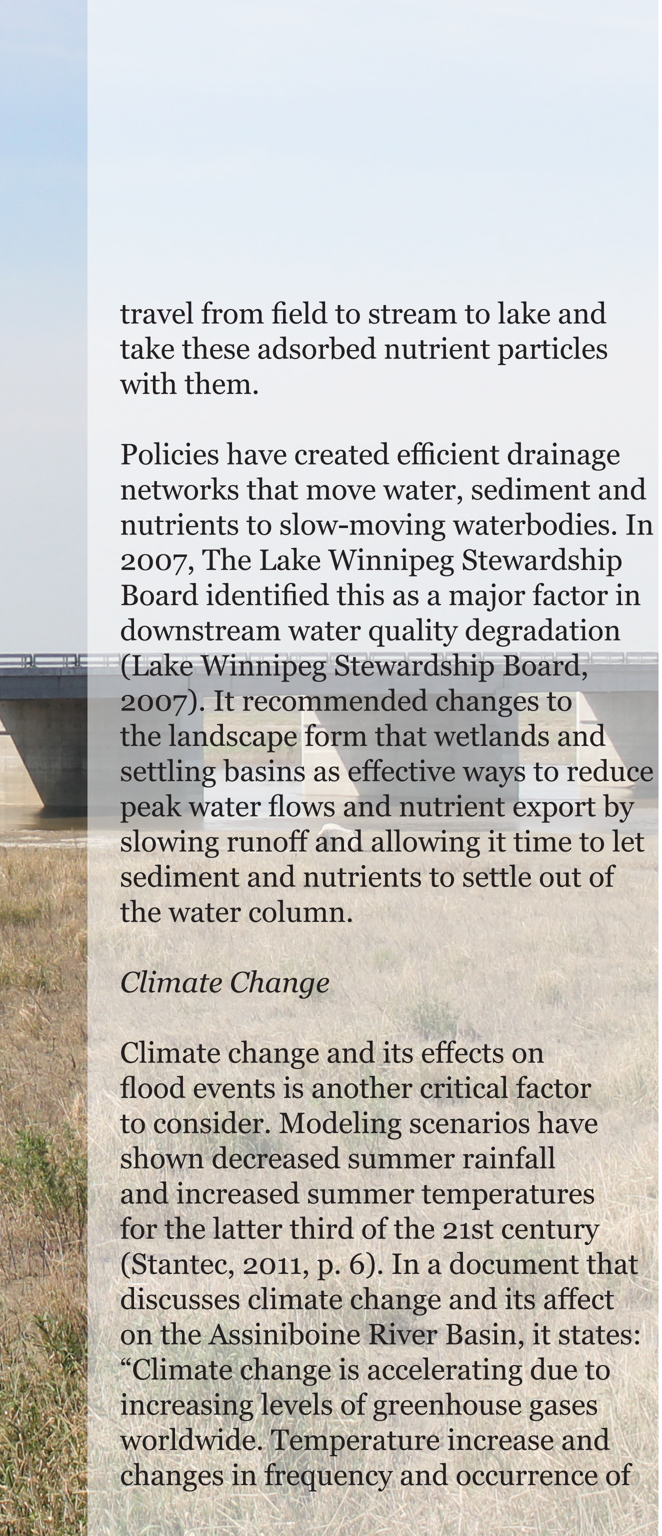
Sediment can also change the physical properties of a watercourse. As sediments settle, the shape of the watercourse changes and affects the speed at which water will flow. An increase in velocity can increase scouring rate of outside edges of river bends further adding to the sediment load in the river.

Nutrients

The sediment that remains suspended in the water column blocks the sunlight. Sedimentation also changes the biochemical characteristics of river systems by carrying adsorbed chemicals such as phosphorous and nitrogen. When sediments are carried to slower moving water, such as a lake or pond, they tend to settle out of the water column. Adsorbed chemicals create conditions that favour the growth of algae.

Fertilizers, urban wastewater, septic tanks, and stormwater runoff all contain several nutrients including nitrogen and phosphorus (World Resources Institute, n.d.). These two nutrients are the primary causes of algal blooms and lake eutrophication in Lake Winnipeg (International Institute for Sustainable Development, 2013) (Figure 2.2). These two nutrients are found in agricultural landscapes and occur both naturally and from external inputs. Nitrogen, a compound necessary for photosynthesis (Mosaic Crop Nutrition, 2016), is typically applied to crops in a variety of forms. Phosphorus by comparison is relatively scarce in the natural environment and released only through rock and mineral weathering (Johnston & Steen, 2000, p.11). The main source of phosphorus is found in commercial fertilizers applied to crops. Phosphorus can be found in runoff in dissolved form or particulate form. These soil particles

Figure 2.3 Newly constructed bridge over the Portage Diversion south of Portage la Prairie. (Image: Rutledge, 2013)



travel from field to stream to lake and take these adsorbed nutrient particles with them.

Policies have created efficient drainage networks that move water, sediment and nutrients to slow-moving waterbodies. In 2007, The Lake Winnipeg Stewardship Board identified this as a major factor in downstream water quality degradation (Lake Winnipeg Stewardship Board, 2007). It recommended changes to the landscape form that wetlands and settling basins as effective ways to reduce peak water flows and nutrient export by slowing runoff and allowing it time to let sediment and nutrients to settle out of the water column.

Climate Change

Climate change and its effects on flood events is another critical factor to consider. Modeling scenarios have shown decreased summer rainfall and increased summer temperatures for the latter third of the 21st century (Stantec, 2011, p. 6). In a document that discusses climate change and its affect on the Assiniboine River Basin, it states: "Climate change is accelerating due to increasing levels of greenhouse gases worldwide. Temperature increase and changes in frequency and occurrence of extreme weather are expected to lead to accelerated ecosystem degradation and economic impacts. The agricultural sector is sensitive to climate change and quantity and timing of water supplies in particular." (Stantec, 2011, p. 31). Future predictions from the Canadian Regional Climate Model says low flows will be about the same in the future, extreme flow years will continue to occur but extreme events may be slightly higher than in past events (Stantec, 2011 p.90). As precipitation events become less frequent but more intense and snow accumulation and temperatures fluctuate, how can we utilize water resources in a way that contribute to the conservation of the supporting ecologies?

Computer models of temperature and precipitation for the next 90 years show that winter and fall precipitation will generally increase in the later part of the 21st century and summer precipitation shows less change in the first two-thirds but appears to decrease for two of the three models in the latter third of the 21st century (Stantec, 2011). Temperature changes show a consistent increase across all months over the next century (Stantec, 2011). Indications are that climate change due to global warming may result in even greater variability and extremes in weather, both for the short term (daily to seasonal and the longer term (years to decades) and contribute to new challenges for water management (Red River Basin Board, 2000).

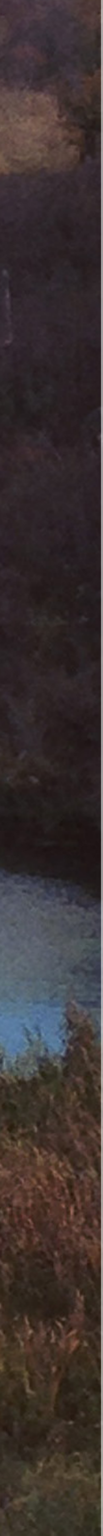
A study done for Manitoba Conservation and Water Stewardship (Genivar, 2012) supports the findings in the ARB Hydrologic Model study but also predicts that earlier parts of the century would see increased yearly seasonal temperatures. Precipitation increases were also predicted for winter, spring and fall, with the largest increase seen in the spring while summer precipitation levels would decrease. Other notable changes include more frost-free days but increased potential for spring flooding and summer drought.

2.3 CURRENT APPROACHES TO WATER MANAGEMENT

Engineered and infield are two types of water control structures that are used to address water quantity in the Assiniboine River Basin (Figure 2.3).

Engineered structures are large-scale, reinforced interventions that are designed to detain or move large

Figure 2.4 Series of small dams constructed to capture sediment located in a ravine in Broughton's Creek Watershed. (Image: Rutledge, 2013)



amounts of water off-site of source-point. They require increased dollars for operation and long-term maintenance. Examples in the ARB include the Shellmouth Dam, the Portage Diversion both constructed in the 1960's and the more recent Lake St. Martin outlet. Together they have the capacity to redirect hundreds of thousands of cubic meters of water. Along with the Red River Floodway, estimates have shown they have prevented over $30 billion dollars in flood-related property damage (Government of Manitoba, 2010, p. 2). The Portage Diversion and the Lake St. Martin Outlet are in the process of being re-designed to handle larger quantities of water. However, none of these structures address water quality.

In-field structures and practices are part of a multifaceted approach to water management. They are often small, located at the source-point and privately managed. They address water quality issues like sediment capture and water filtration by holding smaller volumes of water and allowing filtration to occur through soil percolation and uptake by associated plants. Examples include channels and ditches, small dams, tile drainage, cropland conversion, and restored wetlands and riparian zones.

Hank Venema, of the International Institute of Sustainable Development, has referred to government incentives that promote the construction of these infield structures as "soft infrastructure" (Venema, 2007) that have the ability to work within the landscape to adapt to changing conditions and address water quality.

Channels and Ditches

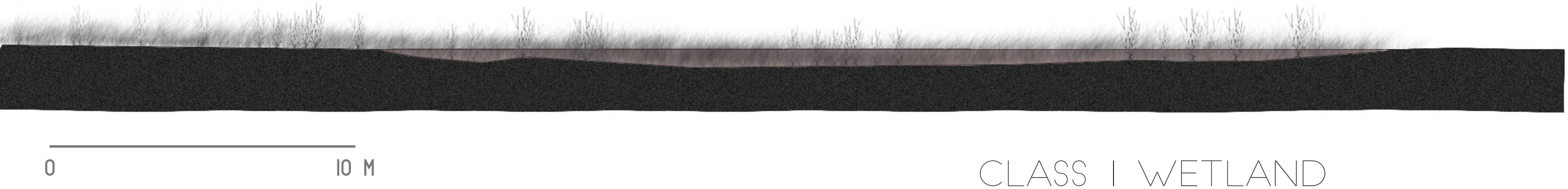
Channelization and drainage have been a typical method of water removal from prairie fields since 1880 when Europeans arrived in Manitoba. These channels create an efficient water conveyance system. As drains and channels function efficiently, the speed at which the water flows, i.e. velocity, also increases. High flow velocity contributes to soil erosion and doesn't allow water to be detained long enough to allow phosphorus to settle out of the water column and the process of denitrification to occur. Many wetlands and prairie potholes are "closed basins" that don't contribute directly to regional flows and downstream loading. However, when drained through a network of channels and ditches have been constructed to connect them and have contributed to downstream peak flows and changes in water quality.

Small Dams

These water control structures are sited in-stream of an existing watercourse and are used to impound surface water for the purpose of flood control, water supply and/or water management (Figure 2.4). Their primary function is to reduce downstream peak flow. Small dams are found to be most effective when located close to headwaters of watersheds or sub-watersheds. The South Tobacco Creek watershed, located 150 kilometres southwest of Winnipeg, Manitoba, has a number of small dams that have been intensely studied over that last twenty years and has provided information on rates of peak flow reduction and associated sediment and nutrient abatement (Agriculture and Agri-Food Canada, 2013b).

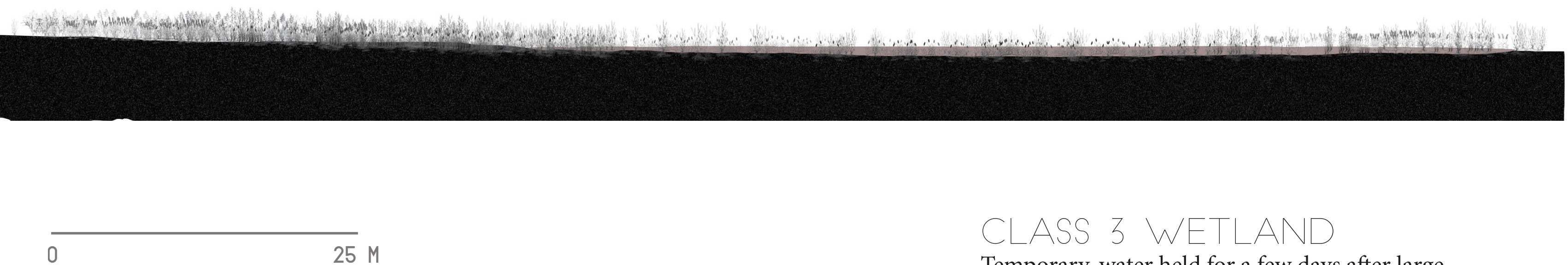
Tile Drainage

Tile drainage removes excess water through increased subsurface flow. Water collects in subsurface weeping tiles and is directed to a discharge



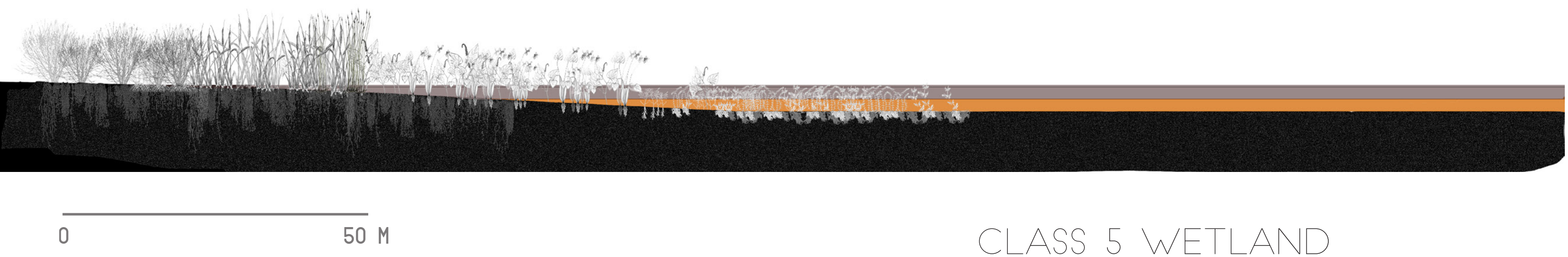
CLASS 1 WETLAND

Ephemeral, dries out quickly



CLASS 3 WETLAND

Temporary, water held for a few days after large precipitation event



CLASS 5 WETLAND

Permanent, open water in the central zone point and vegetated buffer at the edge of the field. As the nutrient rich water passes through the buffer, the vegetative buffer uses the water and nutrients to reduce total loading to the discharge point. Tile drainage has become more popular in the past 5 - 10 years due to higher precipitation events and more farmers growing more specialized crops. Nutrient losses are reduced and there is potential to affect downstream peak flow.

Cropland Conversion
This involves adding perennial crops to the rotation that reduce erosion and nutrient losses. Water quality benefits of legumes in forage are achieved by reduced nutrient fertilizer inputs.

Restored Wetlands
These are natural wetlands that were lost due to drainage, tilling or other alteration but have been restored to recapture natural wetland benefits. Wetlands typically provide little to no downstream peak flow reduction benefits during flood or extreme events unless water levels are lowered prior to the event. Wetlands use vegetation and water retention to provide nutrient filtering benefits. For example, a restored wetland will function most efficiently when located in an area of a water catchment where a large percentage of water will flow toward it. The Manitoba Government has partnered with Manitoba Habitat Heritage Corporation and Ducks Unlimited to create an incentive program that pays dividends to landowners for restoring historical wetlands.

Riparian restoration
This practice involves the establishment of perennial vegetation along a concentrated flow path with the assumption that this vegetation will slow water flow and retain sediment and nutrients that can be used to support growth of riparian vegetation. Water flow velocity is reduced and increases infiltration rate during the growing season. Established vegetation results in greater soil stability and lower soil erosion.

2.4 WETLANDS AND THEIR ROLE AND CLASSIFICATION

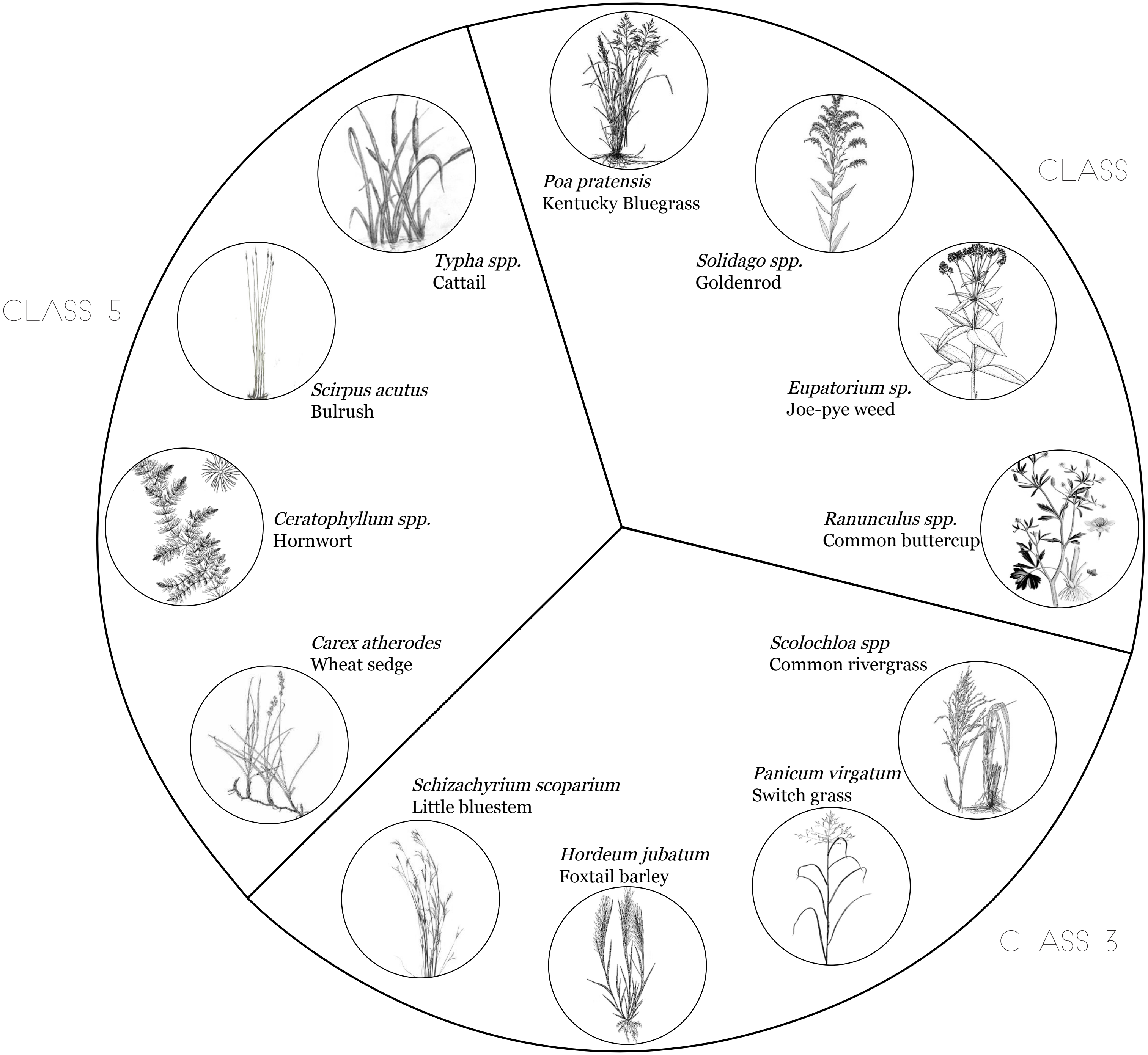
Wetlands play an important role in the ecological function of a watershed (U.S. Environmental Protection Agency, 2007) and they support many ecosystem functions including decreased flow velocity and peak flows (Pomeroy, Fang, Westbrook, Minke, Guo & Brown, 2010, p.4); decreased soil erosion and sediment capture (Mitsch, 1992); decreased vulnerability to drought through groundwater recharge (Department of Ecology State of Washington, n.d.) (van der Kamp & Hayashi, 1998); nutrient retention (Mitsch, 1992)(Jansson, Andersson, Berggren, & Leonardson, 2014); connecting landscapes that create habitats and ecologies; increased ability of the landscape to store and filter water (Groening, 2012).

Wetland classification is hierarchical and based on ecological processes according to Zoltai and Vitt (1995). While it is difficult to measure ecological processes, the ecosystem characteristics of these processes is more quantifiable and are used to define a wetland classification system. The boundaries between wetland types vary, this practicum deals only with freshwater marshes. Each basin and "Waffle Wetland" will see changes in ecological processes as water levels fluctuate. These are important considerations in regenerative design strategy.

The Canadian System recognizes five classes that are defined by physiognomy and hydrology (Figure 2.5). Hydrological characteristics include the amount of time water is present in

Figure 2.5 (Opposite) Class 1, 3, and 5 Wetland sections showing the extent of ephemeral and permanent water levels.

FIGURE 2.6 TYPICAL PLANT COMMUNITIES DETERMINED BY WETLAND CLASS



the basin. Vegetation physiognomy is the way to describe the different plant communities found in each type of wetland based on hydrological processes (Figure 2.6). The classes most readily associated with this practicum are as follows:

Class 1 Wetland

This wetland is ephemeral and fills with water during a precipitation or snowmelt event but quickly dries out. Water can be held for a few days in spring or after a heavy rain. Plants found here would include Kentucky bluegrass and goldenrod.

Class 3 Wetland

This wetland is seasonal and surface water is held for one to three months but dries out by mid-summer. Plants found here include wetland grasses, sedges and rushes.

Class 5 Wetland

This wetland is permanent. Water is held long term with permanent open water in the central zone. Plants along edges include cattails, bulrushes, and floating leaf plants in deep water zones.

2.5 RELATED STUDIES/ WORKS

Methods to hold water on the land has been the subject of many recent studies. Along with the Waffle concept developed in North Dakota, the Manitoba Government has looked at policy changes to support the transition from drainage to storage. It was also the subject matter of the literature review I conducted for the Red Assiniboine Project in Manitoba and by Ducks Unlimited Canada.
In this last document, the group of researchers studied the effects of wetland restoration in the Broughton's Creek Watershed (BCW). Results showed that total phosphorus and nitrogen could be reduced significantly in stream flow as a result of wetland restoration. The results of this study provide the base line restoration information for this practicum. All agree that storing water on the land is a viable method of decreasing peak flows, associated flooding and lake eutrophication.

2.5.1 MANITOBA GOVERNMENT POLICIES

The Government of Manitoba is also looking at ways to improve policies and best management practices that support landowners through watershed-based approaches. It released the Surface Water Management Strategy (Water Stewardship Division, 2012) that outlines a framework and policy direction to improve surface water management. This includes all levels of government and various approaches to water management. The document states watershed and basin approaches are most effective and that watershed boundaries should be considered when developing district plans. The document also proposes a framework to balance drainage and water retention. One main principle is "No Net Loss of Wetland benefits" which included suggestions about restoration and drainage mitigation.

Other initiatives include the Lake Friendly Accord, the Protected Areas Strategy and the Climate Change Adaptation that look at creating an adaptive and multi-faceted approach to managing landscapes and their resources. Wetlands, riparian areas that are important in the regulation of water quality and ecosystem function need to be better understood, protected and restored (Water Stewardship Division, 2012). These are key documents that

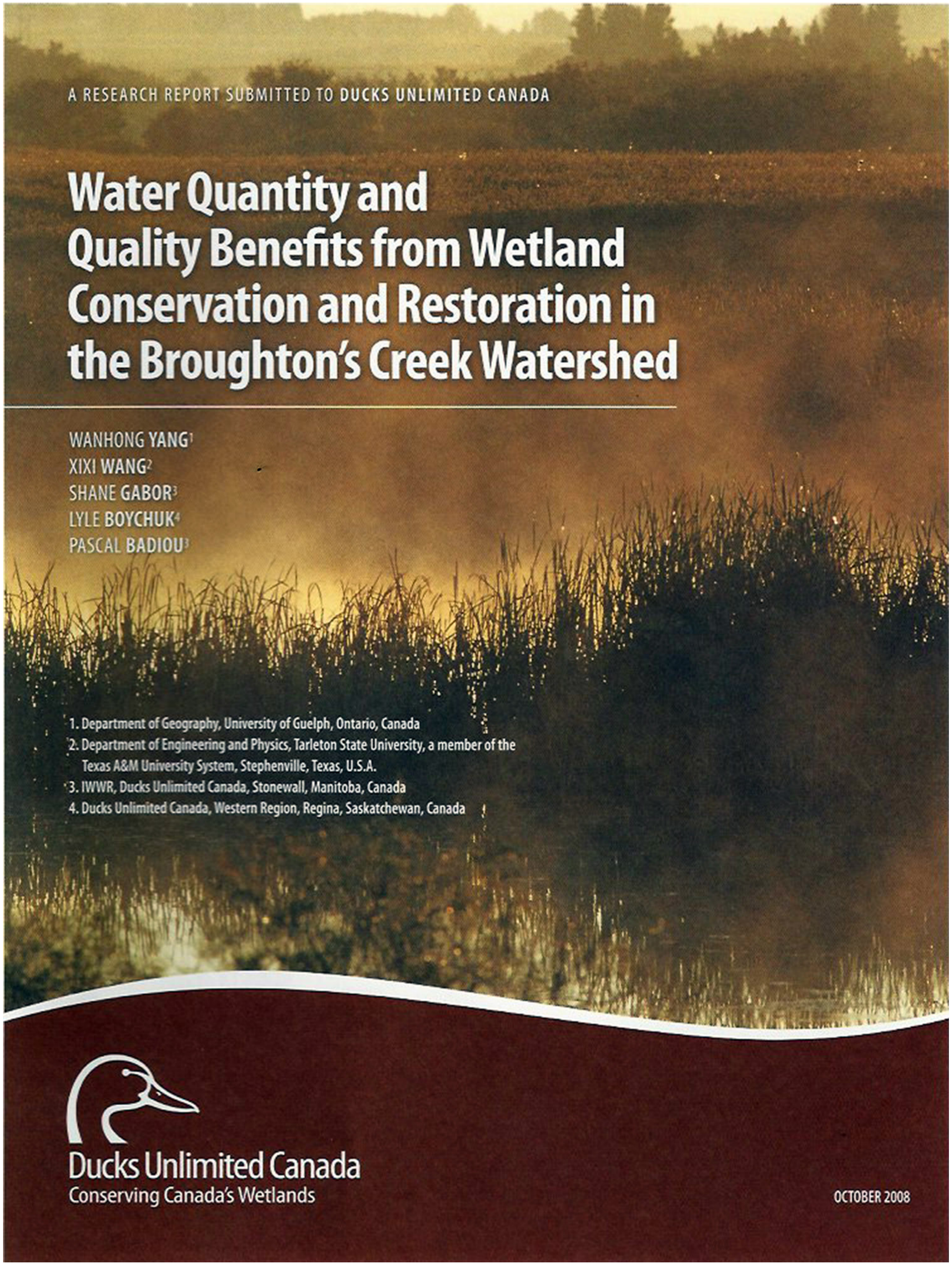


Figure 2.7 Cover of the Ducks Unlimited document: Water Quantity and Quality Benefits from Wetland Conservation and Restoration in the Broughton's Creek Watershed. Image: (Yang et al., 2008)

support the relevance of this practicum and can provide a strategic framework for decisions made here. Future initiatives that will result from the Water Strategy are the new Drainage and Water Retention Regulation, the Drought Management Strategy, and the Wetland Strategy.

2.5.2 BENEFICIAL MANAGEMENT PRACTICES

Agricultural beneficial management practices are farm-site interventions to reduce amount of runoff, sedimentation and nutrient export. Examples include small dams, wetlands, sediment control basins, and others. AAFC reviewed a number of water retention strategies used as beneficial management practices (BMPs). These BMPs are used to decrease sediment, nitrogen and phosphorus in downstream rivers and lakes and can be used alongside current engineered and infield structures. These BMPs include restored wetlands, small dams, water and sediment control basins, tile drainage, cropland conversion and riparian strips. While the primary goal of these BMPs is not to decrease peak flow, it is often a positive side effect. There are a number of BMPs used in the ARB. Each of these practices has optimal conditions to function efficiently.

2.5.3 WATER QUANTITY AND QUALITY BENEFITS FROM WETLAND CONSERVATION AND RESTORATION IN THE BROUGHTON'S CREEK WATERSHED

In this last document, the group of researchers studied the effects of wetland restoration in the BCW (Figure 2.7). Results showed that total phosphorus and nitrogen could be reduced significantly in stream flow as a result of wetland restoration. The results of this study provide base line restoration information for this practicum.

