Lessons Learned from the Greater Edmonton Region: An Economic Framework to Measure Natural Infrastructure Impacts from Watershed Restoration

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EXECUTIVE SUMMARY

Nature-based infrastructure, or natural infrastructure, consists of landscape features such as wetlands, riparian buffers and forests that can improve water quality and lower the risk of flooding and droughts. Natural Resources Canada (NRCan) provided funding to examine the costs and benefits of investing in natural infrastructure, as a climate change adaptation strategy for the greater Edmonton region. The project was to examine if natural infrastructure, from restored or enhanced wetland and riparian areas, upstream from Edmonton could reduce the impacts of flooding and droughts on the landscape and thereby reduce the costs associated with managing water quantity and quality in the region. The natural infrastructure projects were carried out on a subwatershed scale and thus the potential costs savings could be applied to multiple municipalities, and agricultural and recreational areas. Natural infrastructure projects were carried out in 5 rural municipalities in the Modeste subwatershed and the impacts were considered locally and downstream for the City of Edmonton.

Some of the most important information obtain in this project relates to how municipalities in the region could reduce costs from the presence of natural infrastructure on the landscape. Since the natural infrastructure projects were carried out in rural areas, the rural municipalities were directly impacted by the changes in water quality and quantity. The rural municipalities reported that although they are impacted by changes in water quality, the primary impacts from natural infrastructure would be on managing *water quantity* or flooding. The rural municipalities also indicated that one of their largest expenditures is on road maintenance due to washouts that result from flooding. Thus natural infrastructure, if placed strategically across the landscape, could potentially reduce capital and operating costs for road maintenance in rural municipalities. Downstream, in Edmonton, the largest cost savings from rural natural infrastructure would be improved *water quality* for its water treatment plants. The primary cost savings for a water treatment plant would be in reduced operating costs for chemicals used to treat the water due to improved water quality entering the facility. Municipal engineers report that water infrastructure is generally overbuilt as a means of mitigating risk of severe future weather events. Thus, the capital costs of water infrastructure such as a water treatment plant, would not be directly impacted by changes in water quality or quantity, however, natural infrastructure could slow the depreciation values over the life of a facility.

Key to this project was to understand how the water quality and quantity changed over the landscape due to the natural infrastructure projects. This project utilized the *Integrated Modelling of Watershed Evaluation of Best Management Practices* (IMWEBs) model to predict changes to water quality and quantity at site, field, farm, watershed, and river basin scale. The model can predict changes to water quality and quantity due to actual natural infrastructure projects on the ground, or scaled-up versions of the on-the-ground projects as well as identify hot spots on the landscape that would benefit from targeted natural infrastructure projects. Municipalities indicated that they were interested in utilizing the IMWEBs model to assist in identifying where they could invest in natural infrastructure to get their biggest bang-for-the buck for natural infrastructure dollars spent while also reducing impacts on their municipal assets and associated infrastructure expenditures. The IMWEBs modeling could therefore help municipalities be proactive in planning targeted natural infrastructure projects that could reduce municipal infrastructure expenditures and at the same time increase climate resilience and increase other environmental co-benefits.

Although this project was underway for two years, it was halted due to COVID-19, and as a result the work was suspended. This summary document therefore provides information and lessons learned for the cost-benefit analysis from the two years that the project was active. This reports also provides an Economic Framework for a cost-benefit analysis that could be carried out for natural infrastructure at a subwatershed scale, as well as lessons learned for municipalities, and agricultural and recreational areas.

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A WATERSHED APPROACH

A watershed is an area of land that catches precipitation and drains it to a common point on the landscape.[1] As water travels across the watershed, it can be altered by the conditions of the landscape. For example, water quantity can change due to the amount and speed of water flows, and water quality can change due to increased amounts of nutrients, sediments, contaminants that enter the waterways. Land use activities that occur in a watershed can, therefore, have important impacts on the health of a waterbody. Natural infrastructure such as wetlands, forests, and riparian areas can slow down flows and capture and clean water as it moves across the landscape. A watershed approach, therefore, provides a useful boundary for studying the effects of natural infrastructure since it will impact both local and downstream water quantity and quality.