This watershed was the subject of a comprehensive research document written in 2008. Water Quantity and Quality Benefits from Wetland Conservation and Restoration in the Broughton's Creek Watershed (Yang, Wang, Gabor, Boychuk, & Badiou, 2008) is a major contributor to the background information for this practicum. The researchers examined and quantified the affects of various wetland restoration scenarios. Each scenario calculated effects on streamflow, sediment load, and phosphorus and nitrogen loads exiting from the study area. While 100% restoration saw the greatest overall impact, it was found that beyond 80% restoration, the economic inputs outweighed the benefits (Yang et al., 2008, p. 35). For this practicum project, an 80% increase in storage volume is the desired outcome. In the Yang (2008) document, the authors divide the watershed into two general regions based on average topographic relief. The northern half is on average above 550 m mean sea level with an average topographic relief of over 3 m and the southern half is on average lower than 550 m mean sea level with an average topographic relief of less than 3 m (Yang et al., 2008, p, 7).

The BCW is further divided into 58 subbasins. For this practicum, calculations for storm events were done for subbasin 49 only and are highlighted in the following chapter.

Figure 3.1 Google Maps image showing abandoned oxbows and the confluence of the Little Saskatchewan River and the Assiniboine River west of Brandon, Manitoba. (Image: Google Maps, 2016)

3. THE LAKE WINNIPEG BASIN

The Lake Winnipeg Basin is the second largest in Canada and covers a million square kilometers. It includes four provinces as well as four U.S. states (Figure inset) and contains six sub basins. All runoff ends up in Lake Winnipeg. Three large collecting tributaries, the Red River, the Assiniboine River, and the Saskatchewan River feed into Lake Winnipeg. The Nelson River delivers water from the discharge point of the lake and sends it into the Hudson Bay. Each river has secondary and tertiary rivers and streams that feed into them. The Lake Winnipeg Basin has a diverse topography that has a significant influence on basin hydrology along with vegetation, soil conditions and other natural features. Ground morphology in the basin ranges from peat-dominated tundra to expansive, flat temperate plains that are remnants of the Glacial Lake Agassiz lake bottom to undulating, hummocky till more common along the Assiniboine River.

The majority of land use here is agriculture and many wetlands and/or potholes have been drained and connected to the larger hydrological network through drainage channels and ditches.

3.2 ASSINIBOINE RIVER BASIN DESCRIPTION

This practicum focuses on the Assiniboine River Basin (ARB), one of six hydrological divisions in the Lake Winnipeg Basin. The ARB is further divided into three collecting sub basins based on their collecting tributary (The Qu'Appelle sub basin, the Souris sub basin and the Assiniboine sub basin) (Figure 3.2). The study site for this practicum is located within the Assiniboine sub basin.

The entire Assiniboine sub basin is 162 000 square kilometres and includes a variety of topographical, geological and hydrological features such as the Manitoba Escarpment, rolling hills and prairie potholes. The Manitoba escarpment, a pre-glacial feature (Government of Manitoba, n.d.a) is an abrupt elevation change running along a northwestern axis and was formed by the Cambrian beginnings of the Red River and melting glaciers that scoured the soft sandstone (Ashworth & Bluemle, 2005). "Prairie potholes" are another defining landscape feature. They are depressional freshwater wetlands that cover 776 000 km2 and are found west of the Manitoba escarpment in the prairies of north central US and south central Canada (Sloan, 1972). These potholes are considered non-contributing areas and range in size from a few meters across to several square kilometers. They include closed lakes, ponds, and depressed storage areas (Red River Basin Board,

Figure 3.2 (Inset) Graphical representation of the Lake Winnipeg Basin and its location within Canada. (Image: Manitoba Eco-Network, 2007)

3.3 Photograph of characteristic landscape found in the Broughton's Creek watershed containing agricultural fields, rolling hills, wetlands and emergent vegetation. (Image: Rutledge, 2015)

2000, p. 13) that are disconnected from main tributaries and do not contribute to downstream peak flows.

At the end of the last ice age, about 10 000 years ago, (Ducks Unlimited, (n.d.). As glaciers began to recede and scraped the landscape forming these prairie potholes (U.S. Environmental Protection Agency, 2015b). These small wetlands are temporary or permanent with submerged and floating aquatic plants. They are habitat for waterfowl and prairie mammals and provide ecosystem services that include precipitation capture and absorption (U.S. Environmental Protection Agency, 2015b), and act as filters that sequester nutrients (Ducks Unlimited Canada, 2016a).

Soil type is important to understand because it affects hydraulic conductivity, porosity, saturation, field capacity and wilting point (Stantec, 2011, p. 28). Land cover is important to understand because it changes soil moisture and storage capacity.

The majority of land use is cropland and medium soils dominate with some coarse soils (Stantec, 2011). As landowners have built effective drainage networks, non-contributing areas have become connected to streams and tributaries and has changed the basin's hydrology, significantly increasing the velocity and volume of runoff landscape (Pomeroy, Fang, Dumanski, Shook, Westbrook, Guo, Brown, & Minke, 2014).

3.3 Summary of Landscape Characteristics of the Red River Basin and the Assiniboine River Basin

The ARB, which has much more undulating topography and also contains numerous wetlands, also known as prairie potholes (Figure 3.3). These potholes along with other unique geologic and hydrologic characteristics make it an interesting case study for the Waffle® concept ability to apply to another landscape.

3.4 Differences and Why They Matter

Differences in the Red River Basin and the Assiniboine River basin are important because these physical characteristics dictate the hydrological response. since flow velocity and amount are affected by topography and ground cover.

Both basins have a semiarid climate with cold winters and warm summers. The drainage area of the RRB is 116 000 square kilometres and the ARB is 162 000 square kilometres. The RRB has a very slight elevation change, i.e., 69 meters over 877 kilometres while the ARB has a very undulating landscape with abrupt elevation changes like the Manitoba Escarpment. Both basins have a dominant land cover of cropland (RRB Report, 2000, p. 21) with dominant medium soils.

Figure 4.1 West shoreline and emergent vegetation of Lake Whatopanah taken from Rivers Provincial Park campground. (Image: Rutledge, 2015)

4. SITE SELECTION

The quality and quantity of available data and research along with existing cultural attitudes and farming practices were the reasons why the Broughton's Creek Watershed was chosen as a site for this practicum. It had been previously mapped with fine-grain LiDAR (Light Detection and Ranging) mapping technology that provided detailed topography and elevation information that was not available anywhere else in Manitoba. LiDAR maps could be used to understand drainage patterns, calculate storage and runoff volume and provide detailed information for the design proposal.

Ducks Unlimited research has quantified important historical and background information that is essential to develop a design proposal. The number of existing wetlands that had been drained or degraded since 1968 is known for this area and data was collected that quantified the amount of water, phosphorus and nitrogen exiting the watershed.

There was an existing cultural attitude toward conservation and the development of sustainable farming practices. The Alternative Land Use program had been implemented here years ago and local conservation districts have a collective desire to look at alternative ways of retaining water and decreasing downstream nutrient content.

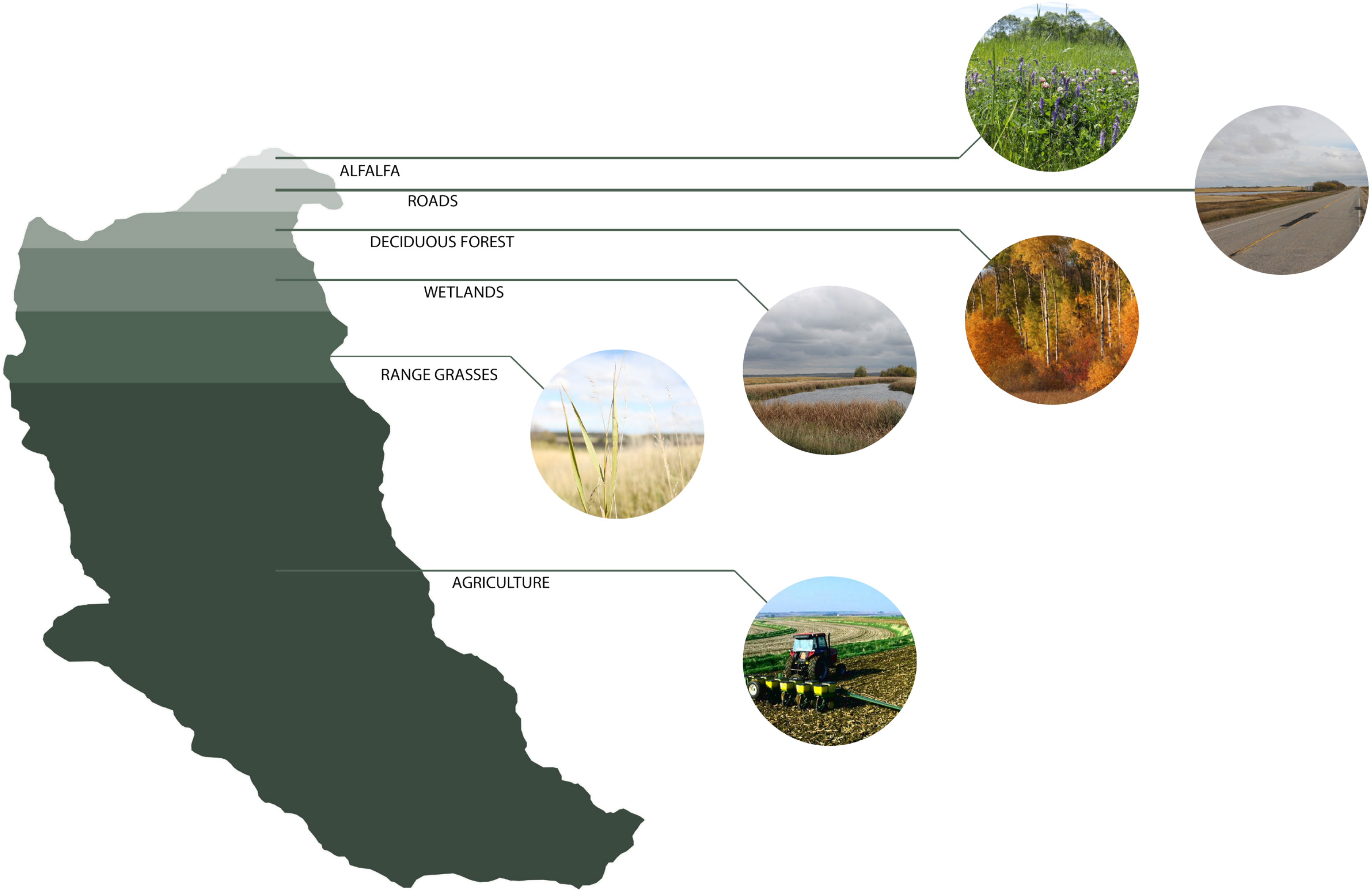


Figure 4.2 Graphical representation of the relative abundance of various type of land cover/land use in the Broughton's Creek Watershed.

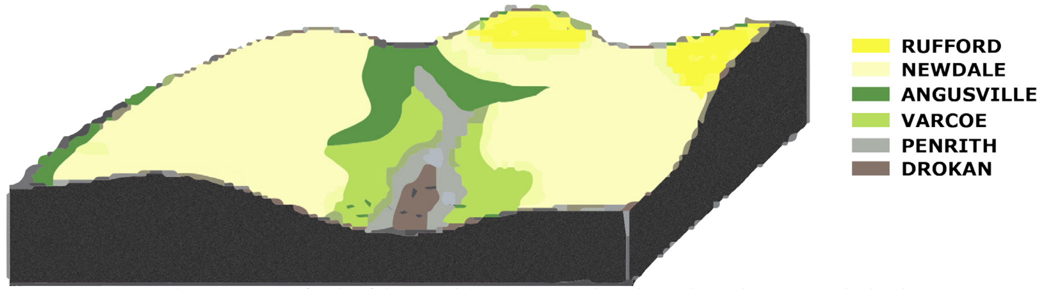


Figure 4.3 Section showing types of soils of the Newdale Association based on relative location in the landscape. (Image: Government of Manitoba, n.d.)

4.2 LAND USE & SOIL TYPE

BCW is located within the Assiniboine River Basin and is forty kilometers northwest of Brandon, Manitoba. The watershed is 25 139 hectares and has a 140 meter elevation drop from north to south. Land use is divided into 72% agriculture, 11% range land, 10% wetlands and the remainder includes forest, roads and forage (Yang et al, 2008, p. 7) (Figure 4.2).

Land is typically hummocky till: a rolling, hilly landform with unsorted gravelly soil materials. Upslope soils are well-drained while downslope soils tend to be highly organic and saturated.

In Manitoba, 52% of soils have high organic matter content and are grouped in the Chernozemic Soil Order (Government of Manitoba, n.d., p. 20) (Figure 4.3). Chernozems are grassland soils and in Manitoba, where productive agricultural is found. They have a thick topsoil horizon with a normal moisture regime and found where native grassland is present. These “black” soils are based on climate and native vegetation patterns. In the BCW, under the Chernozemic Soil Order, the Newdale Soil Series is dominant. This series is well-drained in upslope locations (Yang et al., 2008, p. 7) and can be further divided by moisture influences and position in the landscape.

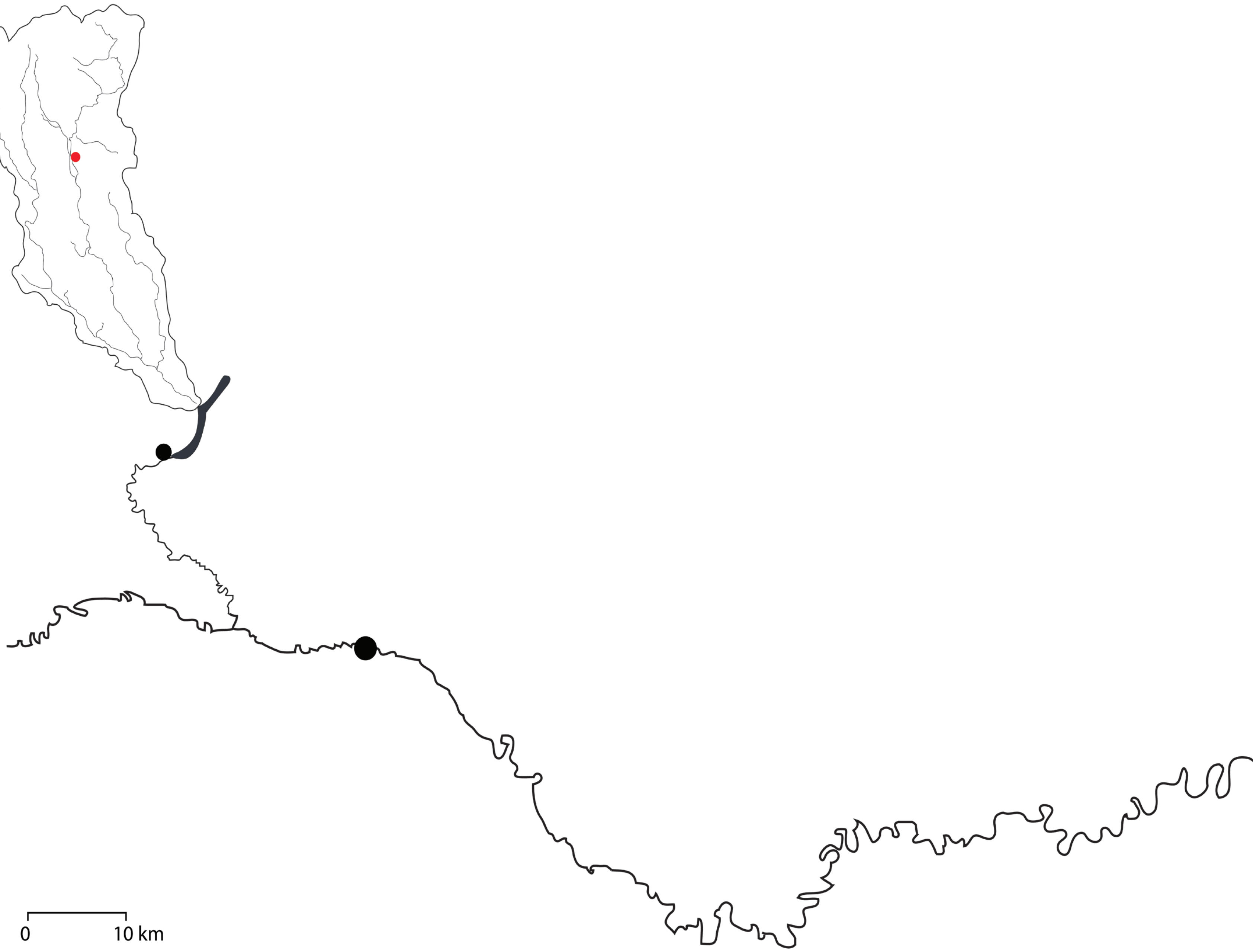
Drokan soils are found in geographically low areas and are poorly drained and often high in organic matter. Rufford and Newdale soils are well-drained and found on ridges or hilltops (Government of Manitoba, n.d.). Soil type is typically medium (sandy loam) with some coarse (sandy) soils and affects hydraulic conductivity, porosity, saturation, field capacity and wilting point (Stantec, 2011, p. 3.6).

4.3 CLIMATE

Data from Environment and Climate Change Canada (Government of Canada, 2016) shows daily average temperatures range from an average of -16.6 degrees Celsius in January to 18.5 degrees Celsius in July (averages were calculated based on data from 1981 to 2010). Snowfall is highest in December and January and rainfall peaks in June through August. Greatest overall precipitation is in June with an annual average of 474 mm.

4.4 BROUGHTON'S CREEK WATERSHED HYDROLOGY

Water generally flows away from higher elevations and settles in lower areas. Hilltops, therefore, are generally drier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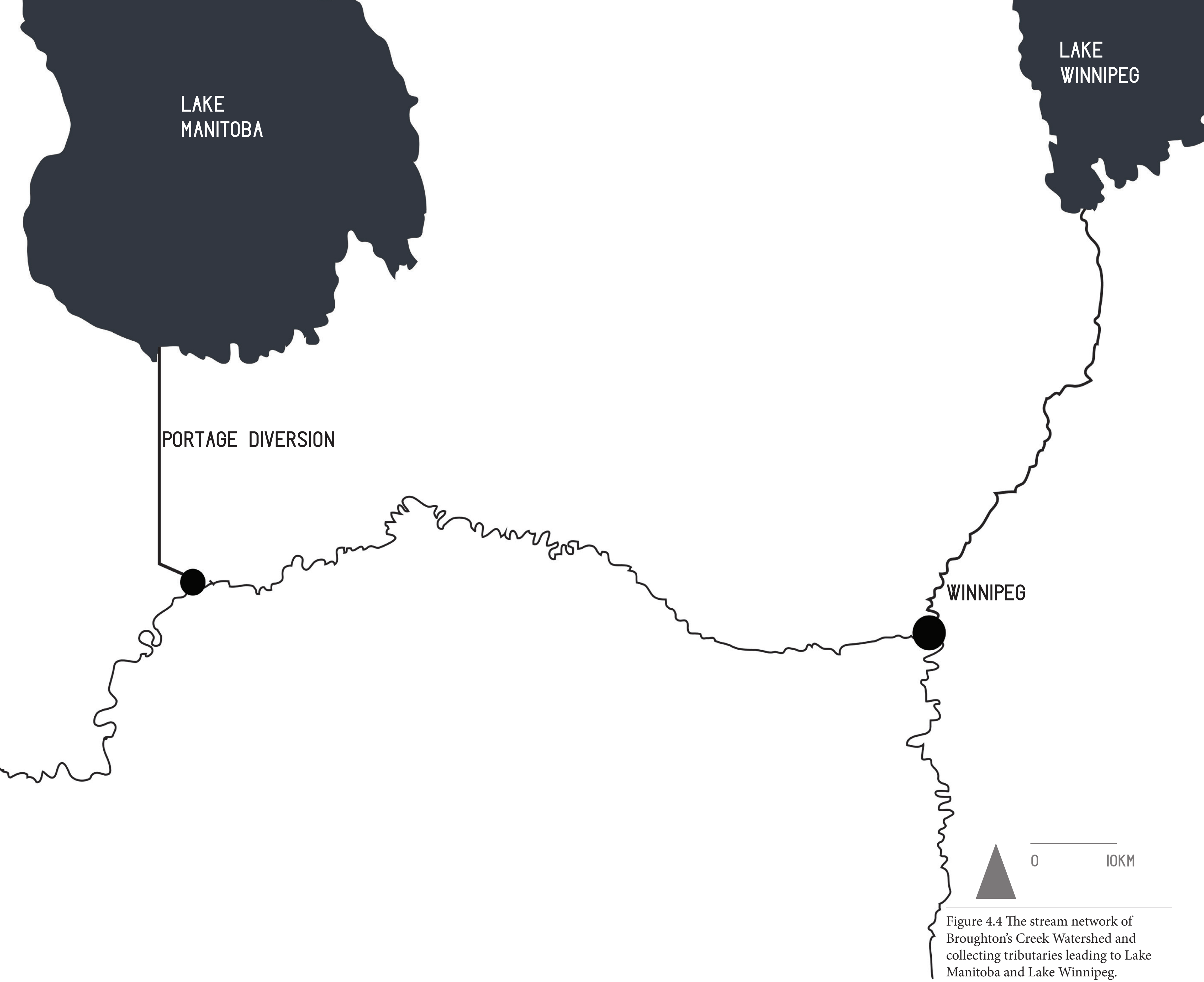


Figure 4.4 The stream network of Broughton's Creek Watershed and collecting tributaries leading to Lake Manitoba and Lake Winnipeg.

THE BUILDING BLOCKS OF THE HYDROLOGICAL NETWORK

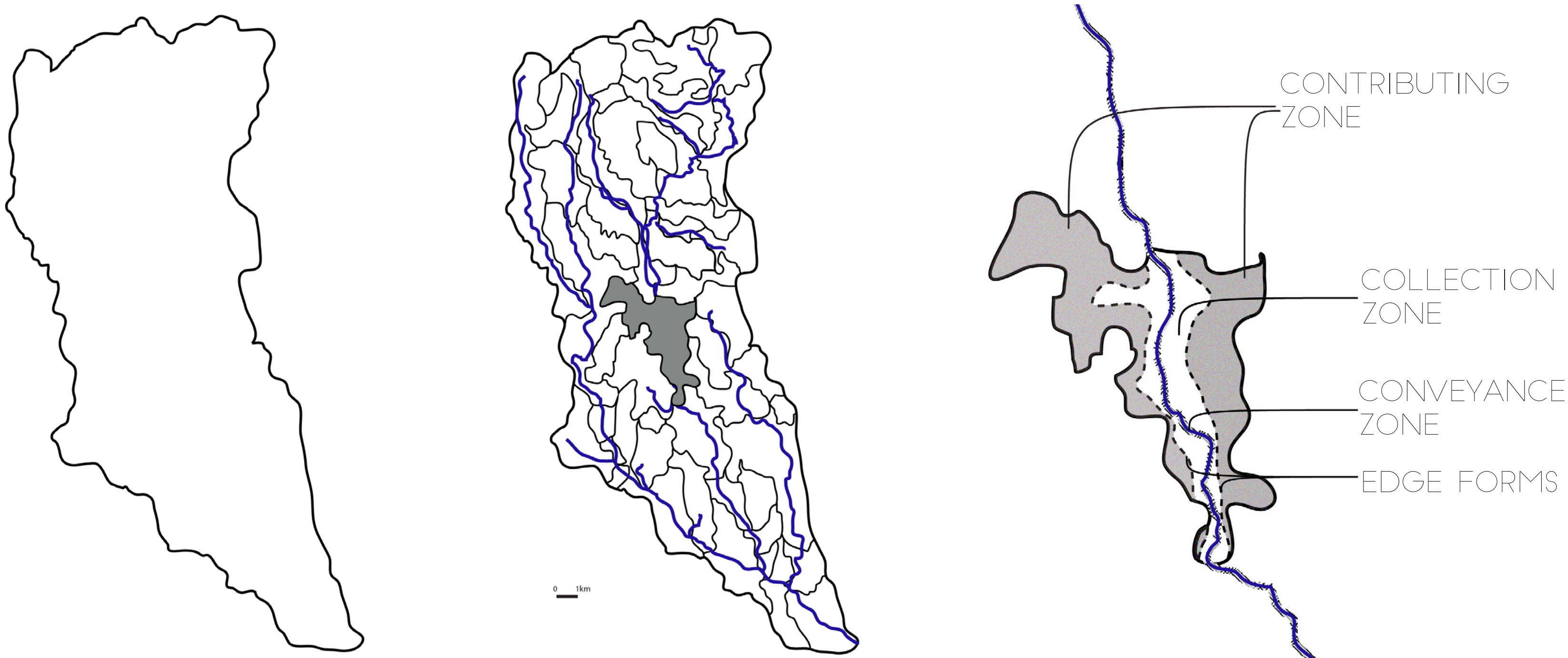


Figure 4.5 Successive divisions of Broughton's Creek Watershed showing William Marsh's zones.

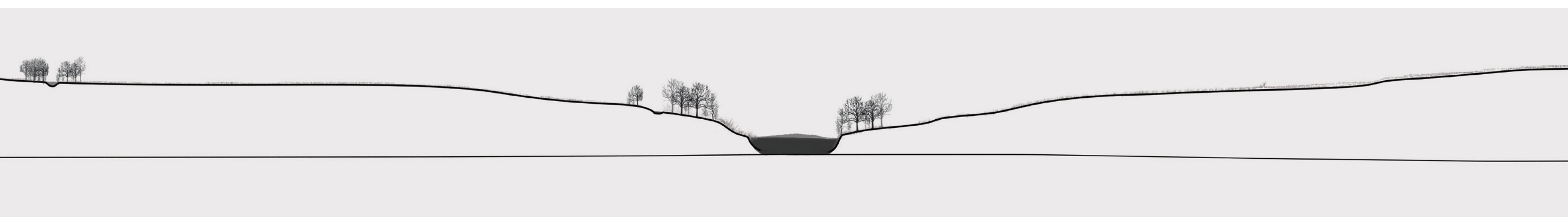


Figure 4.6 Section of Broughton's Creek Watershed showing topographic changes and location of collecting tributary.

with less vegetation and a shallow layer of topsoil. Erosion further affects this process and sends soil downslope. Water accumulation and deeper topsoils provide a favourable environment for more vegetation in these downslope locations. Water also travels downward below the ground surface. These physical processes contribute to ponding and wetland formation (Government of Manitoba, n.d.).

This pattern is seen throughout BCW and shown in the section (Figure 4.6). Broughton's Creek is seen in the centre of the section. Riparian areas line the creek and as you travel farther away from the creek the land flattens somewhat and contains another secondary watercourse. This is typical of the lower half of the BCW. In the Yang et al. (2008) document, the authors divide the watershed into two general regions based on average topographic relief. The northern half is on average above 550 m mean sea level with an average topographic relief of over 3 m and the southern half is on average lower than 550 m mean sea level with an average topographic relief of less than 3 m (Yang et al., 2008, p, 7).

The stream network in BCW flows from north to south and all water ends up in the primary collecting tributary that flows into Lake Whatopanah at the southern tip of the watershed (Figure 4.4). Lake Whatopanah drains into the Little Saskatchewan River and confluences in the Assiniboine River west of Brandon, Manitoba.

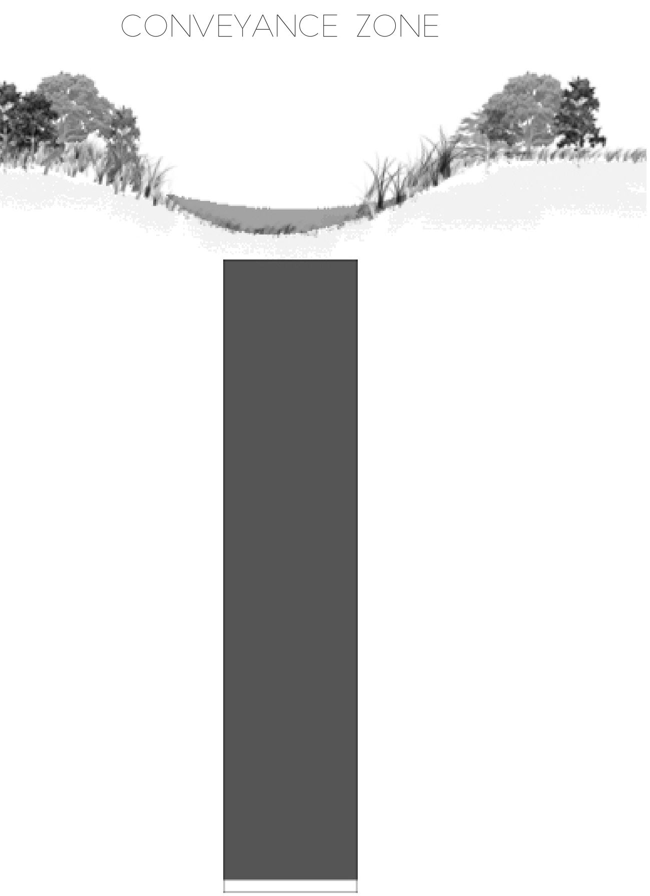
Agricultural drainage and changes in frequency and severity of runoff events have led to more extreme flood events in the Assiniboine River Basin. Damage to cropland and other downstream environments have also increased. Drainage methods are no longer able to manage water quantity or quality of runoff. Over time, draining wetlands and channelized flows have contributed to these issues. Water is no longer detained, filtered or slowed. Since the 1960's, approximately 70% of Canada's wetlands have been drained or filled and since the late 1800's ditches and drains have been constructed to remove the water efficiently.

4.4.1 Analysis of Hydrological Behavior of Broughton's Creek Watershed

Water in BCW travels in a southwesterly direction. Colour gradients show elevation change from the lighter or higher elevations toward the lower or darker locations ending up in an intermittent stream network. These streams flow north to south along the western side of BCW. Water movement at all scales occurs naturally perpendicular to existing contours. During large melt or precipitation events water travels overland toward the southwest corner of the BCW.

However, this general overview cannot fully describe the detailed movement of water within the BCW. At closer inspection water moves and gathers in small depressions. These depressions, referred to as wetlands, sloughs, or potholes are typically closed basins unless they have become connected through drain or channel construction.

FIGURE 4.7 APPLICABILITY OF THE WAFFLE CONCEPT APPROACH



Closed basins are cut off from the larger drainage network and do not contribute directly to downstream flow. Water in closed basins is detained in these depressions and travel much slower through the hydrological cycle by infiltration, evaporation or transpiration.

4.5 MARSH'S LANDSCAPE PLANNING

In chapter nine of the book, Landscape Planning Environmental Applications (Marsh, 2010), William M. Marsh discusses watersheds, drainage basins and land use planning. The hydrology of basins and sub-basins are the building blocks of larger systems and need to be addressed for successful, sustainable watershed planning and management programs (Marsh, 2010, p.199). Marsh also describes three hydrological zones found in each basin or sub-basin. Each zone is differentiated based on its hydrological response and function.

These zones have been applied to a sub-basin in the Broughton's Creek Watershed (Figure 4.7).

The Contributing Zone is the area that receives the majority of water and creates runoff in the form of groundwater, interflow and overland flow. This area is the least susceptible to drainage problems and provides the greatest opportunity for site scale runoff management.

The Collection Zone is the low area of a basin and where Contributing Zone runoff accumulates. It is subject to serious drainage problems and prone to flooding.

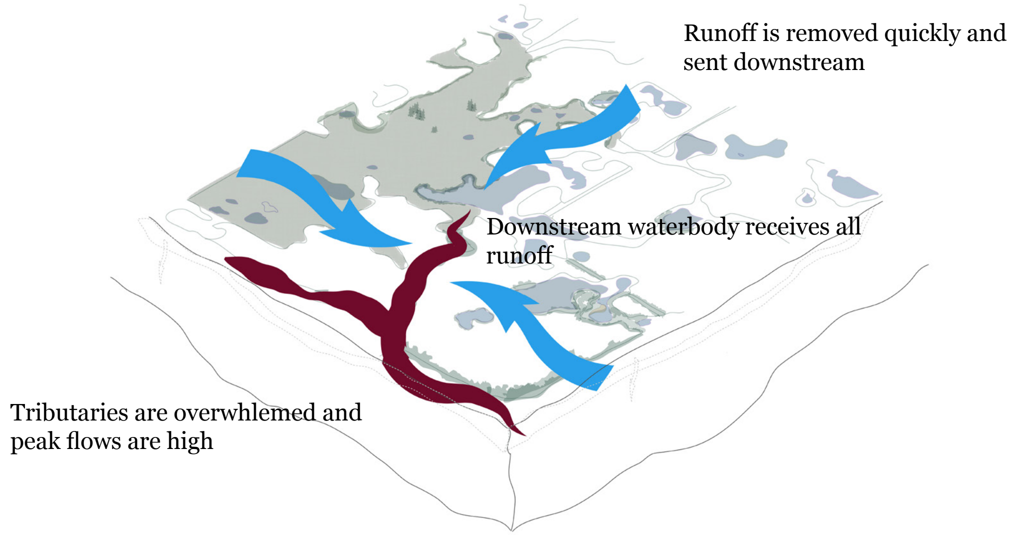
The Conveyance Zone is the central area, at a basin's lowest elevation, and represented by a valley and watercourse that transfers water to main tributaries. This area is the most difficult to manage hydrologically.

Edge forms are another topographic feature to consider, according to Marsh (2010). This area is either concave or convex and separates Contributing and Collection zones. Edge forms are critical to the success of landscape planning. They should be considered as functional links that create specific physical conditions for runoff.

Figure 4.7 (Opposite) Section of Broughton's Creek Watershed showing compatibility between William Marsh's zone concept and various water management strategies.

TRADITIONAL MANAGEMENT

Landscape is managed as one large unit of runoff



MANAGEMENT BASED ON MARSH'S PRINCIPLES

Landscape is managed as multiple small units

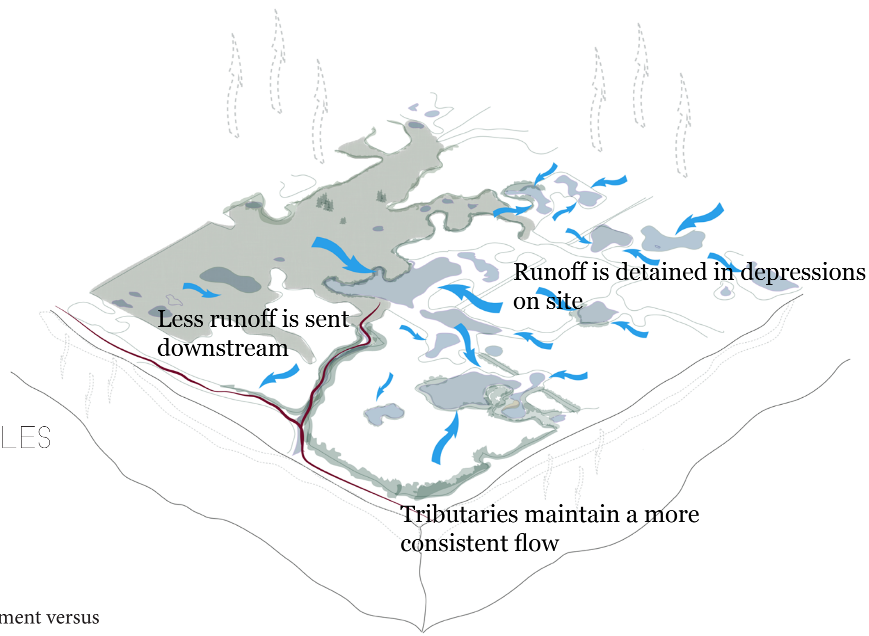


Figure 4.8 Sections showing the downstream effects of traditional runoff management versus the outcome applying Marsh's zone principle.

Any basin or watershed, whether large or small, contains these zones, edge forms and hydrological characteristics. The BCW watershed can also be defined this way.

A section of the Broughton's Creek Watershed shows how Marsh's zone concept could apply to specific geographic locations relative to the collecting tributary. Sections were assigned ratios of contributing to non-contributing areas based on the relative distance from the collecting tributary. The gray and white bars below each section illustrate contributing (white) versus non-contributing (grey). Sections farther away contributed more than sections closest to the collecting tributary (Figure 4.7).

The outer, Contributing Zone is analogous to the outer boundary of a watershed and the area where the opportunity for design interventions and management is most optimal. The Waffle concept would be best suited here. The Collection Zone, or the mid-point in the basin is where small dams, retention ponds and wetlands would be optimized. Controlled tile drainage and other "edge-of-field" structures could also be located here. Land within the floodplain could be used as "sacrificial landscapes" and reserved for water inundation during extreme flood events.

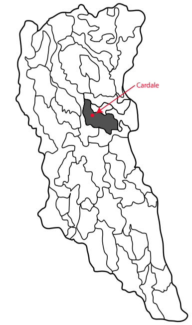
4.6 DIVIDING A WATERSHED INTO DISCRETE MANAGEMENT UNITS

Historically, watersheds have not been broken down into these divisions and are instead one large Contributing Zone (Figure 4.8). They are viewed as one large contributor to downstream runoff. Wetlands, potholes and other depressions have been drained, filled and connected to the larger drainage system. Regulations and other cultural practices have favoured efficient drainage via channels and ditches. To increase capacity and removal rates, these channels are typically straight and wide. However, if Marsh's zone model is applied along with innovative water management techniques like the Waffle concept and other strategies like wetland restoration, the landscape is divided into smaller basins and could be managed accordingly. The landscape could be broken down into individual management areas (Figure 4.8) that would slow and detain runoff. Water detention would create the opportunity for sediments and associated nutrients including nitrogen and phosphorus, to settle out of the water. The landscape can now be managed as individual units that manage water on-site with little or no contribution to downstream flow.

4.7 APPLYING MARSH'S CONCEPT TO THE BROUGHTON'S CREEK WATERSHED

Based on this approach, basin 49 was selected to illustrate Marsh's water management approach (Figure 4.9). Basin 49 was chosen because of the abundance of potholes, it's central location with the BCW and the secondary watercourse. To further focus the design work, the town of Cardale and the land bordered by the surrounding roads was chosen to apply both Marsh's concepts and the principles of the Waffle Concept.

Figure 5.2 Photograph of characteristic landscape found in the Broughton's Creek watershed containing agricultural fields, rolling hills, wetlands and emergent vegetation. (Rutledge, 2015)



5. SITE ANALYSIS

The site selected for this practicum is located adjacent to Cardale, Manitoba 9 Figure 5.1) in central BCW and in the Ducks Unlimited document (Yang et al., 2008) it is within sub basin 49. Sub basin 49 is 487.2 ha and contains two hydrologic response units (HRU's). HRU's are based on soil type, land cover/ land use. In basin 49, agricultural land use is dominant while wetland cover is secondary. Soils of the Newdale Association are typical with the hydrologic soil group "C." Group C soils have between 20 – 40% clay and less than 50% sand and, if well aggregated, have low bulk density. These soils also have moderately high runoff potential when saturated and conveyance within the soil profile is somewhat restricted (USDA, 2007, p. 7-2).

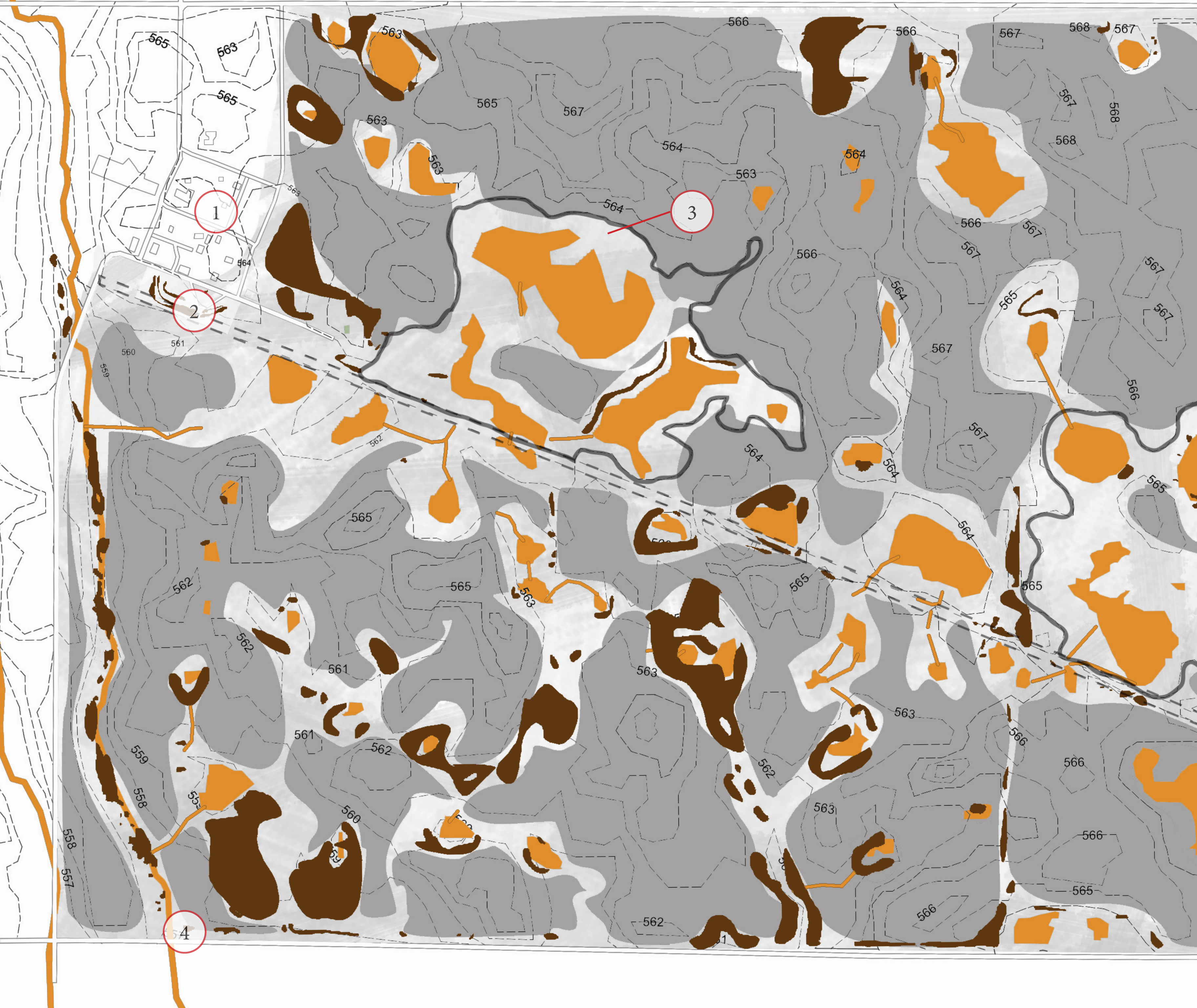
Sub basin 49 was selected for this practicum based on its abundance of wetlands and potholes, its central location within the watershed, the existing intermittent watercourse, cultural features like an old rail line berm, the town of Cardale and its park (Figure 5.2).

5.2 LANDUSE/LANDCOVER

The land is used primarily for crop and livestock production (See fieldspaces in Figure 5.3, 5.4). Areas that cannot be cropped are left to grow on their own and baled for livestock use. What isn't planted is covered in small sections of wetlands and surrounded by large margins of plants that are rooted in soil below water but grow above the surface, i.e. emergent vegetation.

Major landuse/ landcover in this section is agriculture, rangeland, wetlands, and cultural features (Figure 5.4). Contours illustrate the large topographical variation of the site. Intermittent or seasonal watercourse runs along the gravel road on the west side of the section. Water runs north to south and during both visits was overgrown with vegetation.

Figure 5.1 (Above) Map of Broughton's Creek Watershed showing sub basin 49 and the location of Cardale, Manitoba.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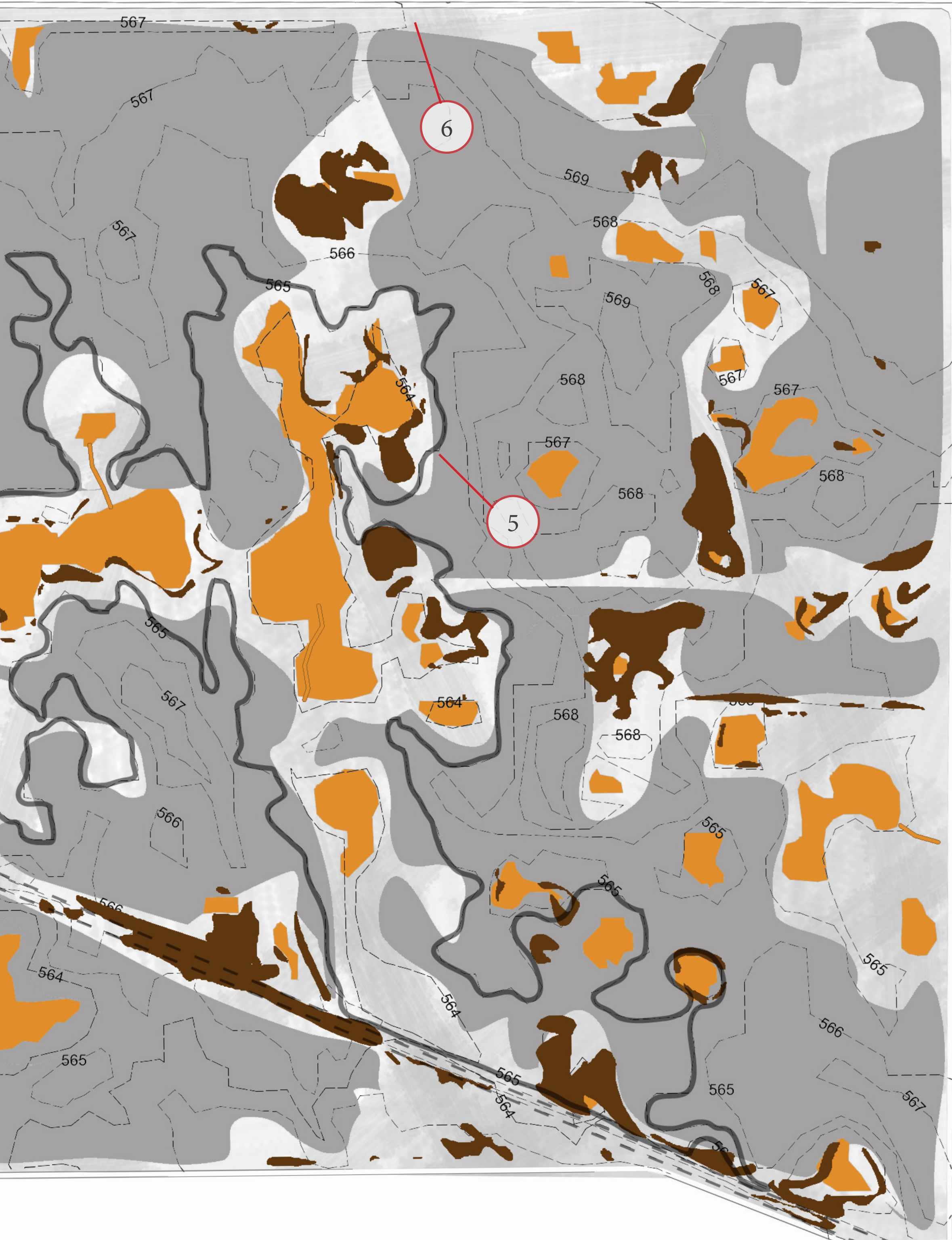


SITE PLAN

Legend

Trees and Shrubs

Emergent Vegetation

Existing Wetlands

Field Spaces

Drains

Railway berm

1 Cardale

2 Park and playground

3 Elevation 563/ Extent of Waffle Wetland 2

4 Outpour culvert and stream

5 Elevation 565/ Extent of Waffle Wetland 1

6 Elevated Road

0 500 M

Figure 5.3 Complete site plan showing Cardale, Manitoba, surrounding elevated roads, waterbodies, drains and vegetation.

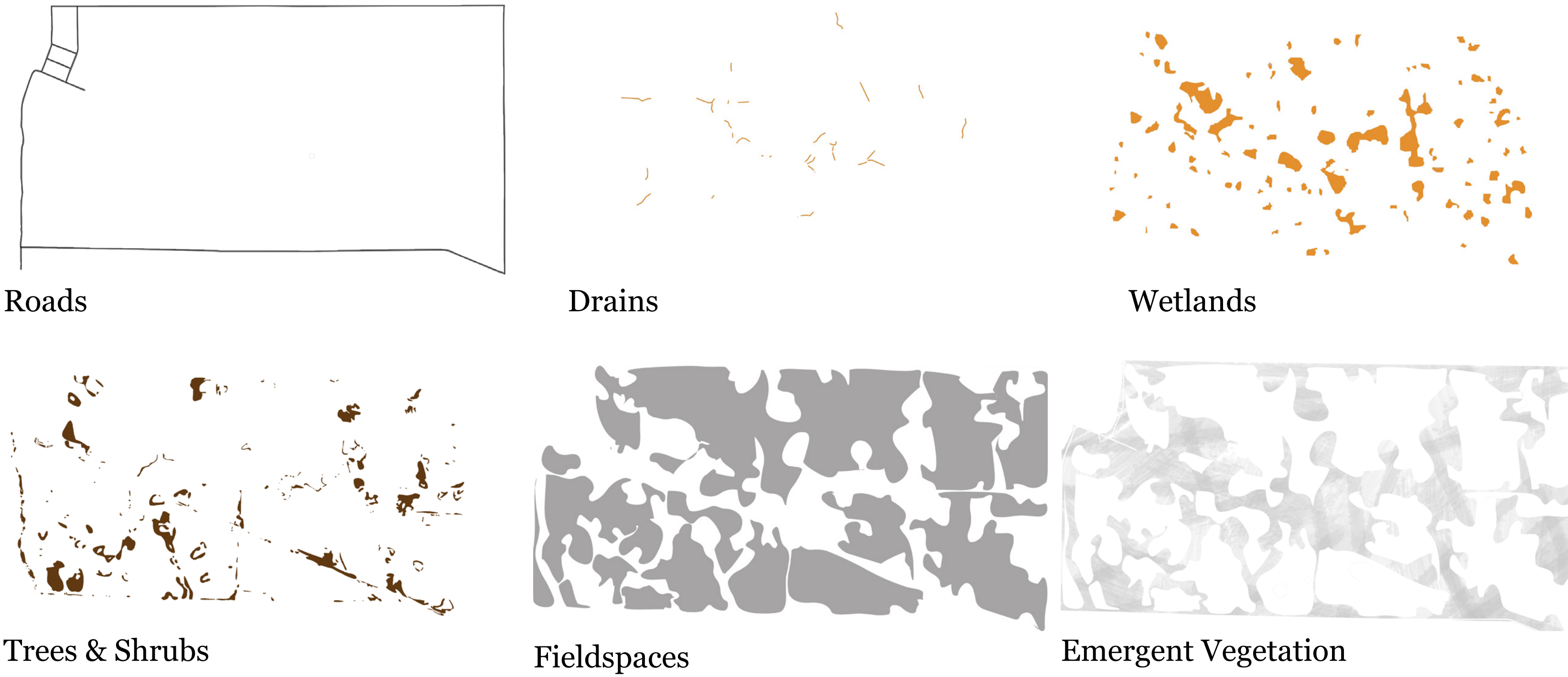


Figure 5.4 Series of images isolating layers of site features.

Figure 5.5 Photograph of rangeland south of Cardale, Manitoba and edge of existing town park. (Image: Rutledge, 2015)

Figure 5.6 Photograph of a wetland or “pothole” northeast of Cardale, Manitoba with surrounding emergent vegetation. (Image: Rutledge, 2015)

5.3 LANDSCAPE CHARACTER

The landscape in the Cardale area and the practicum site is rolling prairie. The flatter areas are used for annual crop production that include wheat, canola, sunflowers and oats. Areas that are not suitable for annual crop production are designated rangeland and contain native vegetation including grasses, forbs and some shrubs.

Rangeland is hayed for livestock (Figure 5.5). The lowest areas are thick with cattails and bulrushes. Trees found in allays or rows signal an existing farmstead or one that used to be. Other groves of trees can be found but are random and often surround the outer edges of wetlands or watercourses.

Rolling prairie, crops and rangeland dominate. Wetlands and potholes dot the land. Margins are covered in cattails and bulrushes. I've been there a few times now. The fall brought the smell of burning fields and the sound of migrating geese as they fly from wetland to pothole. Crops create a panorama of color and smell. Small groves of trees and wetlands with margins of emergent vegetation interrupt the farmer's rhythm.

Wetlands and potholes are the defining natural feature of this landscape (Figure 5.6). From small puddles ten meters across to large ponds over three hundred meters wide they dot the fields and create an unforgettable impression. Deep green grasses give way to bronze, and red rushes and cattails.

The breeze makes the aspen leave shake. Farm equipment can be heard in the distance while the unmistakable feeling of being quite alone cannot be ignored.

The roads leading up to Cardale are worn and marked with little orange flags that warn drivers of cracks and holes in the asphalt that will not soon be repaired. A green sign marks the turnoff.
Cardale itself is a small farming community that has more prosperous days (Figure 5.7). Driving through the town itself takes less than a minute or two. There are only a few homes and yards to be seen. There are hints that this little town was, at one time, a hub of activity but now, is nothing more than a small dot on the map.

Figure 5.7 Historical aerial image of Cardale, Manitoba showing Bawlf grain elevators and commercial buildings. (Image: R.M. of Blanshard, n.d.)

1 Main street building in disrepair.

2 Old brick church.

3 Historical Bawlf Elevator site now a small park and playground.

4 Elevated roadway south of Cardale.

Figure 5.9 Google Maps image showing present day Cardale, Manitoba and the location of notable town features.
(Image: Google Maps, 2016)

5.4 KEY FEATURES

Named after one of its original residents, Mr. John Cardale, the town was settled in 1907 and was a hub of agricultural industry. In the early and mid twentieth century the Bawlf Elevator Company drove its economy when two grain elevators were built there in the early 1900's. But now, a hundred or so years later, the elevators are gone and so are most of the residences (Figure 5.9). However, there is evidence that people are around. The recreational grounds are large and well kept. Some of the buildings with flaking paint are still occupied (Figure 5.8a) and the occasional truck plods down the main streets. The only church in town is an old brick building that is immaculately maintained (Figure 5.8b). The façade, its windows, and the grounds surrounding it are perfectly kept. One can almost hear people chatting as they exit the big wooden doors on a Sunday afternoon. All of these buildings are located along one road at the south end of town. This is the road that also runs along the site of the old grain elevators, which is now a small park with a bronze plaque to mark the historic spot and an old swing set that creeks in the breeze (Figure 5.8c). The local community received a grant from the Manitoba Hydro Forest Enhancement Program to plant a row of trees that are regularly maintained.