As the North Saskatchewan River Watershed starts in the Rocky Mountains and continues across Alberta to the border of Saskatchewan, it comprises multiple subwatersheds within its boundary (see Figure 1). The Modeste subwatershed, the focus of this project, spans 5 different municipal boundaries as shown in Figure 2 below. Municipalities in Alberta play an important role in watershed management because they are one of the major land use decision makers. Their statutory plans and program spending directly influence water quantity and quality. Conversely, municipalities are also impacted *by* watershed health, in terms of the costs associated with providing clean drinking water and maintaining infrastructure. However, the cumulative costs and benefits of improving natural infrastructure across a large watershed, and across multiple municipal boundaries, is not thoroughly understood. This information could be a valuable tool to incentivise the integrative planning between municipalities that is needed to overcome larger landscape and watershed-scale issues.

The 5 counties whose jurisdictions span the Modeste watershed, create a complex political system of land use policies that affect the watershed differently. Each municipality also has one or several programs to incentivise landowners to embrace landscape *best management practices* (BMPs), some of which are considered natural infrastructure. The ALUS program is specifically designed to incentivise private agricultural producers to adopt BMPs. This project focuses on ALUS-funded natural infrastructure

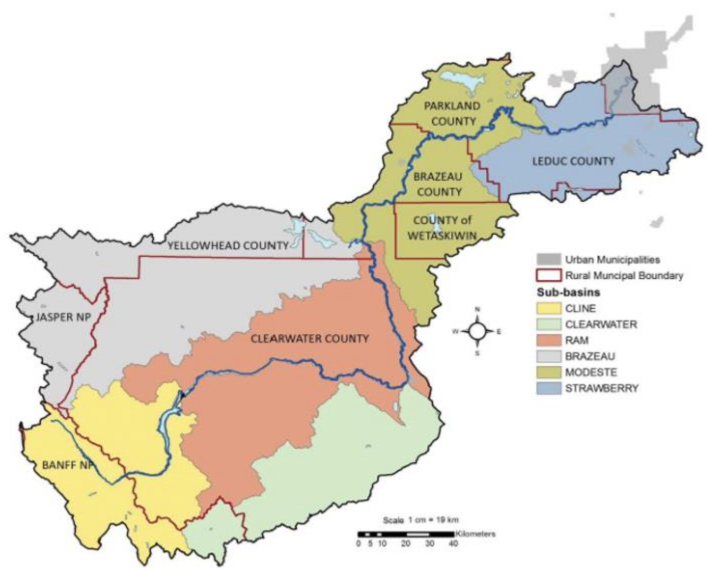
[1] North Saskatchewan Watershed Alliance. Available at: https://www.nswa.ab.ca/our-watershed/

projects, however, other programs such as Clearwater Landcare, Green Acreages, and the Canadian Agricultural Partnership Program, are additional tools available to incentivise landowners in the Modeste to adopt BMPs and related natural infrastructure projects.

Figure 1: North Saskatchewan River Watershed

Source: North Saskatchewan Watershed Alliance. Available online: https://www.nswa.ab.ca/our-watershed/ (accessed on 10 April 2019)

Figure 2: North Saskatchewan River Watershed with Subwatershed and County Boundaries in the Project Region



Source: EPCOR. 2017 Source Water Protection Plan Edmonton's Source Water Protection Plan. Available at: https://www.epcor.com/products-services/water/Documents/source-water-protection-plan.pdf

DEVELOPING AN ECONOMIC FRAMEWORK

BACKGROUND — ECONOMIC FRAMEWORK

A preliminary Economic Framework for a cost-benefit analysis was developed to understand how natural infrastructure can reduce municipal, agricultural, and recreation costs in the Modeste subwatershed. Municipal cost components were developed through a series of municipal stakeholder consultations; recreation costs could be determined through the utilization of an Alberta Parks dataset; and agricultural costs were considered through crop insurance payouts data from the Agricultural Financial Services Corporation (AFSC).

Since the information gathering was halted for this project, this report represents only the data and information gathered up to the project suspension. Thus, the preliminary Economic Framework provided in this report is not an actual cost-benefit analysis, but rather a model for how one could be carried out for natural infrastructure as well as some of the approaches and lessons learned to-date.