Figures 5.8 a-d (Opposite) Photographs of current state of buildings and surrounding landscape of Cardale, Manitoba. (Images a,d, &d : Rutledge, 2015 Image c: Google Earth, 2016)

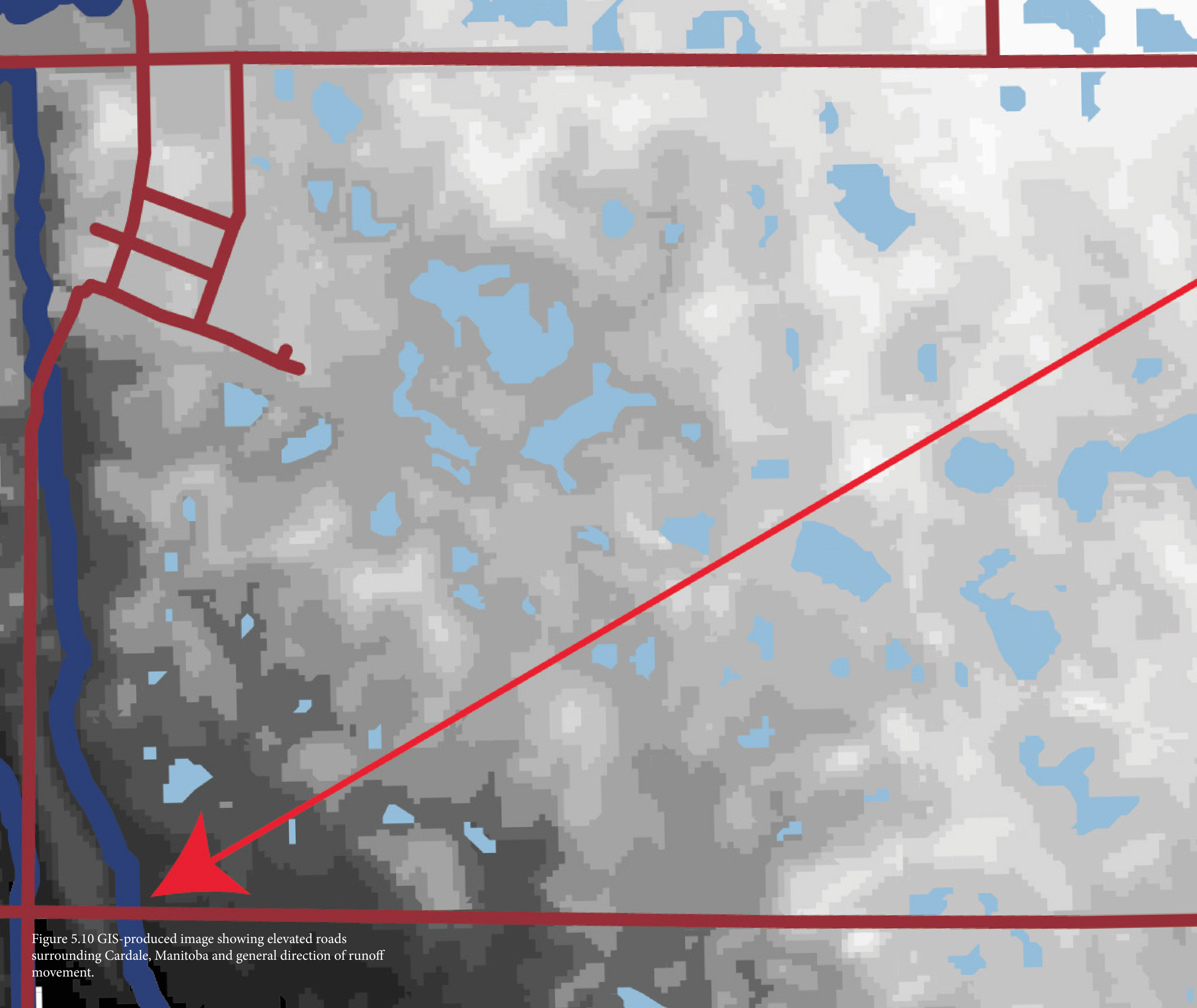
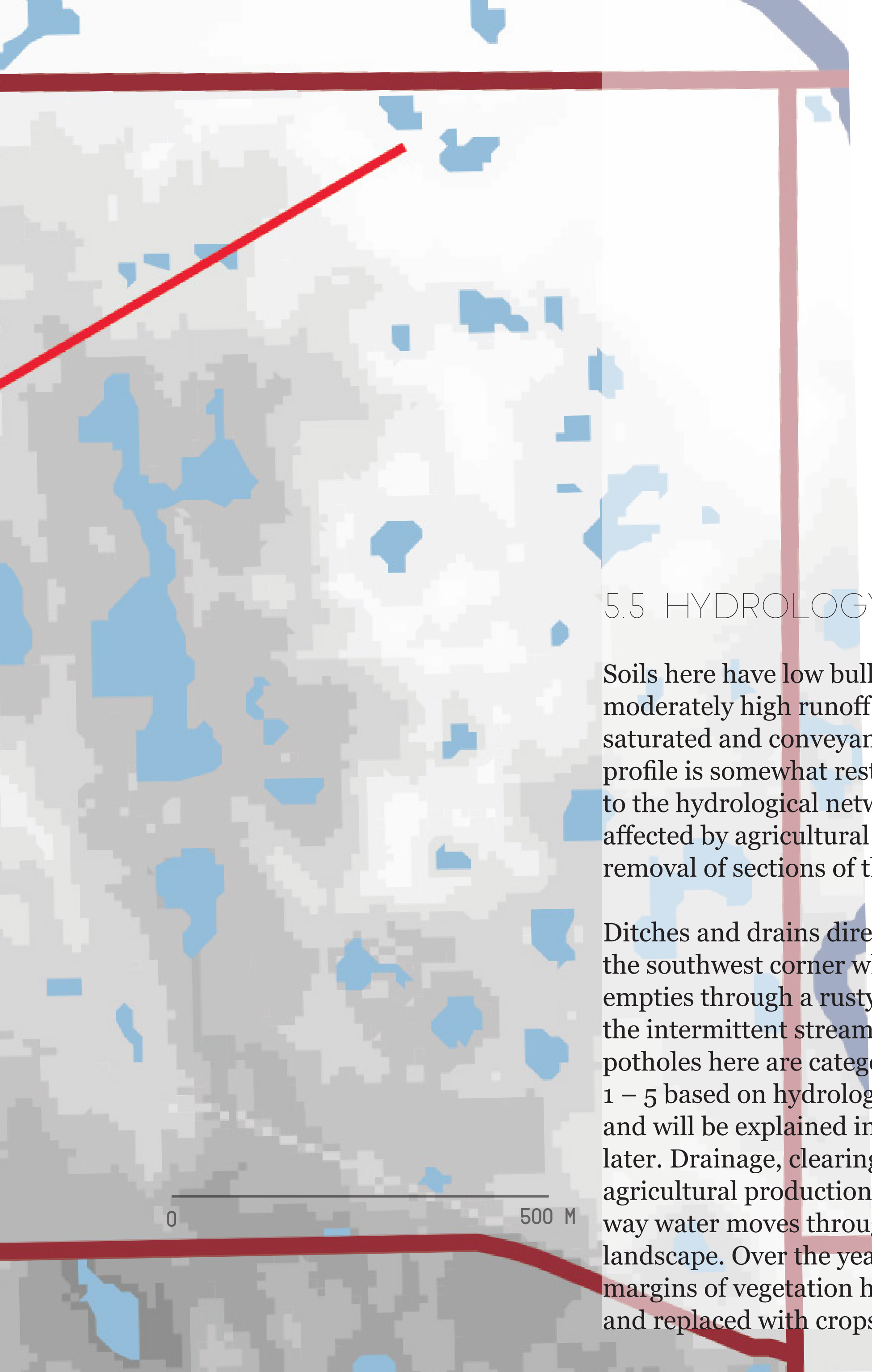


Figure 5.10 GIS-produced image showing elevated roads surrounding Cardale, Manitoba and general direction of runoff movement.



5.5 HYDROLOGY

Soils here have low bulk density and moderately high runoff potential when saturated and conveyance within the soil profile is somewhat restricted. Changes to the hydrological network have been affected by agricultural drains and by the removal of sections of the rail line berm.

Ditches and drains direct water to the southwest corner where water empties through a rusty culvert into the intermittent stream. Wetlands and potholes here are categorized from Class 1 – 5 based on hydrological conditions and will be explained in more detail later. Drainage, clearing and mechanized agricultural production has affected the way water moves through and over the landscape. Over the years, emergent margins of vegetation have decreased and replaced with crops. The rail line has been abandoned and is no longer maintained. As such, this may have led to new opportunities for improving drainage.

An afternoon site analysis of ditches and culverts revealed only one eleven-inch culvert at the northeast corner that brings water into the section. Water that travels through the sections to the north and south are directed into the seasonal watercourse that runs along the western margin through ditches. Any water that doesn’t enter the watercourse through drainage channels will exit the section through the large culvert found at the southwest corner (Figure 5.10).

Figure 6.1 Photograph of a wetland and drainage channel in an agricultural field. (Image: unknown, n.d.)

6. CONCEPTUAL PLANNING & DESIGN STRATEGIES

This practicum aims to increase on-site water storage to decrease downstream peak flow and nutrient export. Yang et al. (2008) concluded an 80% restoration of wetlands is likely to be a turning point, beyond which a small decrease of peak discharges would incur a large increase of costs (Yang et al., 2008, p.35). This practicum will attempt to achieve a 80% increase in water storage volume for the site. The design goal is to create a landscape that showcases water and hydrological processes while also creating an experience to allow visitors to travel through the landscape and experience these different processes.

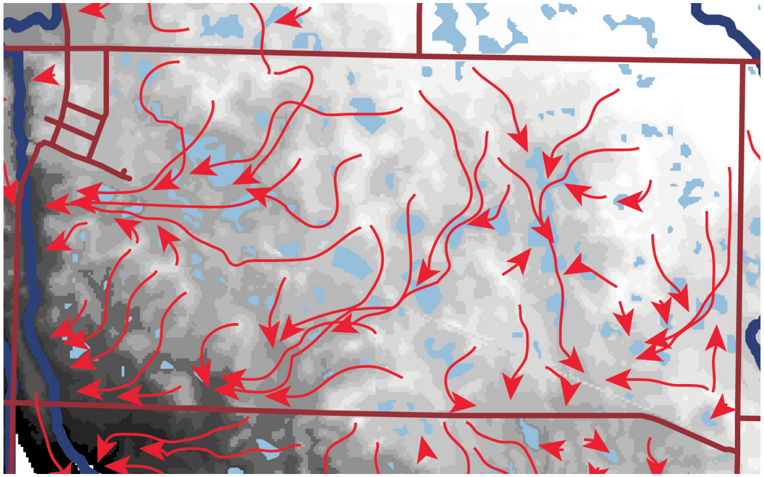
Access and interaction are key components of the design. A number of existing features will be incorporated into the design that can highlight views, create opportunities to rest and educate the visitor. New infrastructure will create connections between nodes, accommodate views to hydrological processes and reveal the changing, dynamic landscape.

Views and experiences will change as water levels rise and recede and when the seasons change. Access to the trails will change depending on whether or not a specific section of the trail is inundated. The remaining sections of rail line will also provide viewing opportunities. The trail system and the water control structures will run alongside or on the top of this berm wherever appropriate.

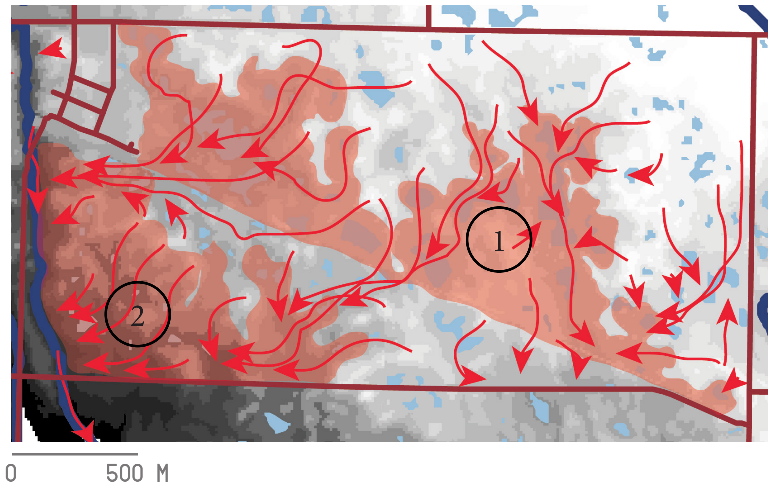
Understanding the site hydrology is the first step. The location of contributing and collection zones and corresponding management interventions will be dictated by where water flows and where it pools.

6.2 PROPOSED HYDROLOGICAL APPROACH

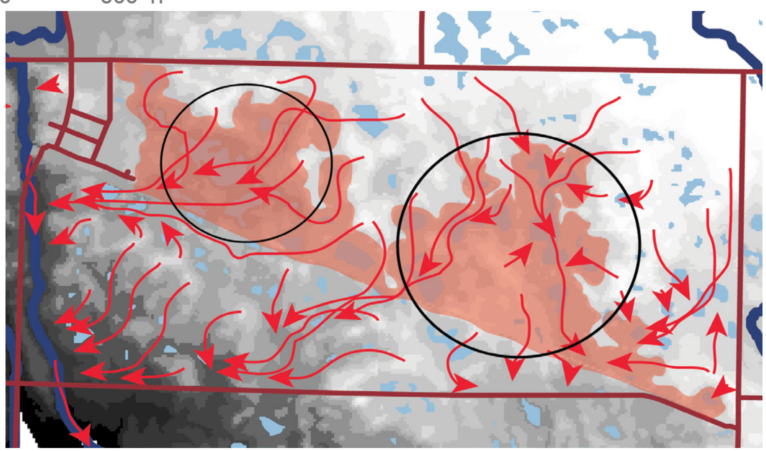
GIS was used to illustrate and understand how existing topography, ditches and drains affect water movement within the site. In the previous



A
Pattern of water movement within the site. General elevation decreases from northeast to southwest (shown light to dark) but a more detailed look shows water moves in a variety of ways and settles in depressions throughout the site. As these pockets became overwhelmed water travels overland toward the stream along the western border.



B
Two zones were identified by examining the topography that revealed where water pooled, travelled and collected. The northern Contributing Zone (1) is primarily on the northern side of the railway berm. Runoff generated here moves toward the southern Collection Zone (2) before exiting via the stream along the western border.



C
Two locations were identified within the Contributing Zone that could act as storage areas based on existing elevations. Levies can be created that take advantage of existing land elevations to create a levy that will hold runoff during high precipitation events. These areas use the basic principles of the Waffle concept and are called Waffle Wetlands.

series of maps, the red arrow shows the general direction of water flow from the northeast to the southwest. Elevation generally decreases from northeast corner of the site to the southwest. The lightest areas have higher elevation while the darkest have the lower elevation. Runoff flows in a southwesterly direction toward the largest culvert on the site located where the stream runs under the road. A site survey of the area revealed this is the only outlet within the section therefore all water exits the section here.

At closer inspection, however, this general pattern does not describe the detailed movement of water in this section (Figure 6.2A). Before exiting the section, water travels overland and gathers in potholes, wetlands and small depressions. Using the Time of Concentration formula, it takes 69 minutes for one drop of water at the farthest point on the site to travel to the exit culvert. As these small basins and drainage channels become overwhelmed, runoff is created and travels overland. Soil particles are scoured and carried away in the runoff.

Before there was a drainage network, the site's small waterbodies and depressions were closed basins, which means that they did not contribute to downstream flows. Water in these closed basins was slower to re-enter the hydrologic cycle through processes like infiltration, evaporation and transpiration. But as the drainage network grew the water in these smaller basins, flowed off the section, travelled to the collector tributaries in a shorter amount of time. As the network became more connected, the speed of the flowing water increased and so did the concentration of soil particles in the runoff.

By restoring the ability of the existing wetlands to store and detain water, the flow is slowed and the concentration of soil particles and nutrient export is decreased. The Ducks Unlimited document supports this claim and recommends the most efficient restoration level is 80% of the original, or 1968, storage capacity.

The areas shown in the next map describe how Marsh's zone concept can be applied. The map reveals a large contributing zone and a lower collection zone (Figure 6.2B). Using elevation information, one can depict where the water is retained and where it runs off.

The northern location is a contributing zone: it receives the majority of the site's water and creates runoff; drainage issues can be addressed here; the southern location is a collection zone: a low area of the section where runoff can accumulate; existing vegetation is an indicator that the location is subject to inundation and prone to intermittent flooding and therefore an undesirable location for runoff management.

While Marsh explains where the optimal locations are to manage water, he does not offer suggestions about the type of management method or structure. Data suggest that the Waffle concept could be one possible water management solution. But it must be adapted. In the original concept, road infrastructure is used to create levies. However, in the practicum site, the undulating landscape of the site does not allow for the implementation of levy structures. Instead of elevated road infrastructure existing topography will be used. This allows for the landscape itself to be used and adapted for storage while minimizing additional infrastructure. These areas make use of the basic principles of the Waffle concept and are called Waffle Wetlands (Figure 6.2C).

Therefore the total surface area of the wetlands correlates directly to its storage volume. Measurements of waterbodies were taken and calculated based on GIS shapefile data provided by Ducks Unlimited Canada. The GIS data assigned waterbody, i.e. wetland, boundaries at the edge of visible water and did not include areas including emergent vegetation or salt lines.

Based on this data, Waffle Wetland 1 (WW1) has 12 individual wetlands with a total of 13.3 ha of water surface and a total amount of stored water of 133 000 m3 (Figure 6.4). Waffle Wetland 2 (WW2) has a total of 7 wetlands with 6.9

Figure 6.2 A - C (Opposite) Series of GIS-produced maps showing detailed movement of runoff, location of Marsh's zones and Waffle Wetlands.

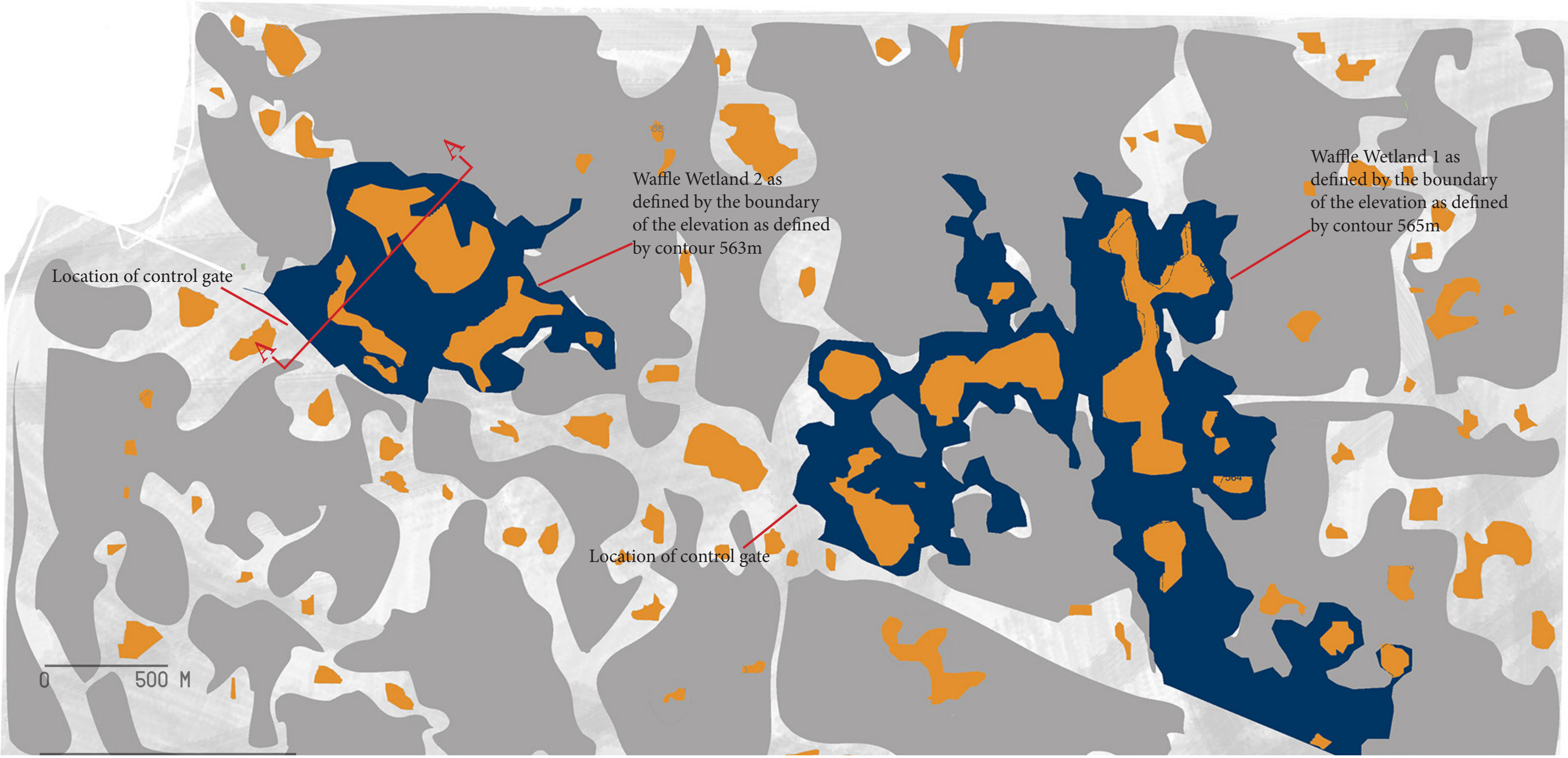


Figure 6.3 Site plan showing the extent of inundation when Waffle Wetlands 1 and 2 are implemented.
Blue shows flooded area up to elevation as defined by contour 563 and 565. Existing wetlands are indicated by orange.

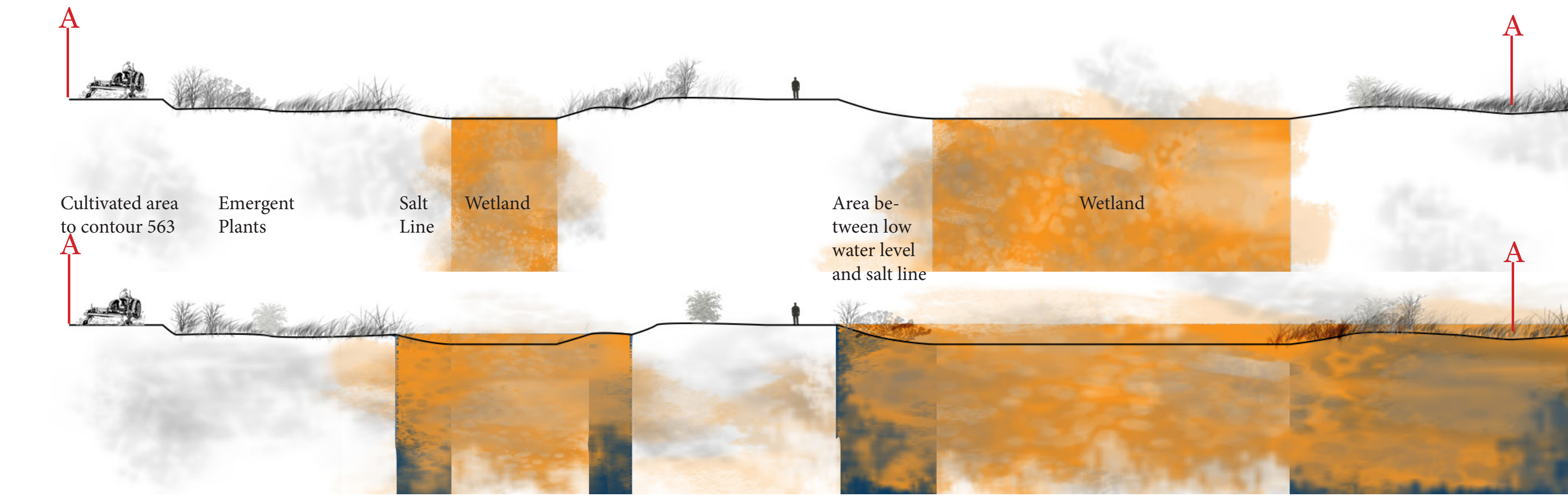


Figure 6.4 Cross section A (See Figure 6.3) showing existing and proposed water levels when Waffle Wetlands are implemented.

ha of water surface and a total volume of 69 000 m³ stored water.

6.3 PROPOSED VOLUMES

Both Waffle Wetlands work together to create detention space for runoff and keep it from overflowing into adjacent fields or into already swollen downstream tributaries. Both Waffle Wetlands are located in places where the majority of land cover is emergent vegetation. Inundation of existing field spaces is kept to a minimum. In order for the waffle wetland approach to meet the 80% restoration threshold as suggested by Yang et al., 2008, each waffle wetland needs to be able to increase its storage capacity by 80%.

WW1 consists of many existing waterbodies surrounded by the elevation as defined by contour 565 and graded to create a continuous enclosure (Figure 6.3). During snowmelt or precipitation events, water would be allowed to accumulate to just below the 565 metre elevation. WW1 also performs initial filtration functions. Water is held here until one of two things occurs: additional storage is needed or water has been stored here for two weeks. Two weeks is the preferable amount of time to effectively improve water quality (Woltemade, 2000, p.307) (Setty, n.d., p. 4). In times of high runoff volume, the control gate would be opened to allow excess water to leave the newly created basin and flow downstream through an existing channel that is retrofitted to accept this volume and the increased velocity of water. At full capacity, WW1 will hold 130 thousand cubic meters of water (Appendix A).

Waffle Wetland 2 consists of several existing waterbodies surrounded by the elevation as defined by contour 563. The wetlands that are included are based on the design assumption that they would be inundated after the site has been graded to create a continuous enclosure at elevation 563. During snowmelt or precipitation events, the control gate

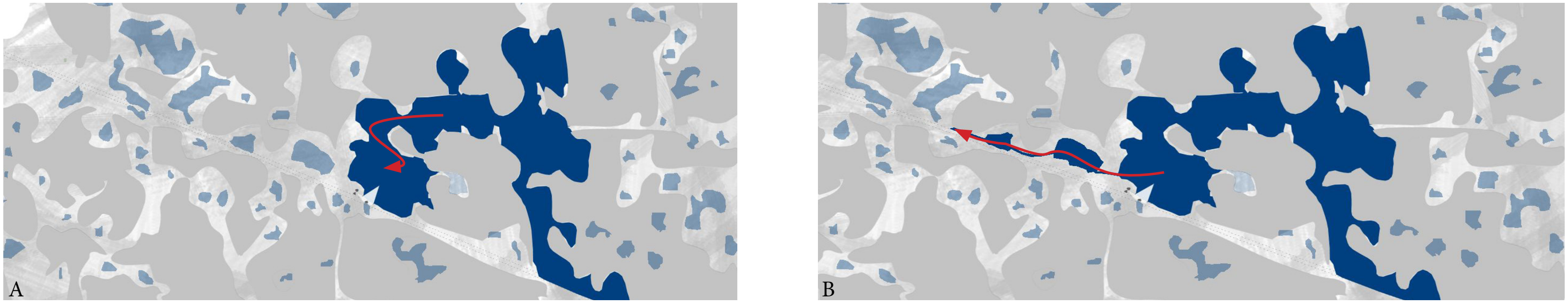


Figure 6.5 A - D Series of maps showing general movement of water from Waffle Wetland 1 to Waffle Wetland 2.

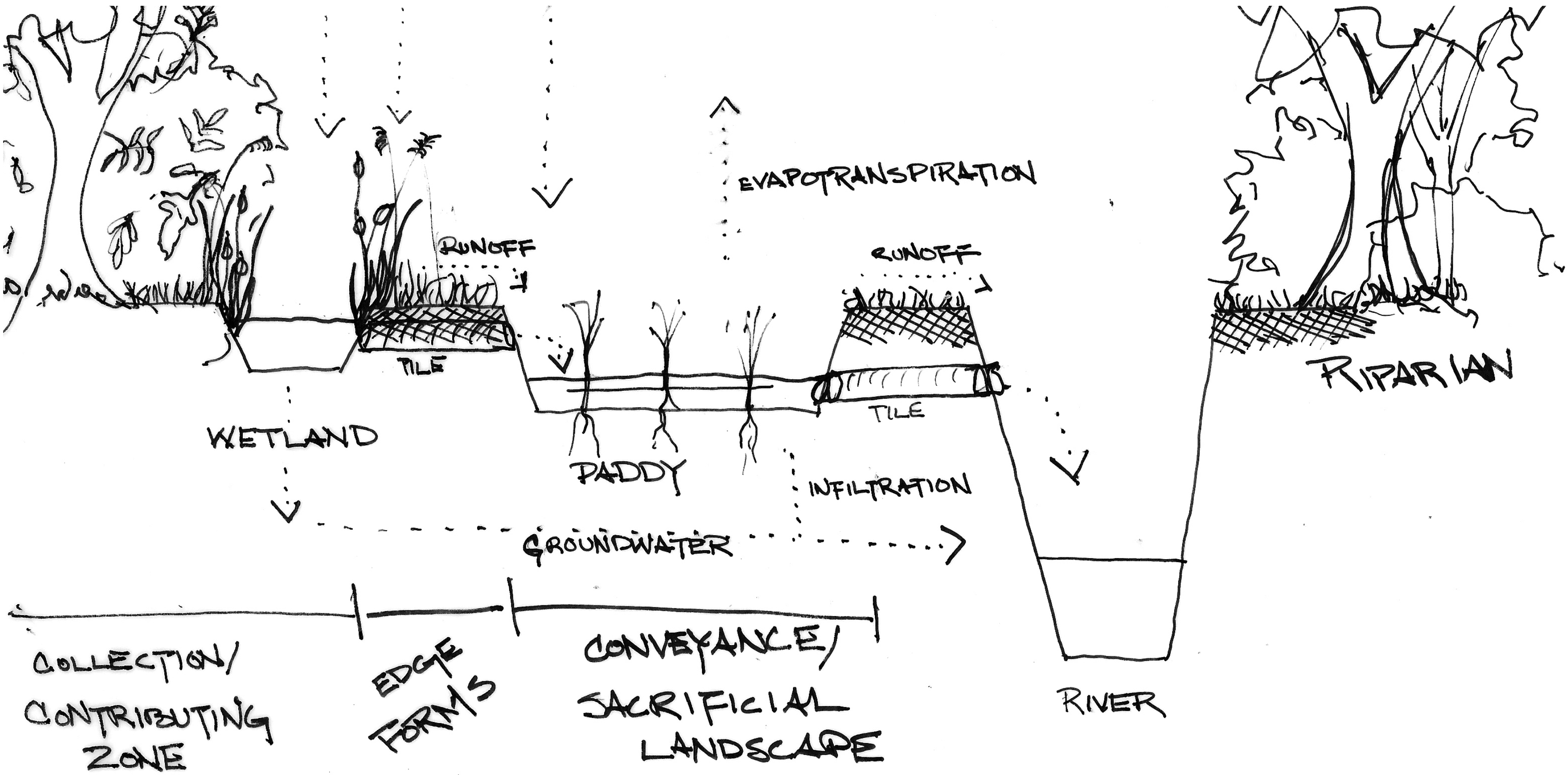
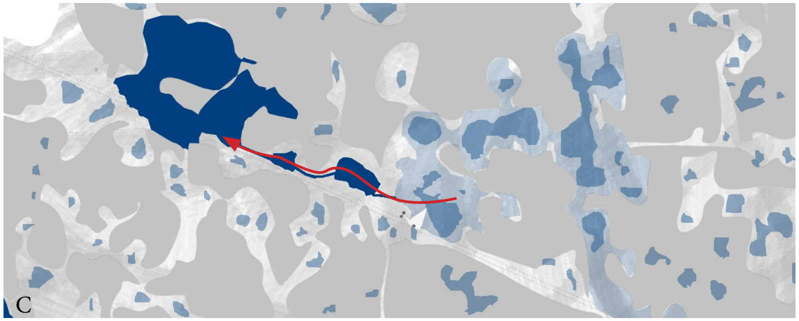
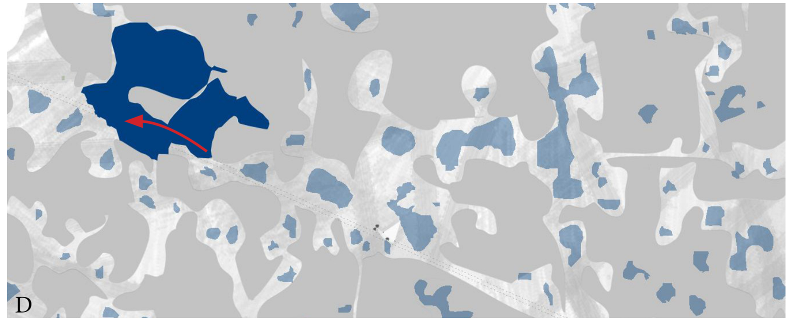


Figure 6.6 Early concept sketch of Waffle Wetland series.





would be closed and water would be allowed to accumulate to just below the 563m elevation. It designed to accept water during snowmelt and precipitation events and retain overflow from waffle wetland 1. Water is stored for up two weeks and then released through a series of water controls gates to allow water to leave the basin and flow downstream (Figures 6.5 a-d). At full capacity, WW2 will hold over 128 000 cubic meters of water (Appendix A).

The resulting difference is an 82% increase is storage volume. Compared to the original conditions of the section, by creating these two locations where storage volume is increased, 66 ha or 66000 cubic meters of water storage has been created.

In times of high runoff volume, the control gate would be opened to allow excess water to leave the newly created basin and flow downstream through an existing channel that is retrofitted to accept this volume and the increased velocity of water and enter the intermittent stream located along the western most road running north to south.

Compared to the original conditions of the section, by creating these two locations where storage volume is increased, 66 ha or 66000 cubic meters of water storage has been created and a 1 in 100 year storm event could be detained on site (Appendix A).

6.4 PROPOSED WATER MANAGEMENT STRATEGIES

The design proposal captures runoff and creates a landscape that optimizes slow release, reduces runoff impacts of agriculture; and creates opportunities for ecological restoration and recreation (Figure 6.6). Regenerative design strategies include decreasing runoff by increasing the holding capacity of existing wetlands, increasing water quality through runoff detention and filtration, and designing a memorable, valued place for trail users through experiences that highlight changing hydrological conditions.

The practicum site contains a number of viewsheds, or locations that emphasize particular views of the landscape, can be supported with new infrastructure to create connections between the design intervention, the hydrology and the resulting changes in the landscape. The arrival area in the existing park space is the first opportunity to set the tone of the project and create interest for what is to come. Materials can be used here that are used elsewhere along the trails and at the rest stops, nodes and boardwalks. Water is another key feature in this project and can be emphasized at the arrival area. Using existing topography and proposed changes in water levels, possible views and pathways through the landscape were explored (Figure 6.7). It was important to understand how the trails will be accessed during high and low water levels.

Universal access is also important to allow for different modes of transportation. These modes would include walking, biking, winter recreation, wheelchairs and mobility scooters. Winter access is another opportunity. Allowing the trail design to accommodate cross country ski trails and snowshoe trails would increase the utility of the landscape and possibly expose the user to agricultural fields during the winter.

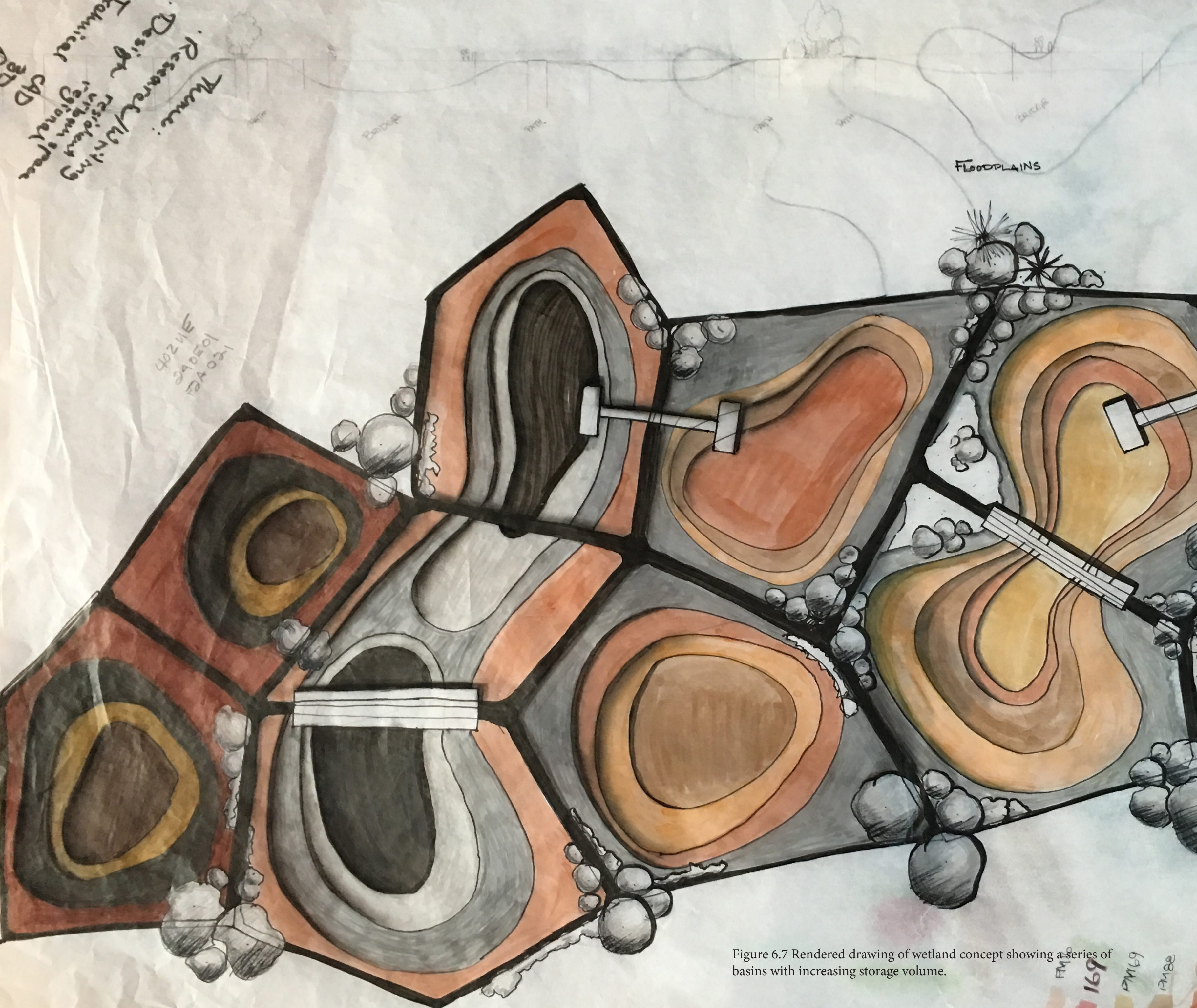
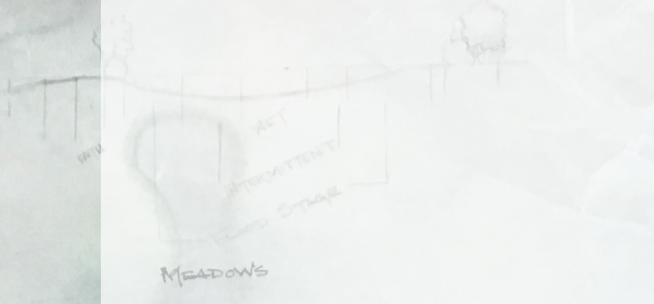


Figure 6.7 Rendered drawing of wetland concept showing a series of basins with increasing storage volume.



The old rail line is still evident in some parts of the site. The image here is taken at the southeast end of the section. The rail line is the large berm at the centre of the image. In the final design it is incorporated into the berm structure and some of the trail system will run on top of it. However, much of the berm that the old rail line was built on has been removed, likely to allow for drainage from the north side of the section to the south. The existing rail line creates an opportunity to view the landscape from an elevated point. Using Google Earth underlays to illustrate existing high and low water level situations, it is clear that the rail line could play a major role in connecting the landscape to the arrival area and to the town itself.

Topography, hydrology, existing vegetation and infrastructure like culverts, ditches and dams, land use and soil type will be considered to create spaces that allow for water to collect and move from one location to another and allow sediment and associated nutrients to settle out of the water column. These spaces will be designed to hold water for the optimum amount of time and existing contours will be used to increase the storage volume of existing wetlands to fulfil the 80% optimal restoration hydrologic requirements (Yang et. al., 2008).

6.5 Design Strategy 1: Decrease Runoff by Increasing Capacity of Existing Wetlands

Landscape features such as topography, drainage and on-site retention will work together to meet the goal of "no net increase in water or nutrients exported from a watershed." (Government of Manitoba, 2014) This document, part of Tomorrow Now - Manitoba's Green Plan released after a series of public consultations states it is "an eight-year strategic action plan for mobilizing Manitobans to work together to protect the environment while ensuring a prosperous and environmentally conscious economy". To achieve no-net increase in water or nutrients wetland services will be restored and increased by designing water storage systems based on the principles of the Waffle Concept and on the research findings in Water Quantity and Quality Benefits form Wetland Conservation and Restoration in the Broughton's Creek Watershed (Yang et al., 2008).

6.5.2 Design Strategy 2: Increase Water Quality Through Detention and Filtration

Water detention and filtration occur in the site's wetlands and waffle wetlands. During high precipitation and snowmelt events, individual wetlands will incorporate into one large one for period of time (Figure 6.8). Soil sediment and associated nutrients will settle out of the water column and denitrification will occur.

6.5.3 Design Strategy 3: Trail System Design that Exposes User to Experiences that Highlight Changing Hydrological Conditions

Performance-based design principles emphasize ecological function restoration while protecting cultural landscape features. Runoff can be used as a place-making device. Ecological components of the design will emphasize regional character, mimic natural riparian areas, create native plant mosaics, capture stormwater and redirect into riparian

Figure 6.8 Conceptual drawing of wetland concept showing a single-basin concept with inlet and outlet.

areas, create effective and efficient hydrology, account for human use and biological needs, and create an informal trail system that emphasizes viewsheds and educates trail users about ecological restoration, optimization and hydrological processes. A multi-layered design approach will create opportunities for landowners, surrounding communities and natural systems.

Experiential qualities are woven into the design to emphasize management solutions and ecological services restoration. It will show a multi-layered design approach to the prairie landscape that creates opportunities for landowners, surrounding communities and natural systems.

What features are designed to allow users to view or interact with the wetland? What can they see in terms of the new functions of these wetlands? Water storage and conveyance are two important factors in the design strategy and will allow for basin creation. Water control structures serve as the foundation for trails and pathways and allow visitors to experience these landscape functions and changes over time.

A sketch exercise was done to discover viewing opportunities based on water levels and topography. Water control structures and trails are located next to wetlands to allow visitor to experience changes over time and during fluctuating moisture levels.

6.6. VEGETATIVE STRATEGY

The wetland structure and function including margins and riparian zones will fluctuate as water levels change. The plant communities that will establish over time will be based on hydrologic and physiognomic factors in these basins. Many smaller individual wetlands will be incorporated into one large one for periods of time and over time, plant communities will respond accordingly.

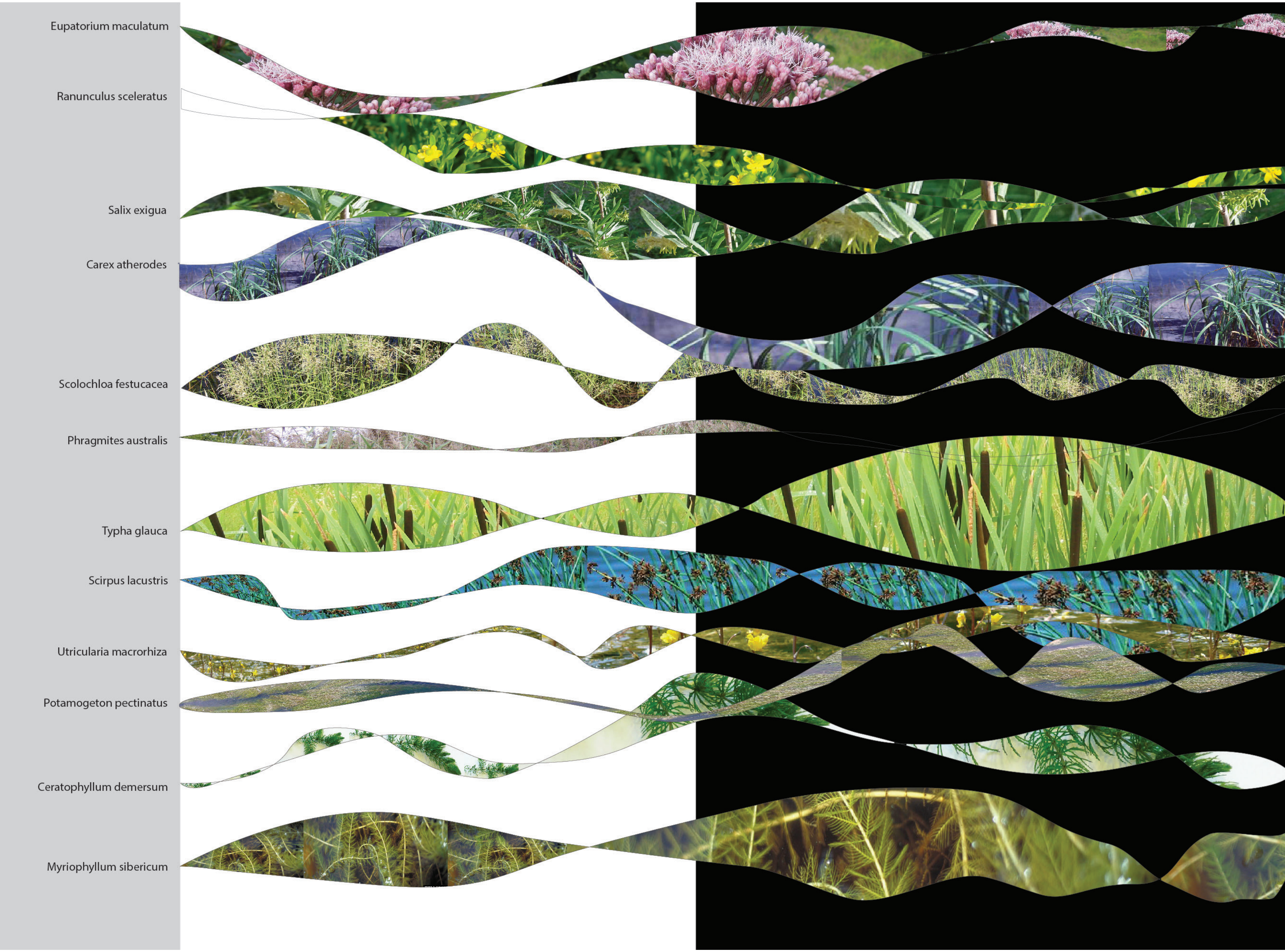
The plant communities that establish will be strongly dictated by moisture requirements that will in turn dictate there optimum location within or adjacent to the wetland. The planting plan will be strongly dictated by moisture requirements of the plants and their optimum location along the edge of a wetland (Figure 6.9).

6.6.1 HYDROLOGIC ZONES

To understand how changes in water storage volume affects hydrological activity within a wetland, it is valuable to determine the various hydrological zones within a basin. The degree of inundation is a major factor in the presence or absence of plant species. Six hydrologic zones have been identified (Appendix B).

Plant communities will vary based on the changing water levels and it is important to include plants that thrive when water levels fluctuate.

FIGURE 6.9 RELATIVE ABUNDANCE OF TYPICAL WETLAND SPECIES BEFORE AND AFTER WAFFLE WETLAND IMPLEMENTATION

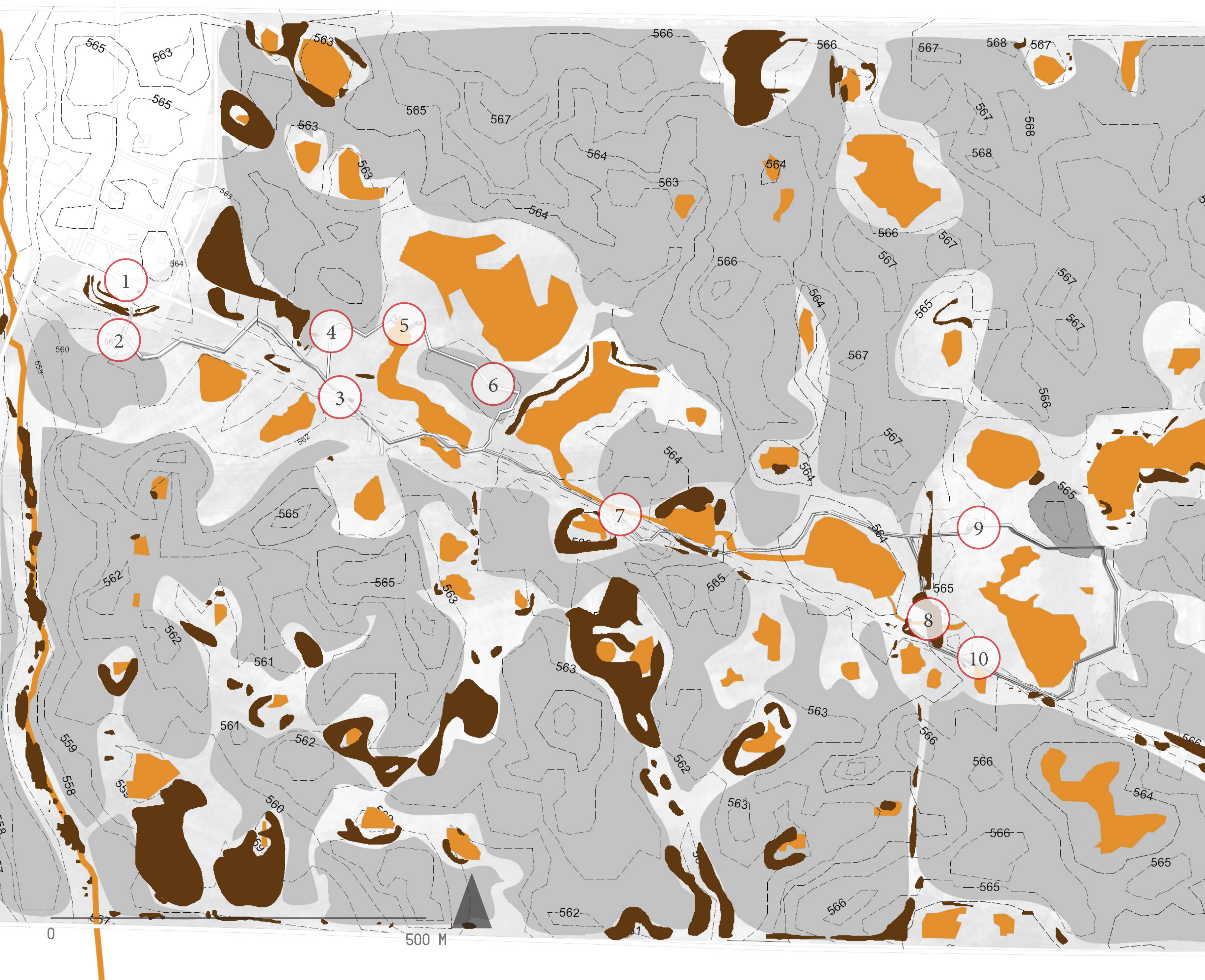


6.6.2 SOIL SALINITY

Soil salinity is a factor at the practicum site. During in-person observation and through aerial photographs, these areas are seen as white bands that circled the high water mark of many of site's wetlands. These white bands were devoid of plant material. Saline soils in this region are high in calcium carbonate and usually have a dominant upward movement of water. Salts accumulate on the surface as water evaporates or by capillary action that brings salts into the root zone. Factors that make these soils more vulnerable to surface salts include high water table, cultivation and/or lacking vegetation (Tober, Duckwitz, & Sieler, 2007, p.1).

Plants will establish based on individual salt tolerance and ability to re-vegetate saline soils. It is also important to plant a variety of species with differing salinity tolerances to increase stand productivity. Also deep-rooted species can effectively draw down soil water levels and reduce upward movement of salts (Saskatchewan Agriculture & Food, 2007, p. 4). A hybrid green wheatgrass, i.e. NewHy hybrid wheatgrass, was developed by the USDA and produced a strain that combined the persistence, vigor, productivity and salinity tolerance of quack grass with the quality, drought tolerance and growth from of Bluebunch wheatgrass (Saskatchewan Agriculture & Food, 2007, p. 2).

Using available data (Tober et al., 2007), the table in Appendix C contains a list of plants that are both salt and moisture tolerant and could be used to revegetate areas of the site that have been affected by salt.



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7. DETAILED DESIGN

Legend

Trees and Shrubs

Emergent Vegetation

Existing Wetlands

Field Spaces

1 Arrival Area

2 Trail Start

3 Main Gathering Node

4 Elevated Boardwalk

5 Floating Boardwalk

6 Short Loop Trail

7 Short Loop Trail

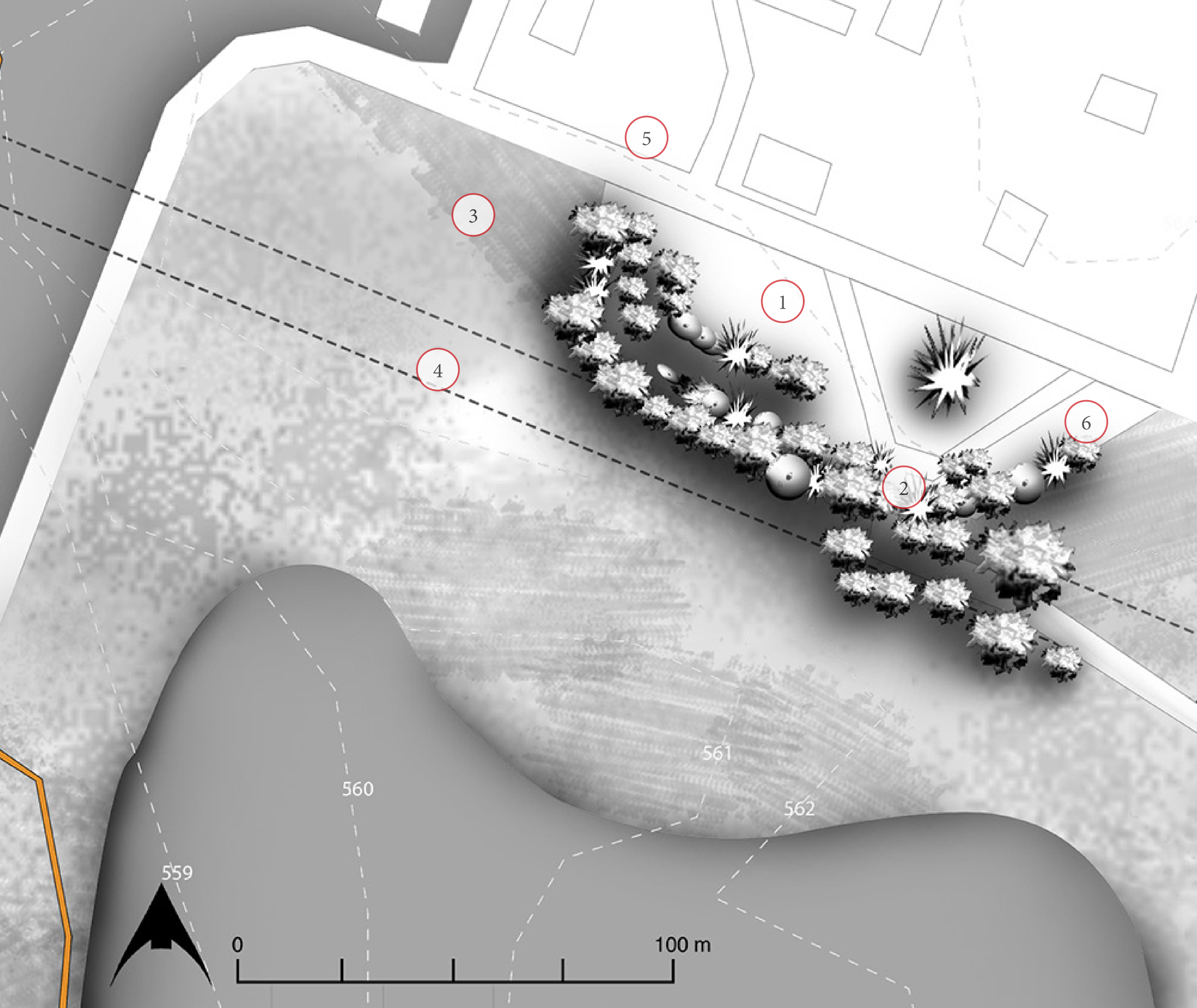
8 Main Gathering Node

9 Long Loop Trail

10 Berm and Gathering Area

In each design decision, flooded and non-flooded hydrological conditions are taken into account. Two distinct scenes are created: one with typical water levels and numerous individual wetlands of varying sizes and shapes; and another that has higher water levels and combines all the smaller basins into one. The character of the landscape changes as the wetlands amalgamate, become larger and more expansive. Each condition creates a unique character central to the design intent. Trail systems, nodes and access are designed with these two water levels in mind. Another important approach to the site design was to minimize new infrastructure on the landscape. Wherever possible, the existing landscape is kept unchanged, design features are mostly informal and low maintenance whenever possible (Figure 7.1).

Figure 7.1 (Opposite page) Practicum site plan showing landscape features and location of design interventions and water control structures.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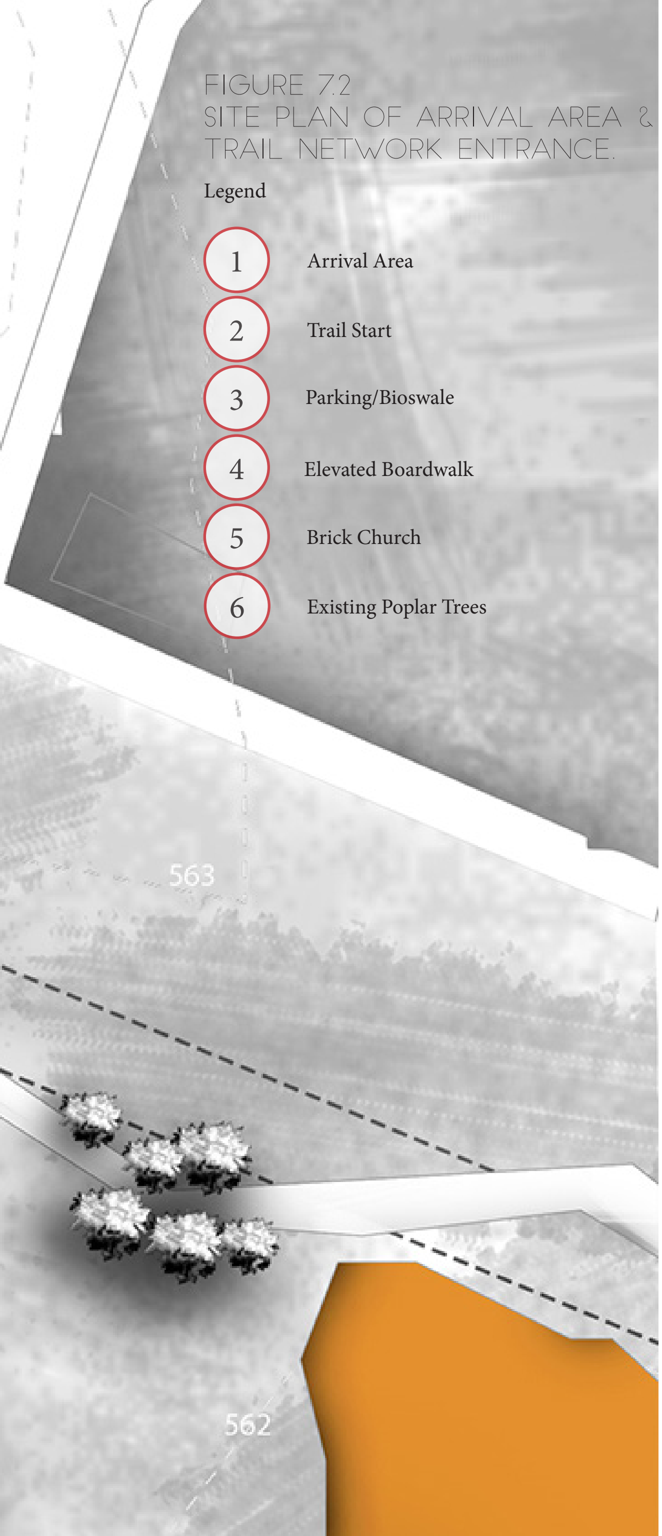


FIGURE 7.2
SITE PLAN OF ARRIVAL AREA & TRAIL NETWORK ENTRANCE.

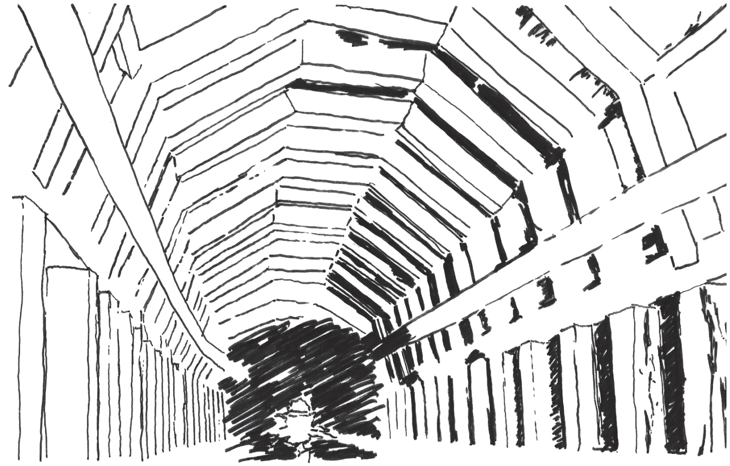


Figure 7.3 Concept sketch of old railway bridge cover.

7.2 ARRIVAL AREA AND TRAIL NETWORK

7.2.1 ARRIVAL

The specific design of the building or interpretive center is outside the focus of this project, however, a short explanation of why the arrival area is located at the southwest end of Cardale is briefly discussed.

The location creates an opportunity to showcase the town's history while making the trails easy and convenient to access. School buses can park and turn around while cars and foot traffic have easy access to the entrance site. From aerial photographs, it is clear that the old rail lines run diagonally through the arrival area (Figure 7.2). The historical brick church is adjacent and all the town roads run directly to and around this site making it a sensible space to use for trail entrance (Figure 7.4).

It also marks the spot where decades of commerce and activity occurred. It is a place that welcomed townspeople and new visitors and could be a place for parking and bioswale (Figure 7.5).

The existing line of poplar trees planted along the south border of the existing park creates a strong threshold and blocks visitor's view beyond this point. This visual barrier draws the visitor in and creates curiosity and intrigue. Design ideas for the arrival area include a small pond with concrete pads jutting out above the pond for climbing, wetland plants reflect those that are found along the trails and design details like lighting that mimics traditional railway controls and a canopy at the trail start suggests an old wooden train bridge (Figure 7.3).

Figure 7.4 Perspective of arrival area showing water feature and historical railway design features.

Figure 7.5 Sketch of parking lot and bioswale.

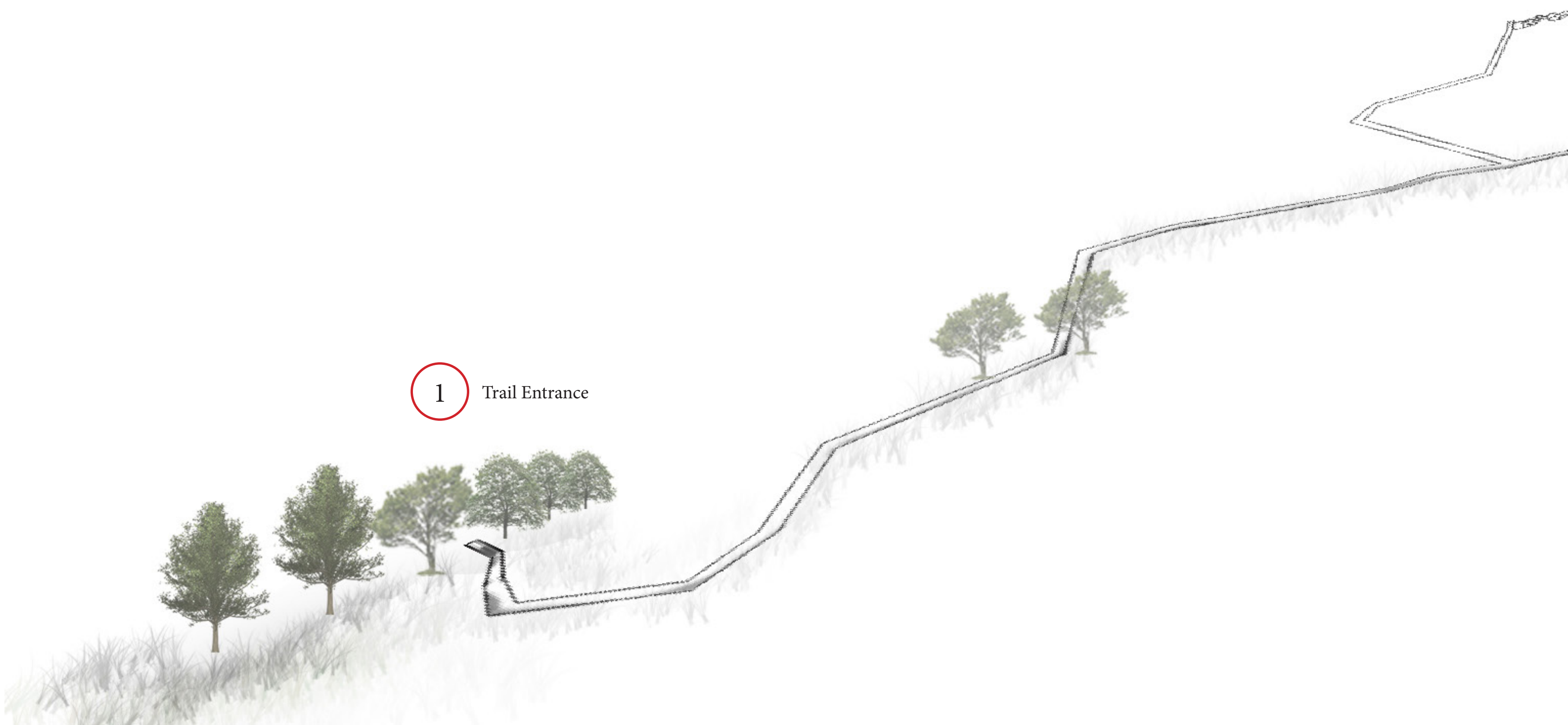


Figure 7.6 Perspective of the trail network, isolated, showing short and long loop options.

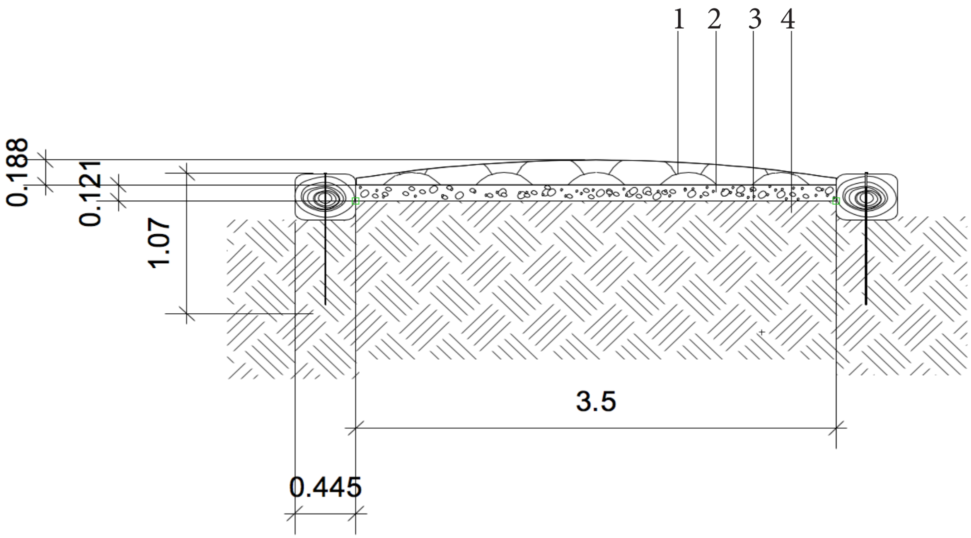
7.2.2 TRAIL NETWORK

Two lengths of trail have been designed to accommodate various abilities and levels of access (Figure 7.6). The short loop trail is 1.6 km and could be walked in about 30 – 40 minutes. This trail is designed to accommodate universal access. Slopes are 5% or less wherever possible. In areas where the incline is great than 5% but still less than 8%, rest areas are intermittently found. Trail width is typically 3m but narrows slightly when it travels along the berms at waffle wetland 2 at elevation 563 m. The long loop trail is 3.6 km and could be walked in about an hour. This trail is designed to accommodate visitors during low to moderate inundation events.

There are different trail materials used based on the dynamic hydrological conditions that will occur and on the desired experience. Design choices were made based on physical location, viewsheds, existing landscape features (natural and built), universal access, gathering locations, embedded energy and opportunity to use local or recycled materials. Pathways are designed to withstand changing moisture conditions. Water levels will fluctuate and at certain times, some sections will be inaccessible to foot traffic. The areas and pathways closest to the entrance are designed to be accessible during all but extreme events. Pathway elevations and management of control gates are part of this plan.

FIGURE 7.8 PERMANENT WATER-BOUND PATH SURFACE TWO-LAYER CONSTRUCTION METHOD WITH GEOCELL OPTION

Zimmerman, 2011, p. 229



1. Surface course crushed gravel in geocell 19 cm crest
2. 0/32 ballast base course 12 cm
3. Geotextile
4. Building ground as subsoil or sub-structure

Figure 7.9 Black and white sketch of trail network entrance surrounded by trees and with surface treatment of in-laid boards.

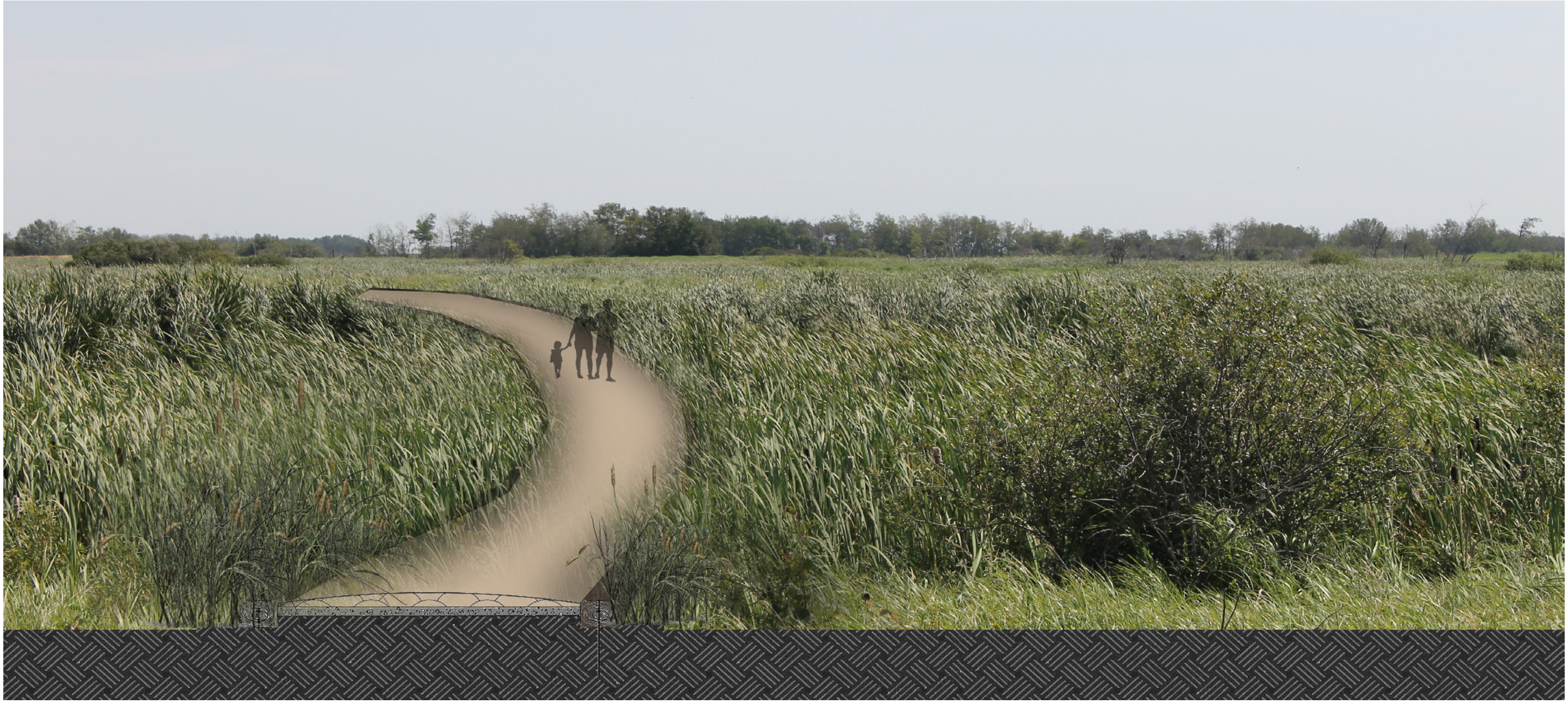


Figure 7.7 Section/perspective of informal trail design showing gravel surface among existing emergent vegetation.

7.3 MOVING THROUGH THE LANDSCAPE TO THE MAIN GATHERING NODE

As the visitor passes through the arrival area and crosses the row of aspen trees, they move into the landscape over a gently elevated pathway. Trees line both sides to create enclosure and encourage forward movement to the open trail ahead. This part of the trail is a bit more formal than what is found in the rest of the trail system. Wooden planks laid into the ground and surrounded by compacted limestone intermittently planted with mosses created a soft, but even surface. Over time, the mosses will grow around and in between the planks (Figure 7.9).

Passing through the thicket, the landscape opens up to pre-existing emergent vegetation (Figure 7.7). An informal pathway of crushed limestone is found here. This pathway type is designed for locations along the trail that are seasonally inundated or after a high precipitation event. It is designed to have a low impact on the surrounding site, be universally accessible and have low overall construction requirements and minimal maintenance.

Geocells are used to protect against floodwaters from displacing the pathway material. Geocells are high-grade plastic frames that expand to look similar to a honeycomb. They are manufactured in various thicknesses and the honeycomb cells are filled with substrate - in this case a coarse to fine-grade crushed limestone. These cells prevent the limestone from being displaced during high water events. Geocells are fixed in place with dowels and reinforced with a rot-resistant wooden frame (Figure 7.8). The foundation of these crushed limestone

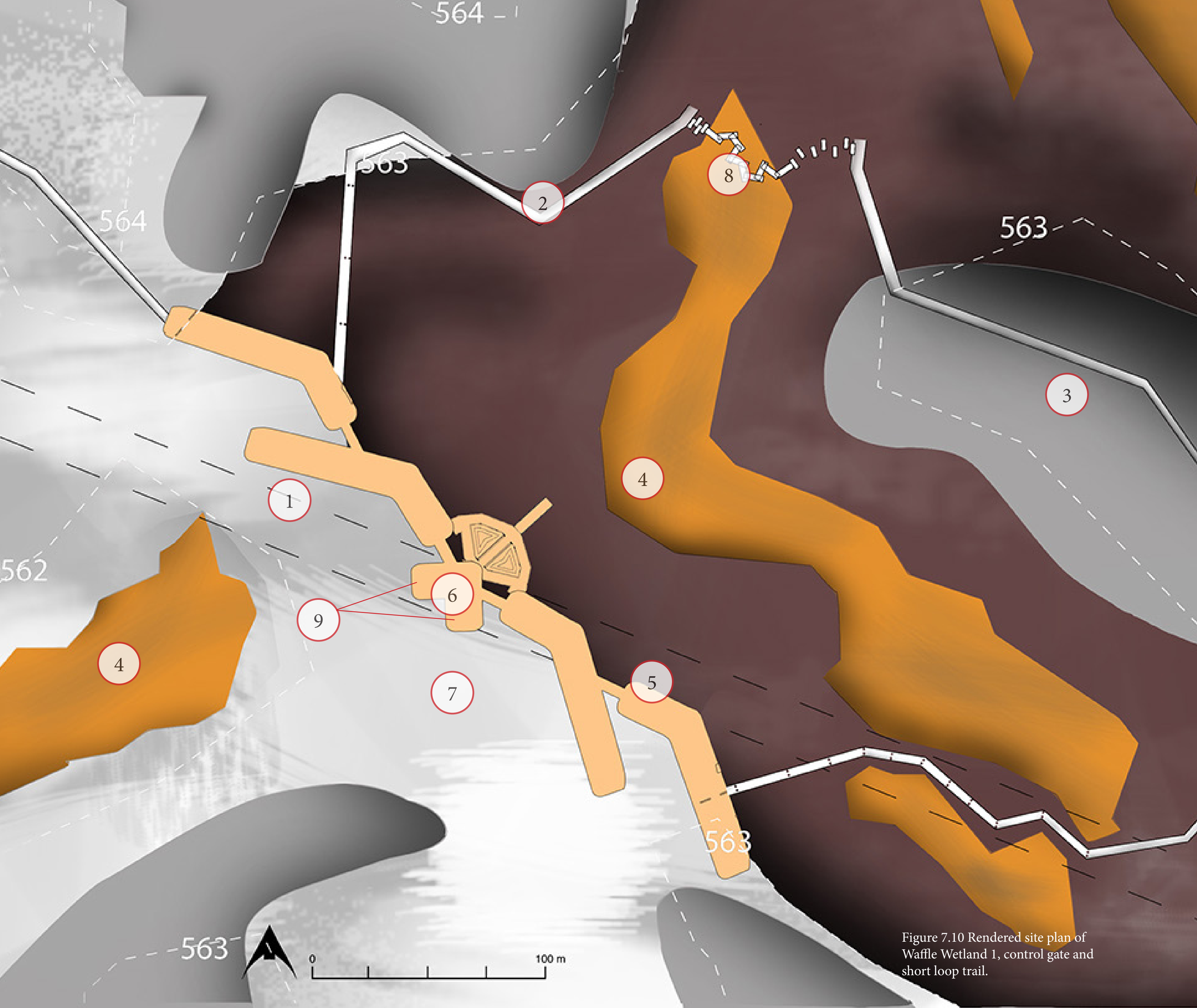


Figure 7.10 Rendered site plan of Waffle Wetland 1, control gate and short loop trail.

1 Waffle Wetland 2 Berm Series

2 Secondary Node/Elevated Boardwalk

3 Short Loop Trail

4 Existing Wetlands

5 Water extent at flood level

6 Main Gathering Node

7 LayFlate Gates

8 Floating Boardwalk

9 Viewing Portal

pathways will be specified to maintain integrity on the existing soil that is organic, highly porous and instable. Vegetation and the upper mantle of wetland soil will be cleared and replaced with a foundation of geotextile and a series of limestone grades. Each layer is compacted to specification.

After a 10-minute walk, the visitor encounters the first of the two waffle wetlands. This is the main gathering node, berm series and water control gates (Figure 7.10). The arrival is meant to entice the visitor by using existing vegetation and path shape to hide and expose the node ahead. When water levels are high, the water would be lapping up close to the top of the first series of berms and the gathering node is seen in the distance straight ahead while another secondary node can be seen off to the left.

The berm series is 220 m long and located where the original 563 m elevation comes closest together which also minimizes the amount of earthworks (Figure 7.11). The berms are just over 1 m and are built in segments that are 70 m long (Figure 7.13). Pathways run the length of each segment and are flanked by native grasses and other native flowering plants.

7.4 THE MAIN GATHERING NODE

The main node and boardwalks are designed to maximize the physical location, viewsheds and existing landscape features. It creates a resting place for visitors and offer opportunities to view the landscape, wetlands and hydrological infrastructure. Both the short and long trails travel through the main node that overlooks Waffle Wetland 2 (Figure 7.12). Connections between these features are design to withstand changing moisture conditions and water levels.

The main gathering node is the largest design intervention, the longest series of berms and holds the largest number of water control gates. The berm and dike structures are used in the project to close the contour of each waffle wetland. The berms are located at points where the structure and the needed materials can be efficiently minimized. The berm series is 220 m long and is used to connect the contour at elevation 563m. These berms

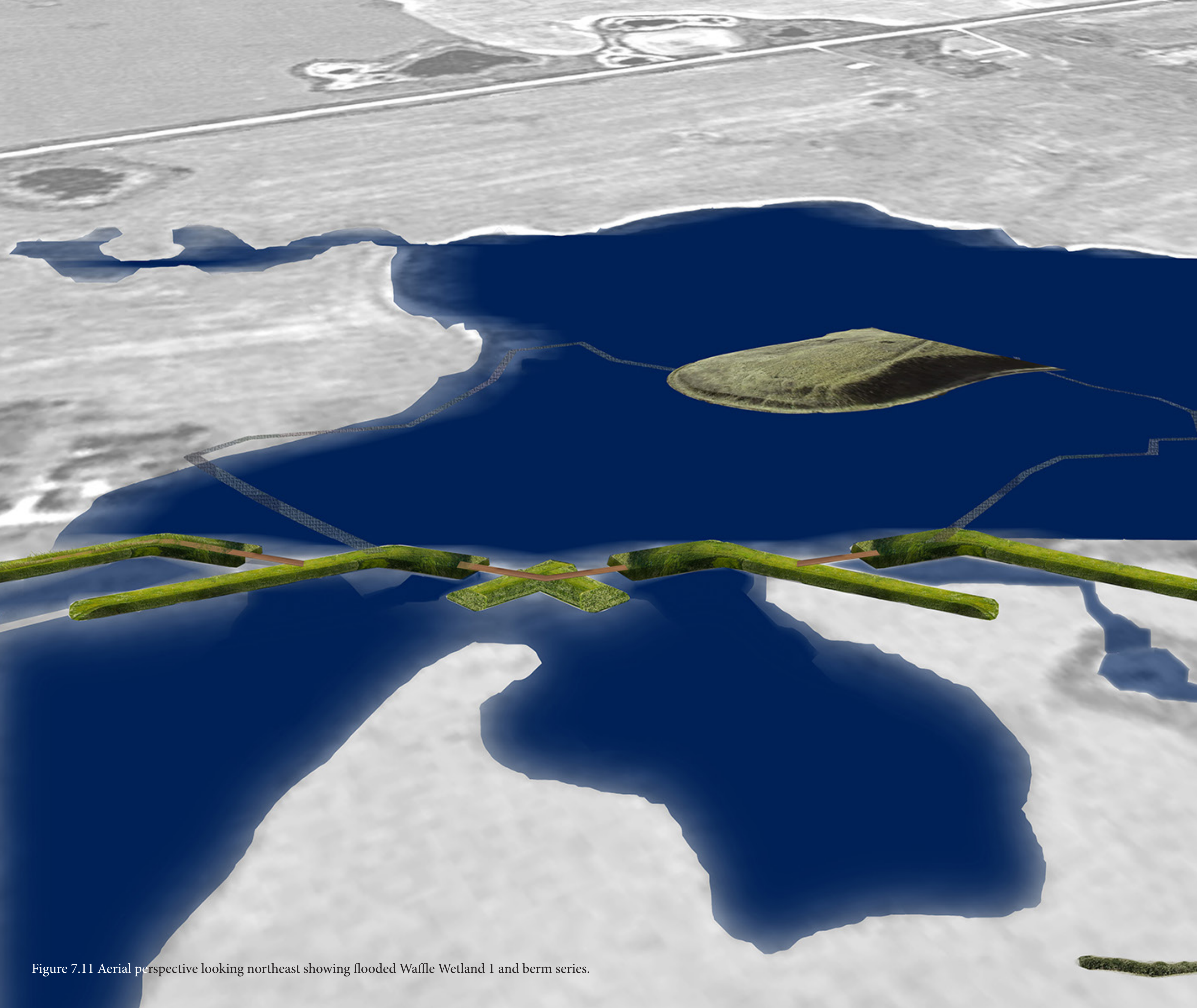


Figure 7.11 Aerial perspective looking northeast showing flooded Waffle Wetland 1 and berm series.

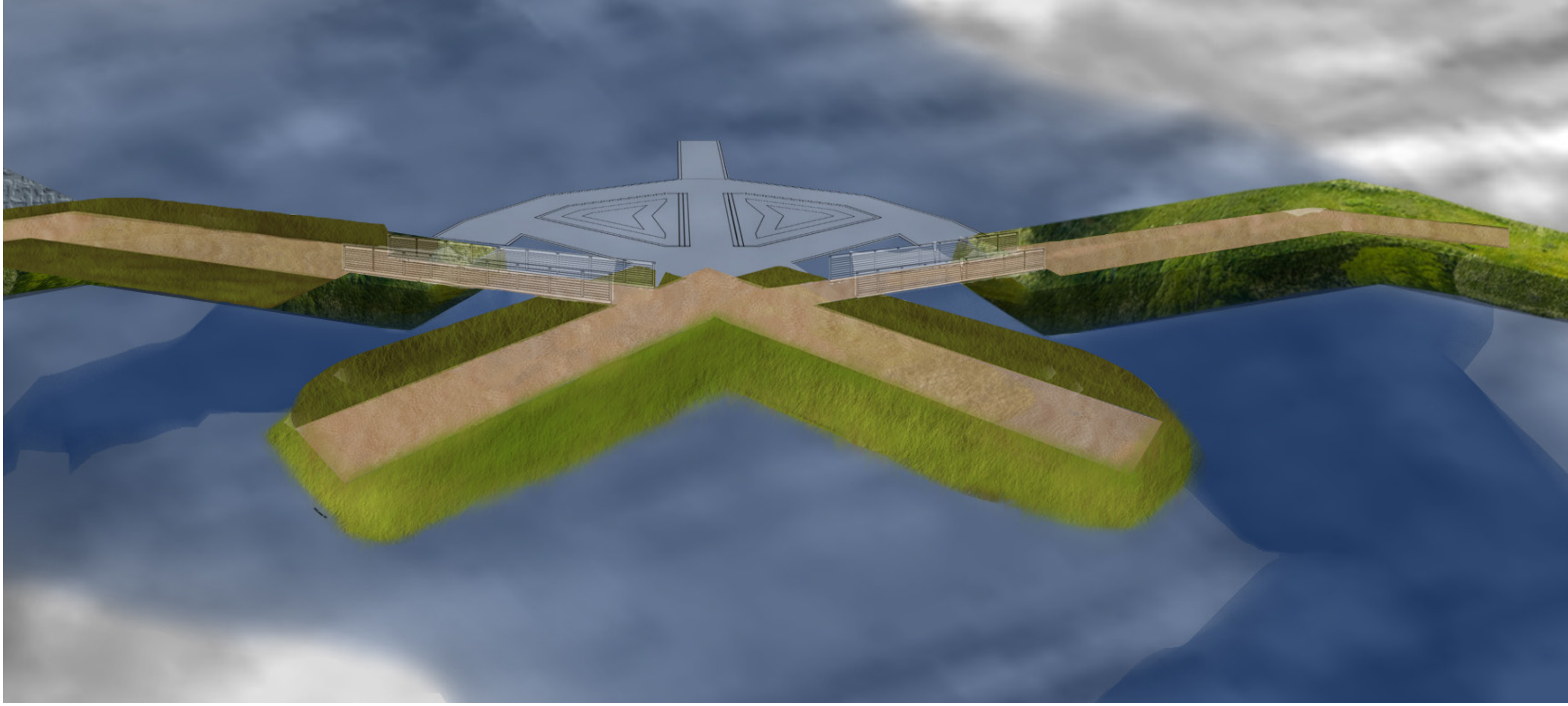


Figure 7.12 Rendered perspective of the main gathering node, walkways and berm series at Waffle Wetland 1.

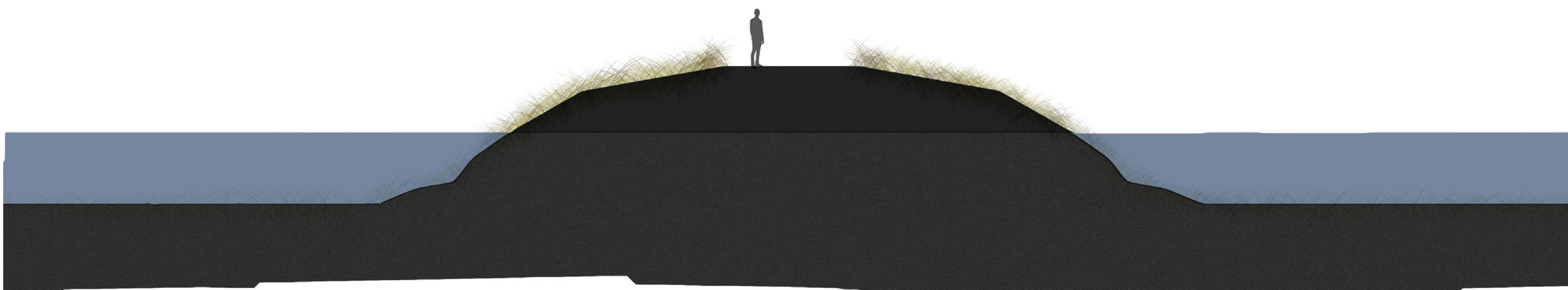
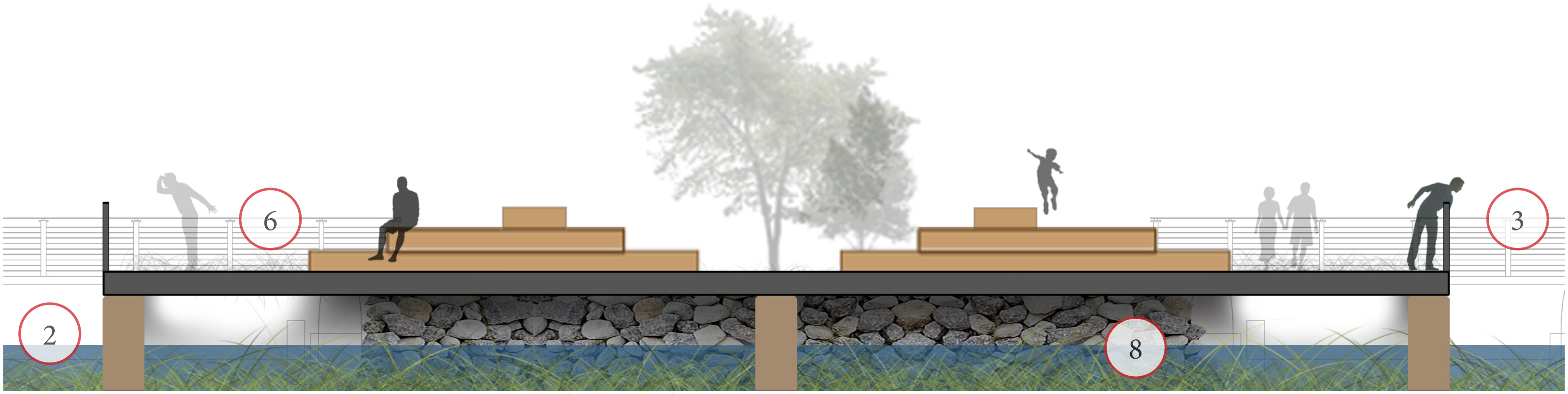
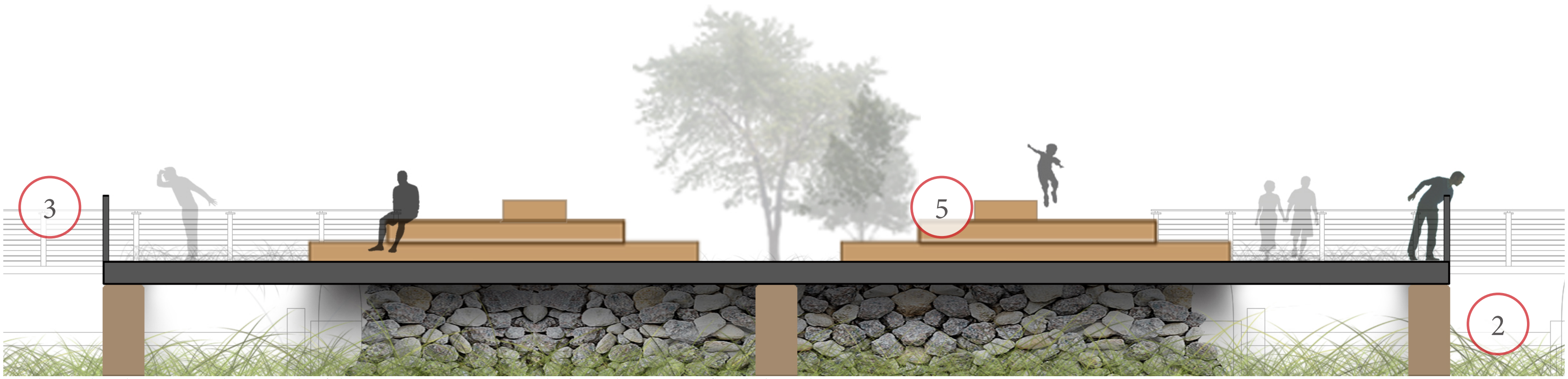


Figure 7.13 Section showing size of Waffle Wetland 1 berm and height of water at flood stage.

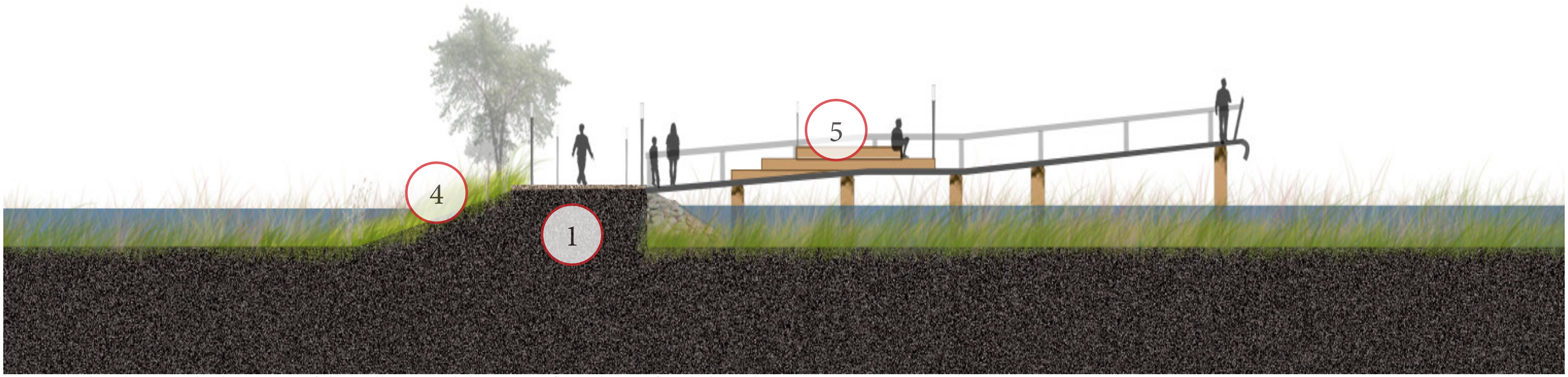


7.14a Rendered section looking south of the main gathering node platform during flooded conditions.

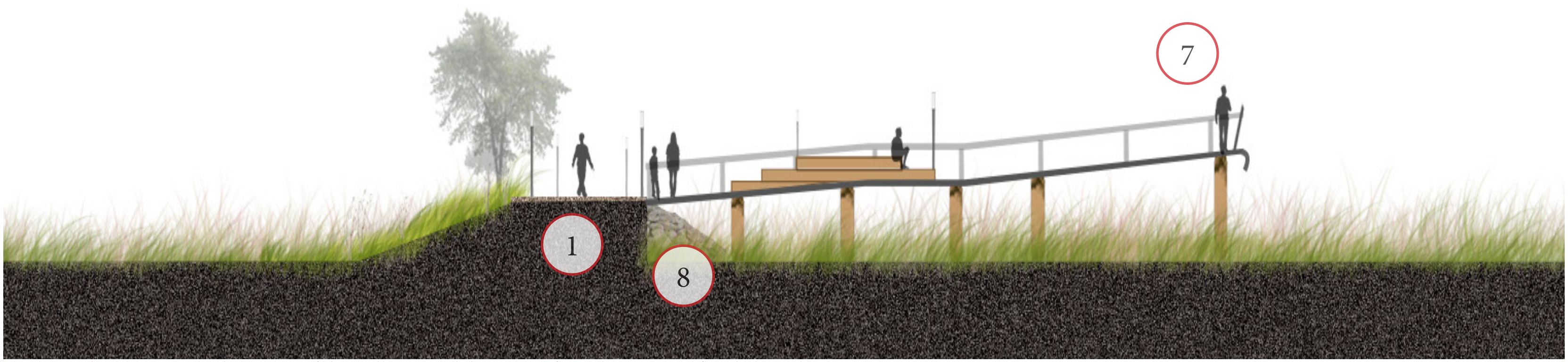


7.14b Rendered section looking south of the main gathering node platform during non-flooded conditions.

1 Waffle Wetland 2 Berm
2 Water Control Gate
3 Galvanized Metal Walkway
4 Native Grasses & Flowering Plants
5 Wooden Seating Platform
6 Viewing Portal
7 Central Walkout
8 Rip Rap



7.15a Rendered section looking west of the walk-out and drop away floor during flooded conditions.



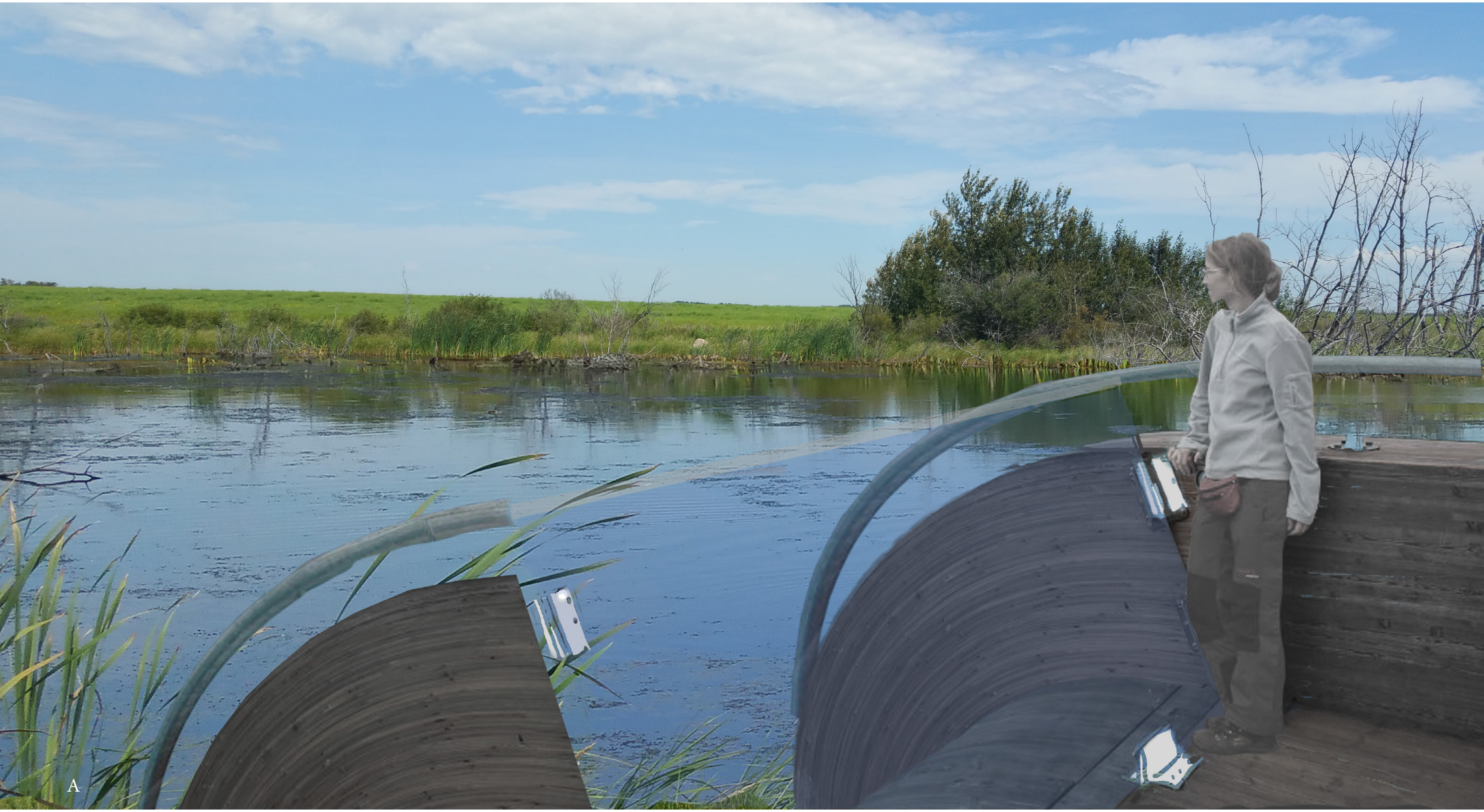
7.15b Rendered section looking west of the walk-out and drop away floor during non- flooded conditions.

are long and low at just over 1 m above the original ground elevation. There are five segments that are 70 m in length and separated by perforated, galvanized metal sections that reveal the water control gates. The impression is that you are walking on water, directly above the conveyance. The pathway that runs on the berm is crushed gravel and is partially bound by tall native grasses and flowering plants.

The main gathering node has a large platform with two seating areas for large groups to gather (Figure 7.14 a,b). The platforms have risers that are stepped to create different viewpoints. This node creates a place to experience the main hydrological structures and bring the visitor up close to the processes.

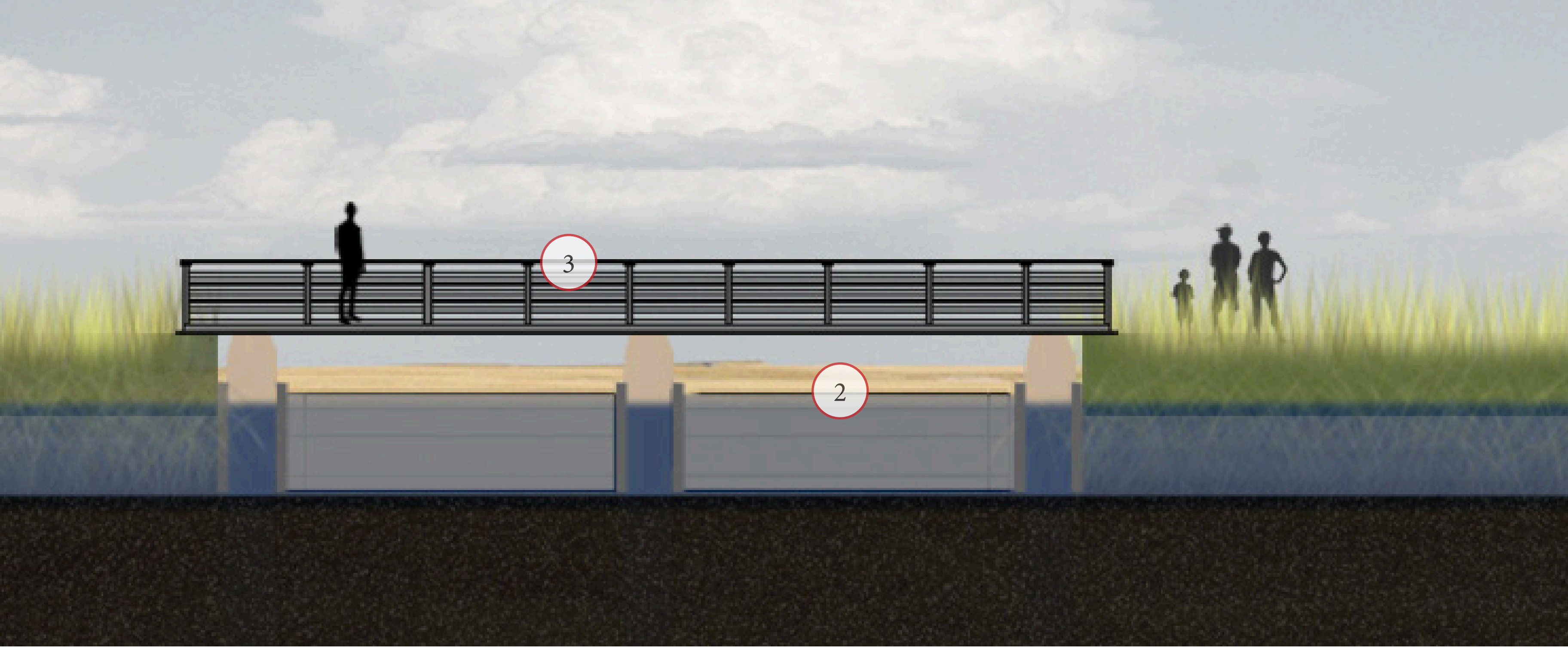
A viewing portal is found on both sides of the main node that faces the intake side of the LayFlat gates. The floor of the node seems to drop away while a large piece of glass tilts slightly forward to give the visitor a sense of leaning into the water (Figures 7.16 a,b). The two renderings use overlaid images from the Stegastein Viewpoint project designed by the Norwegian architects Todd Saunders and Tommie Wilhelmsen, show flooded and non-flooded conditions.

The central walkout is the highest point in the landscape. A narrow, gradual incline brings one or two visitors at a time to the northern tip of the main node. The turret-like feature has the “drop-away” floor and tilted glass panel giving the feeling of floating above the landscape (Figures 15 a,b). In drier



7.16 A,B Rendered perspectives exploring the application of the Norway project, Stegastein Viewpoint viewing portals during flooded and non-flooded conditions.


B



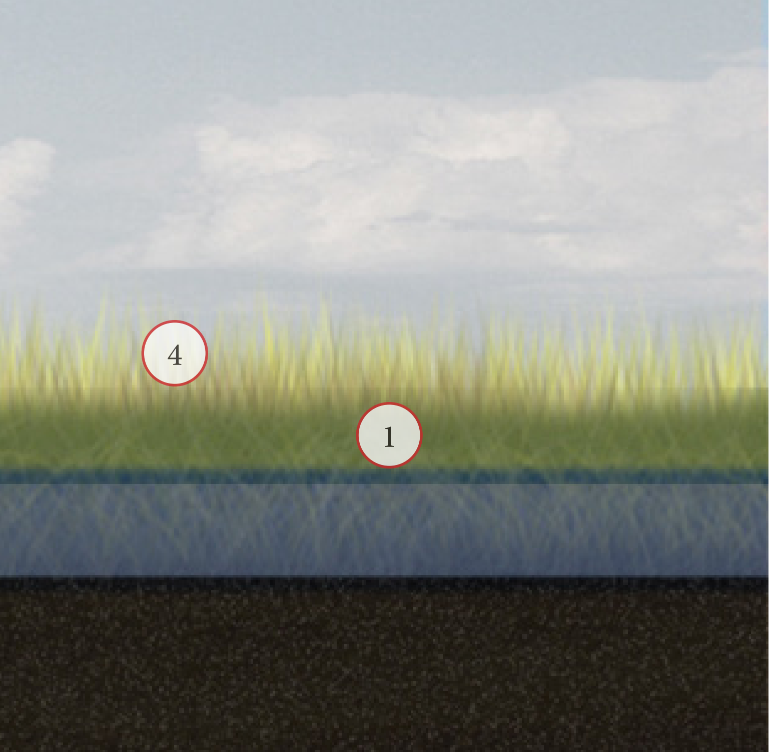
7.17 Rendered section elevation of closed LayFlat water control gate.

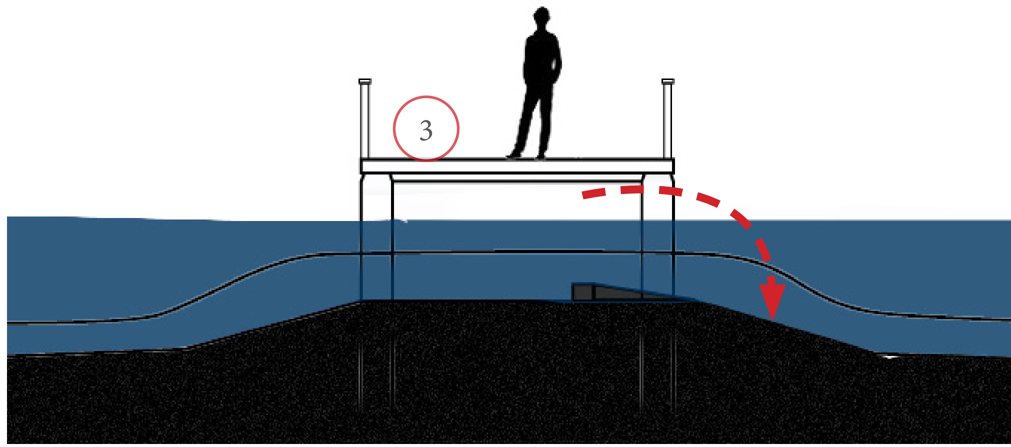
1 Waffle Wetland 2 Berm

2 Water Control Gate

3 Galvanized Metal Walkway

4 Native Grasses & Flowering Plants





7.18 Cross-section of open LayFlat water control gate showing direction of gate action..

periods, the cattails would sway just below your feet and it wetter times, the water would be heard splashing against the rip rap below. Looking out from this point, the visitor can see the entire landscape and is enticed to choose where to go next.

7.5 LAYFLAT GATES

In the original Waffle Concept, weirs and culverts were used to control and convey water. In this project, control structures were chosen on their ability to fit within the existing landscape features and allow for maximum exposure of the conveyance processes. LayFlat water control gates form is long, low and slim profile (Figure 7.17) and fits within the existing landscape and maximize exposure of the conveyance process.

It is a tilting weir that opens downwards and are appropriately sized for the project site and can be remotely operated and monitored. These gates also allow for unique observation opportunities as the water flows over the top of the open gate (Figure 7.18). Precedents provided on the company's website (AWMA Water Control Solutions, n.d.) include similar water control and flood enhancement works projects.

The LayFlat Gates can also enhance the experiential qualities. The wetland basins that are created in this practicum require control gates are less than two metres deep. The gates shown in Figure 7.17 and 7.18 are one such type and open in a downward direction. This allows for unique observation opportunities as the water flows over the top of the open gate and as water flows from one basin to the next.

There are two locations for these gates at each waffle wetland. It was important for the purpose of this design to allow as much exposure and access to these control systems as possible. Each location provides a unique viewing angle and segments are connected to each other by a see-through walkway. The walkway surface is made of perforated, galvanized metal that sits overtop the LayFlat gate structure. In WW1 the LayFlat gate is

Figure 7.19 Rendered section-elevation of landscape character and proximity of agriculture to the trail network.

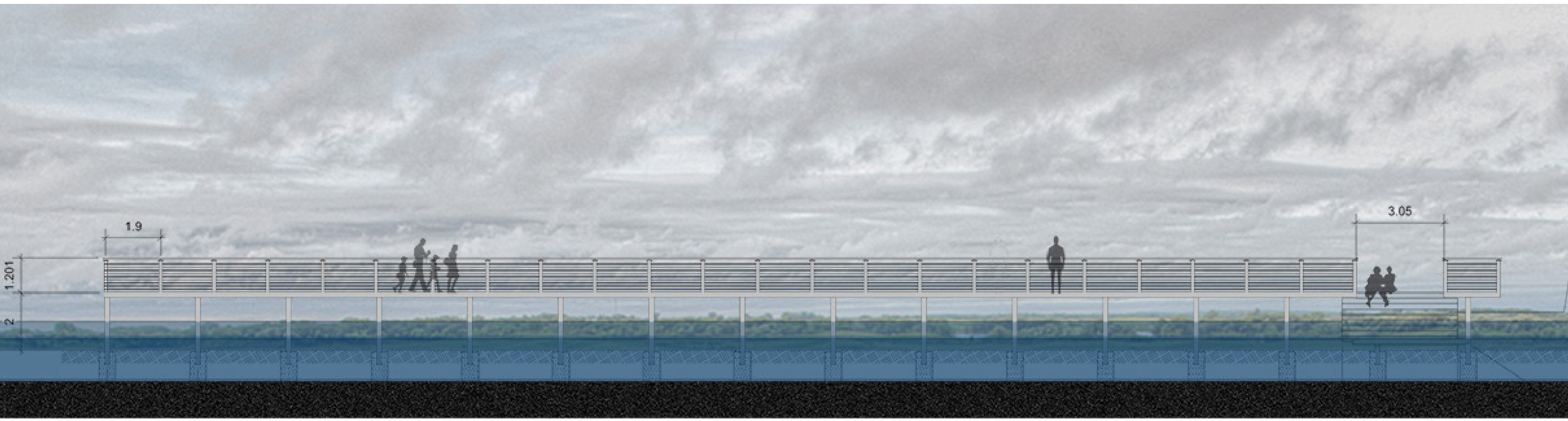
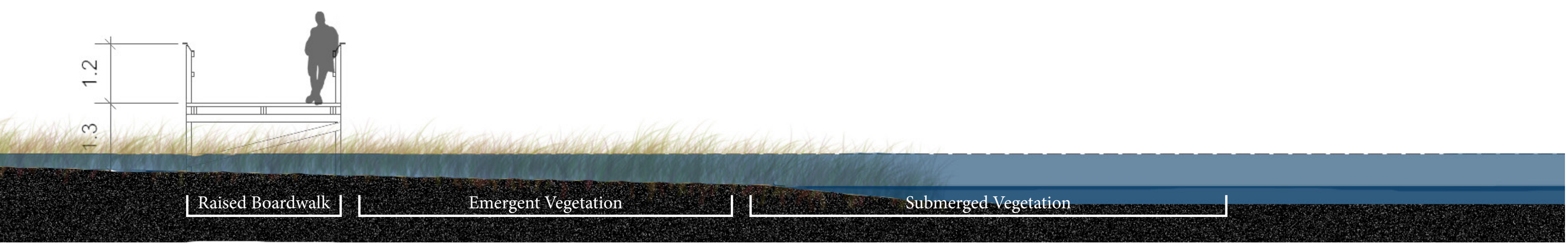


Figure 7.20 Rendered construction drawing of the elevated boardwalk and access point to floating boardwalk.



7.21 Cross-section of elevated boardwalk showing flooded and non-flooded water levels.

positioned to be at a distance from the trail so users can watch it from a greater distance and in WW2, the main node provides two locations where the user can look beneath their feet and watch the gates open and close, and watch the water rushing through.

7.6 Short Loop Trail

The short-loop trail directs people toward the elevated boardwalk, over the floating boardwalk, onto an island with various outlooks. The crushed gravel trail leads east and south to end up back on the constructed berms. Elevation changes and pathway direction are designed to allow visitors to view the landscape in all directions and provide opportunities for unique viewsheds.

Visitors come in close contact with crops on one side and wetlands to the other when walking north along the short-loop trail (Figure 7.19). It is this proximity to existing land use that creates experience and forces the trail user to understand the variety of functions the landscape performs. Walking towards the elevated boardwalk about 120 m in the distance, the visitors will see water and islands of emergent vegetation (Figure 7.22).

7.6.1 Elevated Boardwalk

The elevated boardwalk brings the user above the vegetation and creates a view of the landscape to the east and west (Figures 7.20, 7.21). The visitor can see the floating boardwalk segments below and the island in among the wetlands. The length of the boardwalk is meant to suggest a runway for kids as they try to catch waterfowl as they fly overhead or peer through the railing to watch the ducks dive below the surface of the dark water. This view from above is meant to elicit wonder, curiosity and maybe a bit of apprehension about moving forward onto the floating boardwalk. Mystery creates excitement.

7.6.2 Floating Boardwalk

The floating boardwalk located at the permanent water level in WW2 is modeled after a recently constructed precedent project in Manitoba. The Brokenhead Wetland Interpretive Trail in Manitoba has used floating dock billets to decrease construction impact on the wetland soil and ground (Wakshinski, Richmond, Acheson, & Smith, 2016, p. 58). These floating boardwalk sections that raise and lower with fluctuating water levels replace traditional post and pile construction and creating a lighter intervention that decreases its ecological footprint. Small anchors are secured in the ground allowing the billets to remain in place. Children and adults will be seen skipping down and navigating the bobbing dock sections or on all fours

Figure 7.22 Rendered sketch of typical wetland landscape that would be seen walking through Waffle Wetland 1.

Figure 7.23 Aerial perspective of island and floating boardwalk during flooded conditions.

leaning over the edge with their nose close to the water's surface, searching the dark water for anything that moves.

At the far end of the floating boardwalk is a mound of prairie landscape that remains above water even when the water control gates are closed and runoff is allowed to inundate WW2. This island is a reprieve for wildlife and native plants that prefer drier conditions (Figure 7.23). It is also an opportunity for trail users to step off the wobbly floating boardwalk and to walk among tall grass prairie and view the landscape and see where they started out. The main node and platform is 200 m to the southwest and in flooded conditions, one might wonder if a canoe could get them back to the start a bit quicker.

The pathway is informal and shape can change by mowing a new path. Rest spots and elevated viewing opportunities are easily changed too. No wooden benches are found here - for seating in this area, haybales are strategically placed alongside the path.

7.7 LONG LOOP TRAIL

Circling back to the main node, the other option, the longer trail provides an opportunity to access to the eastern most waffle wetland. An informal compacted trail runs the length of the rail line and gives opportunities to view the landscape from an elevated point. To the north you can see the newly constructed channel that connects the two waffle wetlands and to the south you can see fields, tree groves and natural wetlands. The rail line berm is straight but the path meanders from side to side providing different viewsheds.

As the visitor approaches WW1, the trail takes them over a bridge that lies over the runoff channel. It is positioned so that the visitor can now see the LayFlat gate from a short distance and watch the water come

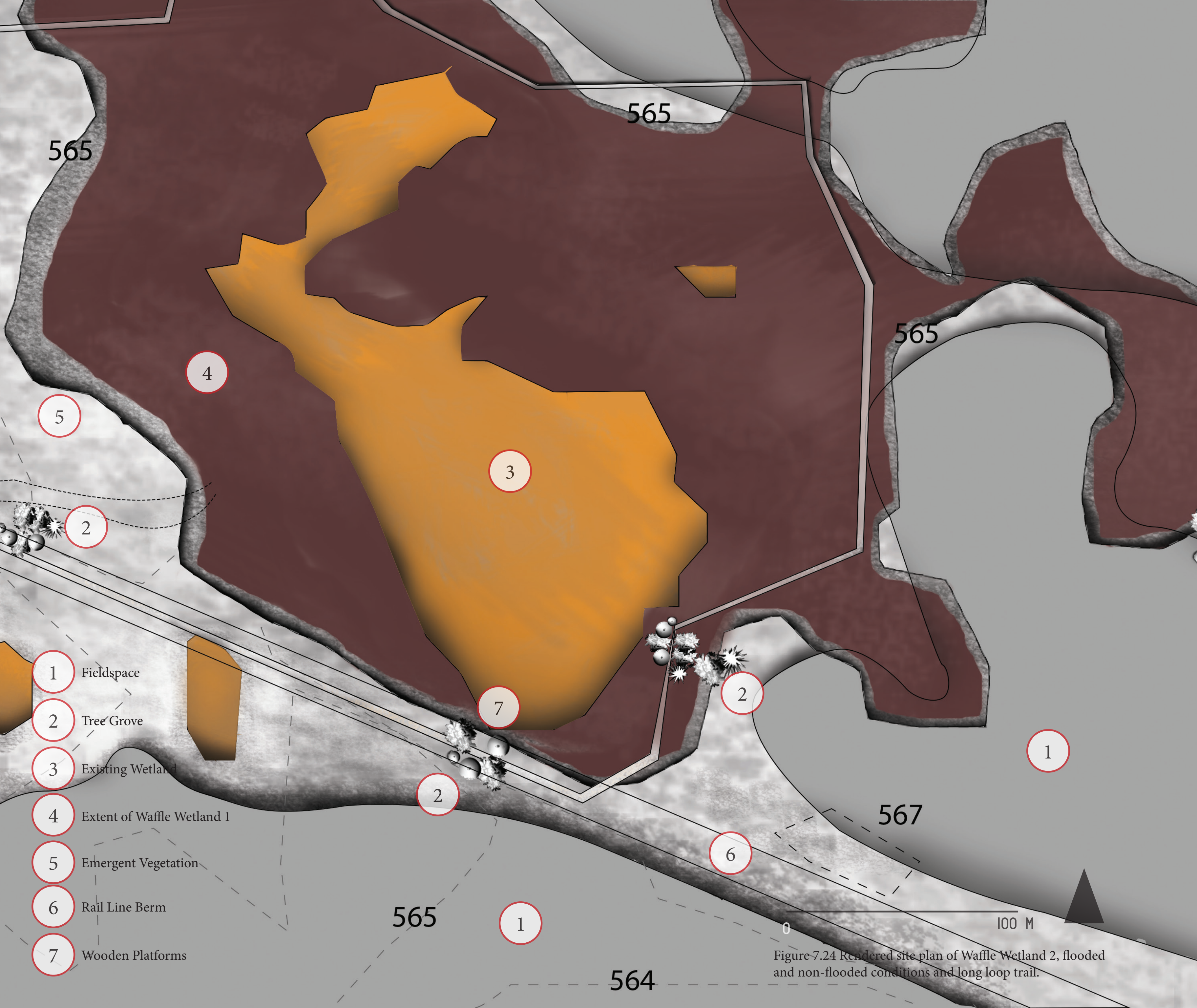


Figure 7.24 Rendered site plan of Waffle Wetland 2, flooded and non-flooded conditions and long loop trail.

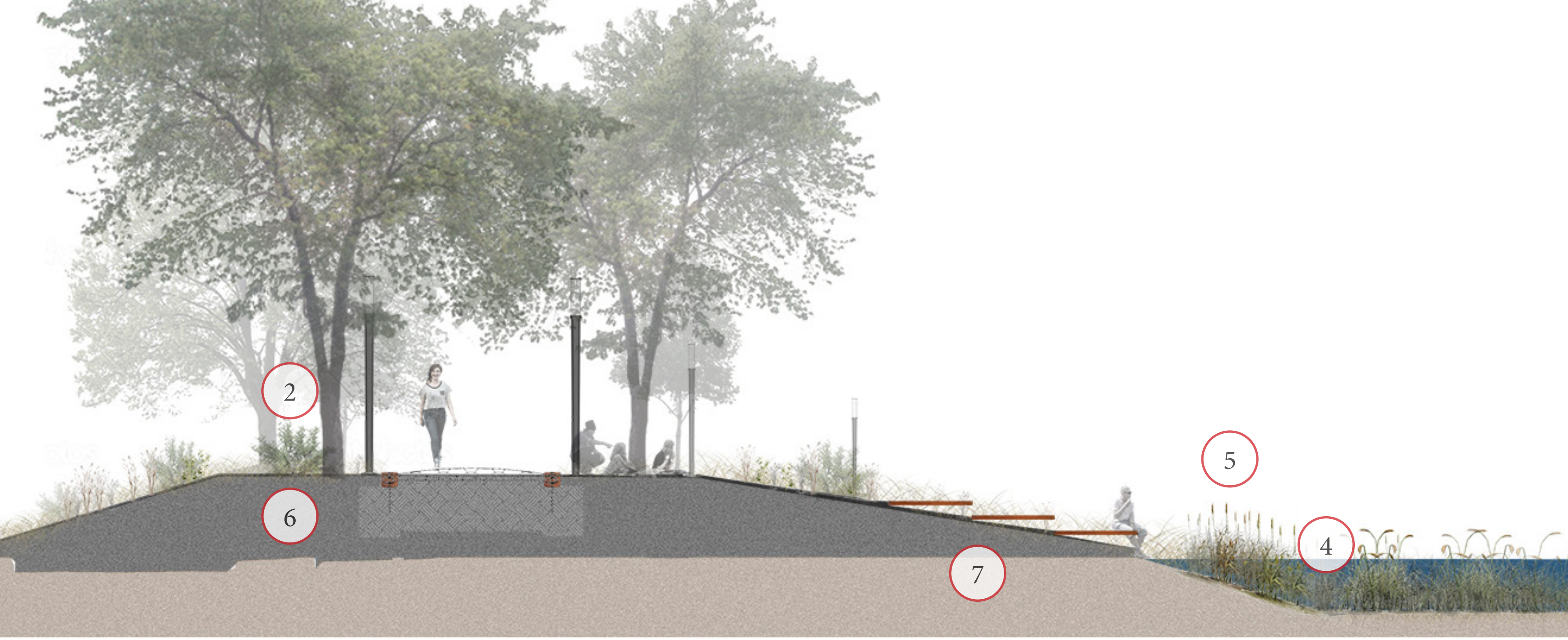


Figure 7.25 Rendered section of Waffle Wetland 2 berm and inset wooden platforms during flooded conditions.

toward them and under their feet.

The dike constructed to close off the contour at elevation 565 m is 40 m long and much shorter than the series of berms at WW2. It is where the old rail line once ran. The new berm will be incorporated into the remnants of the rail line at the east end and will curve to the west and north to follow the 565 m contour (Figure 7.24). This curved landform creates the foundation for a series of wooden platforms built into the north-facing side of the berm. These platforms were also used at the arrival area.

The berm itself measures 3m across at the top and has a gradual slope on either side (Figure 7.25). Trees are planted to provide shade and a sense of scale as the user views them from various locations in the landscape. The sides of the berm are planted with native forbs and grasses. The platforms give the impression that they are free-floating and are interspersed with sections of native plants. These plantings create a sense of enclosure among an expansive landscape. Plants are chosen based on their moisture needs and height. Smaller flowering plants are found at the top of the berm and taller shrubby plants are found at the lower sections. A hierarchy is created and the suggestion of plant succession is also seen as plantings change species composition and associations as you move closer to the lowest ground elevation.

As with the rest of the design, these features and experiences change with hydrologic conditions and water levels. At times, the landscape is dry as seen above but at other times, the landscape will be inundated with runoff and will create a completely different experience (Figure 7.26, 7.27). The trail is meant to surround the visitor in vegetation. The idea is to create an environment that allows for direct interaction and experience with the flora and fauna of the area.

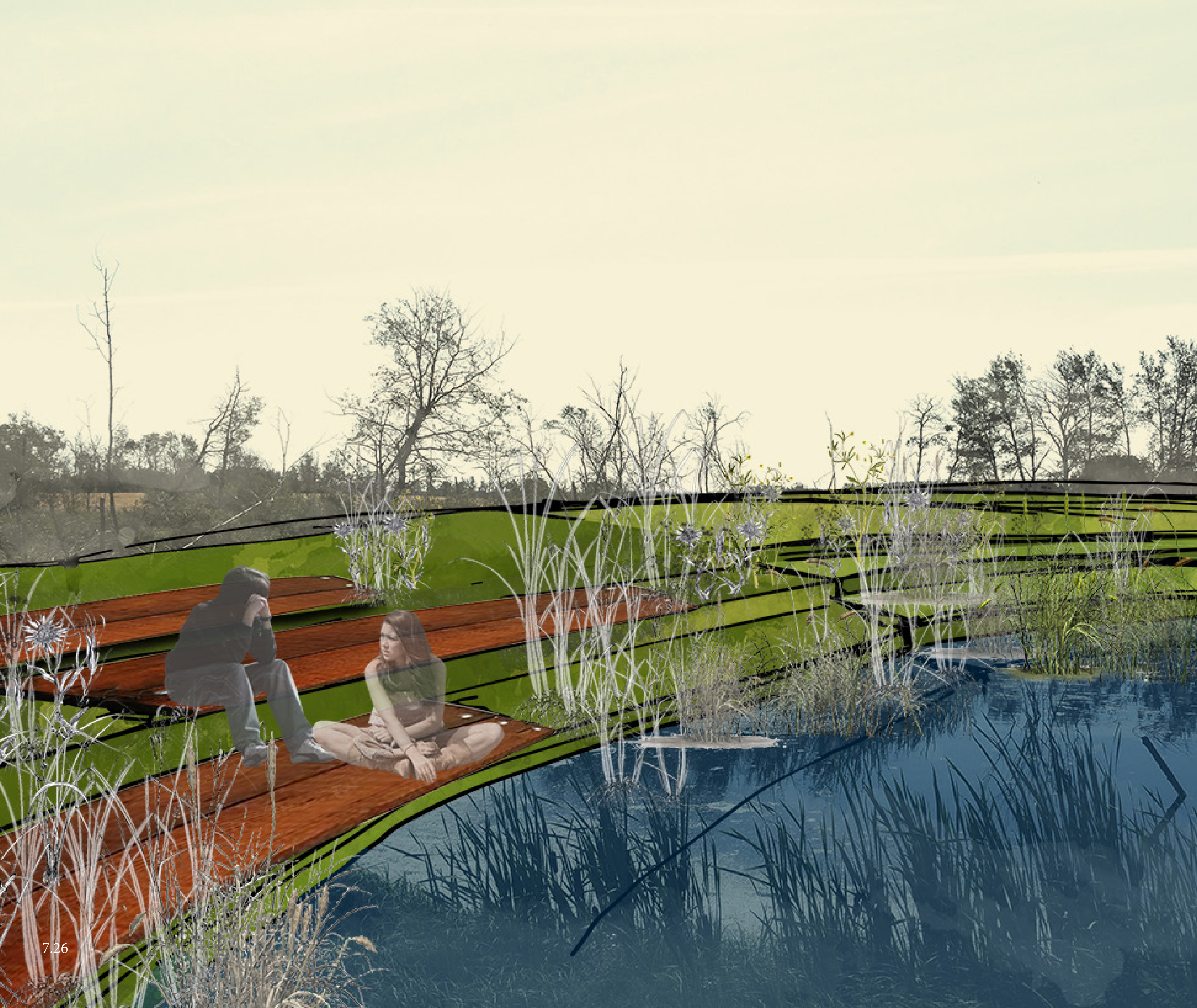

7.26

Figure 7.26 Rendered perspective showing Waffle Wetland 2 berm, wooden viewing platforms and extent of inundation during flooded conditions.

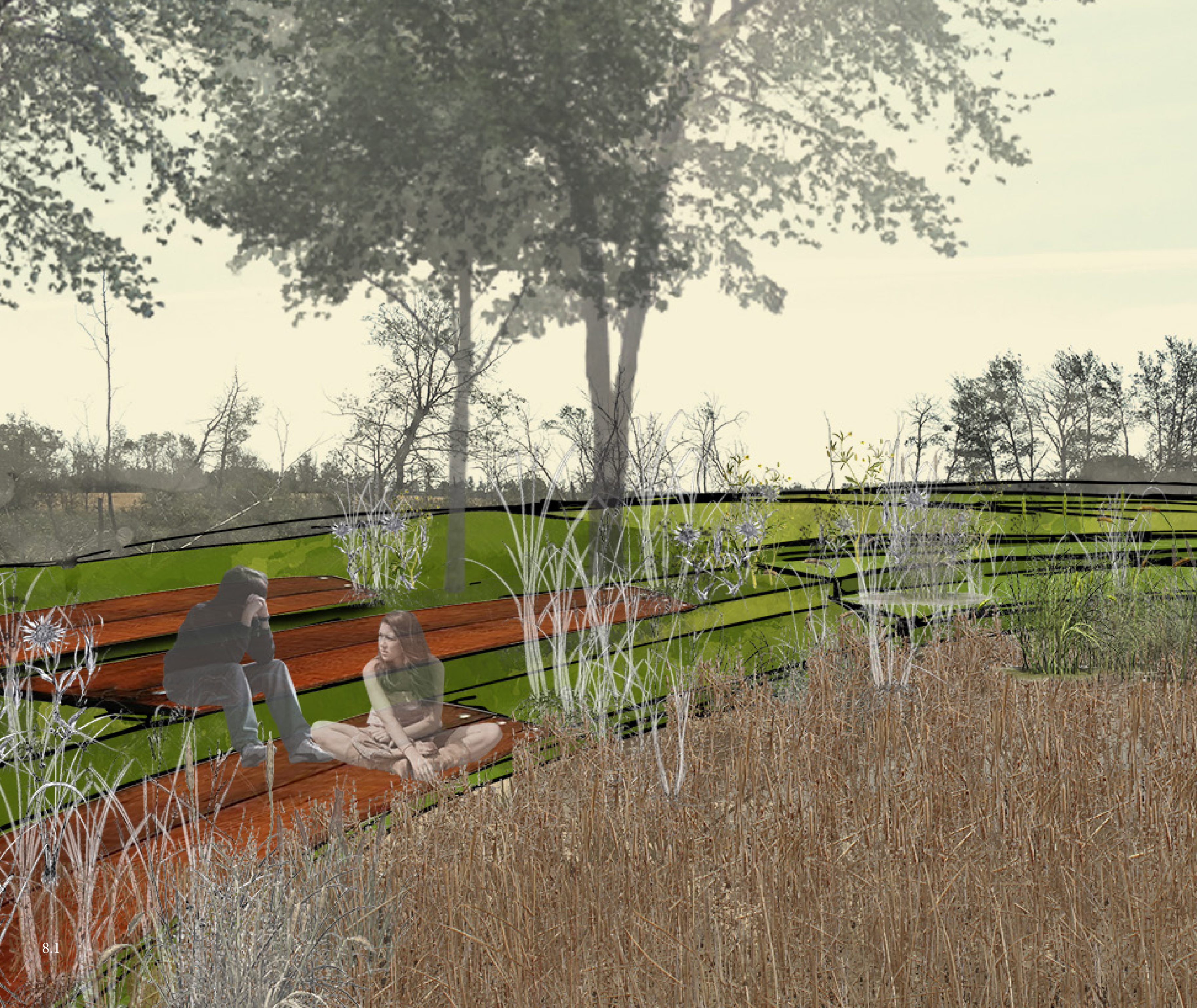

8.1

Figure 7.27 Rendered perspective showing Waffle Wetland 2 berm, wooden viewing platforms and extent of inundation during non-flooded conditions.

Figure 8.1 Assiniboine River. (Image: Rutledge, 2015)

8. DISCUSSION & CONCLUSION

When the project began, the intent was to explore the possibility of applying The Waffle® concept to a site in the Assiniboine River Basin while effectively and sustainably manage runoff. Through exploration of the Waffle® concept and attempts to apply it in the Broughton's Creek watershed, it became clear that the topographically diverse landscape required diverse water management strategies and infrastructure. However, the underlying ideas of the Waffle® concept were adapted and used along with other retention/detention systems.

The original Waffle® concept used existing elevated road infrastructure to act as a series of dikes that hold water on the land. It the adapted approach, the road system was inadequate so existing landforms were modified. Topography was examined to modify the existing topography by adding berms and dikes in order to hold back or retain water.. In this practicum, it was important to minimize the amount of infrastructure and earthworks so contours were selected that naturally formed basin-like structures and created large enough storage that satisfied the 80% increase in storage goal.

In the original Waffle® concept the approach was generic and was applied to the entire region. In this practicum, there was no one-size-fits-all solution. Existing landforms are variable and each storage basin takes on a unique shape. In the original application, no consideration was given to the added benefits such as human use or potential to educate that could be woven into the system if it was approached from the perspective of landscape architecture. In this practicum, using these principles and considering how the landscape would change over time, an opportunity was created that reveals hydrological processes and creates access. While access would not be an aspect of every adapted concept site, it was important here to offer a way for visitors to experience the landscape and understand how the newly created storage and infrastructure contributes to downstream water quantity and quality management.

Landscape architecture has the ability to translate processes, natural or otherwise, into an experience that anyone can understand, remember and value and conserve through design. It can synthesize a variety of knowledge including art, science, engineering, botany and horticulture and create solutions and experiences that are understood by a variety of users. Successful design in a way that can be interpreted by any one, young or old, educated or not. The visitor's understanding does not necessarily have to be because of signage that describes "What's Happening Here." In fact, if landscape architecture is successful, these interpretive additions are not always necessary. Successful design allows the landscape to speak through experience: How did it make you feel? What did you do while you were there? What did you smell? What did you see and touch? What do you remember?

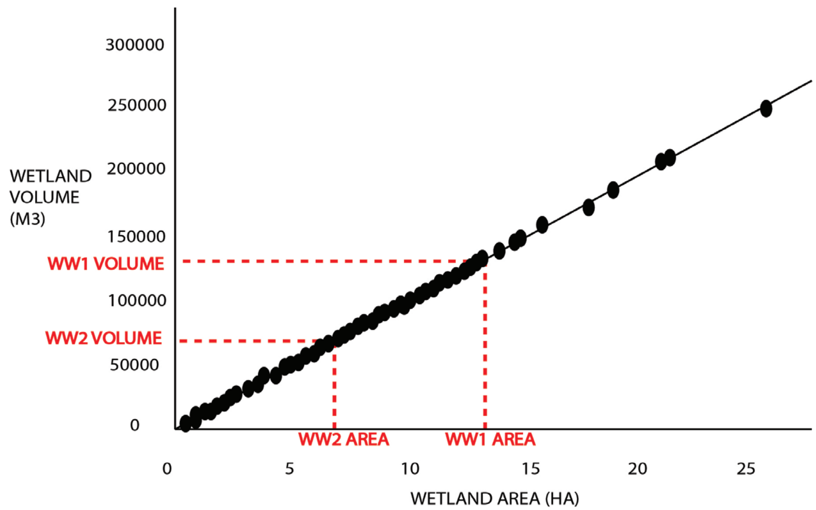
In this project trail systems, control gates, berms and viewing nodes come together to influence the character of a new prairie landscape. By creating two waffle wetlands, the character of the landscape changes as the wetlands combine to form large, expansive waterbodies. The design of the landscape combined with natural and pre-existing elements come together to create an experience of the senses without the need for literal explanation. Ecological processes, including dynamic hydrological conditions, is translated in a way that describes these processes and creates an experience for everyone to understand, remember, value, and conserve.

APPENDIX A

PROPOSED VOLUME AND STORM EVENT

Waffle Wetland 1

	Area	Volume
Existing	13.3 ha	133 000 m³
Proposed	67.8 ha	678 000 m³



Waffle Wetland 2

	Area	Volume
Existing	6.9 ha	69 000 m³
Proposed	18.6 ha	186 000 m³

80% increase of site waterbodies	144.4 ha	
Total area of existing site waterbodies	80.3 ha	
Total amount of area needed to meet 80% restoration of site waterbodies	65.7 ha	
Total proposed area of combined waffle wetlands	86.4 ha	
Existing area of waterbodies within waffle wetlands	80.3 ha	
	Area	Volume
New storage volume created	66.1 ha	661 000 m³

VOLUME OF WATER TO FALL ON THE PRACTICUM SITE IN A 100-YEAR STORM EVENT (RETURN PERIOD)

Volume = area (m^2) x amount of rainfall (m)

Volume = 5 379 378 m^2 x 0.0883 m^3

Volume needed to manage 100-year storm event onsite= 474 999 m^3

New storage volume created = 661 000 m^3

* 6-Hr Rainfall Intensity Duration Frequency Curve
for Broughton's Creek Watershed

FREQUENCY (%)	RETURN PERIOD (YEARS)	RAINFALL IDF VALUE (MM)
1	100	88.3
2	50	79.9
3	33	75
5	20	68.7
10	10	60.1
20	5	51.1
30	3	45.1
50	2	37.5

Table: Water Management & Structures Division
Manitoba Infrastructure & Transportation

100 YEAR STORM EVENT COULD BE STORED ON SITE

APPENDIX B
HYDROLOGIC ZONES *

ZONE	ZONE DESCRIPTION	HYDROLOGIC CONDITIONS
1	DEEP WATER POOL	1 - 6', PERMANENT
2	SHALLOW WATER BENCH (LOW MARSH)	6" - 1' DEEP
3	SHORELINE FINGE (HIGH MARSH)	REGULARLY INUNDATED
4	RIPARIAN FRINGE	PERIODICALLY INUNDATED
5	FLOODPLAIN TERRACE	INFREQUENTLY INUNDATED
6	UPLAND SLOPES	SELDOM OR NEVER INUNDATED

*MARYLAND, 2000

APPENDIX C
SALT AND MOISTURE TOLERANT PLANTS USED FOR REMEDIATION*

HERBACEOUS PLANTS	FORBS & LEGUMES	TREES & SHRUBS
BEARDLESS WILDRYE	YARROW	SEABERRY
NEWHY HYBRID WHEATGRASS	BLANKETFLOWER	SILVERBERRY
TALL FESCUE	SCARLET GLOBEMALLOW	FOURWIND SALTBUSH
WESTERN WHEATGRASS	TWO-GROOVED MILKVETCH	SILVER BUFFALOBERRY
STRAWBERRY CLOVER	CANADA MILKVETCH	GOLDEN CURRENT
CREEPING FOXTAIL	LEWIS FLAX	HAWTHORN
PRAIRIE CORDGRASS	MAXIMILIAN SUNFLOWER	CARAGANA
MEADOW BROMEGRASS	STIFF SUNFLOWER	GREEN ASH
CICER MILKVETCH	PRIMROSE	ROCK MOUNTAIN JUNIPER
ORCHARDGRASS	PURPLE PRAIRIECLOVER	COMMON LILAC
SWITCHGRASS	FRINGED SAGEWORT	PONDEROSA PINE
REED CANARY GRASS	YELLOW CONEFLOWER	SKUNKBUSH SUMAC
ALSIKE CLOVER		AUSTRIAN PINE
WHITE CLOVER		CHOKECHERRY
		FREEDOM HONEYSUCKLE
		SCOTCH PINE
		BLUE SPRUCE
		JUNEBERRY
		VILLOSA LILAC
		CREEPING JUNIPER
		SIBERIAN LARCH
		AMERICAN PLUM
		SIBERIAN CRABAPPLE
		BOXELDER
		LAUREL WILLOW

*SASKATCHEWAN AGRICULTURE & FOOD, 2007

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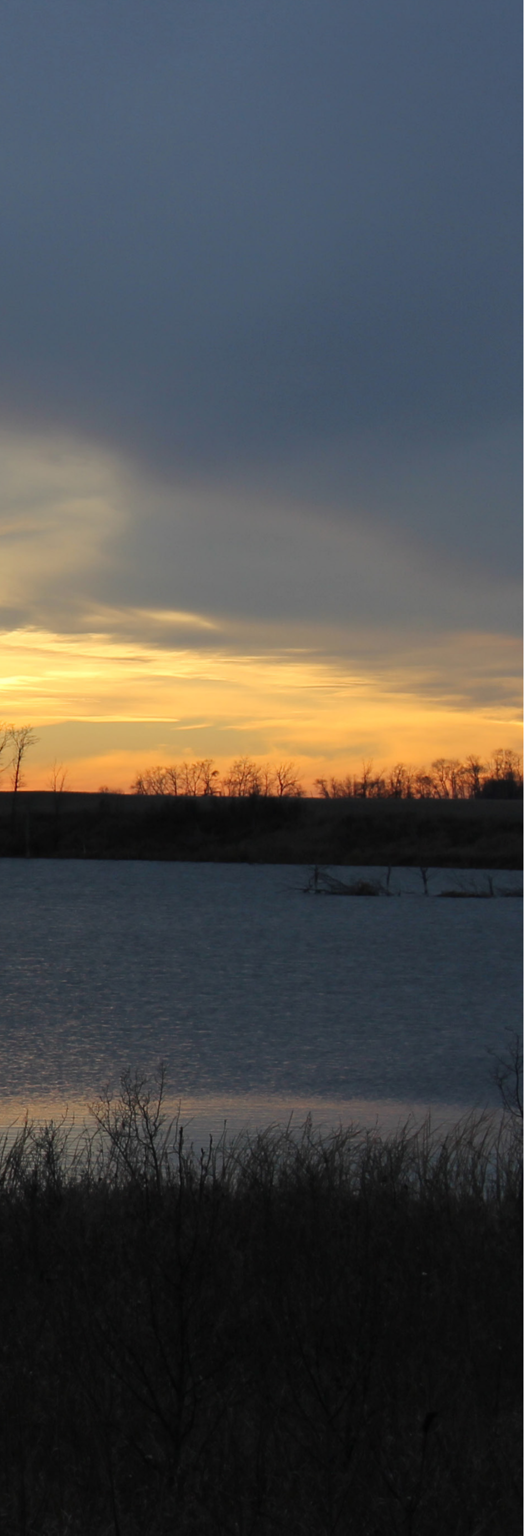

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