QUANTIFYING ECOSYSTEM SERVICES

In order to begin a cost-benefit analysis, the project team needed to first determine how water quantity and quality changed due to the natural infrastructure. Once the changes in water quantity/quality are determined, potential costs savings can be measured. To quantify the ecosystem services from natural infrastructure, the project team utilized the **I**ntegrated **M**odelling of **W**atershed **E**valuation of **B**est Management Practices (IMWEBs) model, a cell-based watershed hydrologic model developed by Watershed Evaluation Group at the University of Guelph. The IMWEBs model is the only one in Canada that is designed for quantifying water quantity (drought and flooding) and quality (sediment and nutrients) of agricultural BMPs such as manure and nutrient management, riparian and surface water management, pasture management, and marginal cropland management at a site, field, farm, watershed, and river basin scale.

The input data for the IMWEBs model include climate (precipitation, temperature), topography, soil, landcover/land-use, land management practices (planting, harvesting, tillage, fertilizer and manure application), and BMPs (such as manure management, riparian access management, and rotational grazing). The IMWEBs outputs includes time series (daily, monthly, and yearly) and spatial distribution of water quantity and quality (flow, sediment, nitrogen, and phosphorus) at site, field, farm, watershed, and river basin scales. The differences of IMWEBs simulation results between a baseline scenario (such as existing landscape conditions) and a BMP scenario represent the water quantity and quality benefits of BMPs. The BMPs in this project are those that relate specifically to natural infrastructure.

Lessons Learned from Quantifying Ecosystem Services

Some of the lessons learned in utilizing the IMWEBs model for this project include the following:

- IMWEBs modelling has the capacity to characterize site-specific wetlands and riparian buffers and quantify their effects on water quantity and quality. However, wetland and riparian data availability and quality are of concern. There is a wetland layer for Alberta but the data quality is low. There is limited or no data for potential wetland restoration sites. There is a necessity to develop wetland inventory data including existing and lost wetlands, and also riparian buffer health assessment data for quantifying their provision of ecosystem services.
- For IMWEBs modelling we need to collect data to characterize point sources such as wastewater treatment plants (WWTP) and lagoons. Unfortunately, it is very challenging to have access to discharge and water quality data of these WWTP facilities in the Modeste Creek watershed. Natural infrastructure has the potential to work with built infrastructure such as WWTPs to fulfill ecosystem requirements such as water quality limits in a watershed. Therefore, it would be important to gather WWTP flow and water quality data for IMWEBs modelling and also examine the tradeoffs of natural and built infrastructures on protecting watershed health.
- For IMWEBs modelling we need to define wetland scenarios (for example losing or gaining wetlands of a specific size). It would be important to work with project partners such as ALUS Canada, North Saskatchewan Watershed Alliance, Parkland County, Alberta Environment and Parks, and Alberta Agriculture and Forestry to develop various planning scenarios so that the natural infrastructure scenarios such as wetlands and riparian buffers reflect realistic planning and management goals.

A Cost-benefit Analysis Structure

Once the ecosystem services are quantified and water quantity/quality changes are determined, the project team can apply those changes to municipal, and recreational and agricultural areas to determine the potential cost savings. For example, less money could be spent on water treatment facilities. The cost savings can then be entered into a cost-benefit analysis (CBA). The intention of the CBA is to sum all of the costs and all of the benefits of the projects, and then evaluate if the benefits exceed the costs.[2] If the benefits are larger than the costs, then it is assumed that it makes economic sense to proceed with the projects (given there are no other better cost-saving alternatives).

Scenarios

A key element of the CBA structure includes scenarios for different levels of natural infrastructure investments. The scenarios allow us to see whether it makes economic sense to carry out a project or not. This project considers 3 scenarios.

- **Scenario #1--Do-nothing**. This baseline scenario implies that wetland loss will occur over time. This scenario assumes that water quantity and quality issues in the region will worsen as the degradation of wetland and riparian areas increase.
- **Scenario #2--Maintain.** This scenario implies a no-net loss of wetland and riparian areas (and avoided degradation to current natural infrastructure through new or increased maintenance). This scenario assumes that by maintaining the current wetland and riparian areas in their current state, water quantity and quality in the region will stay the same or improve if they were not previously maintained.
- **Scenario #3--Enhance.** This scenario represents an enhancement of current or new wetland and riparian areas. This scenario assumes that improvements or additions to wetland/riparian areas would be made across the landscape, and as a result would improve water quantity and quality in the region.

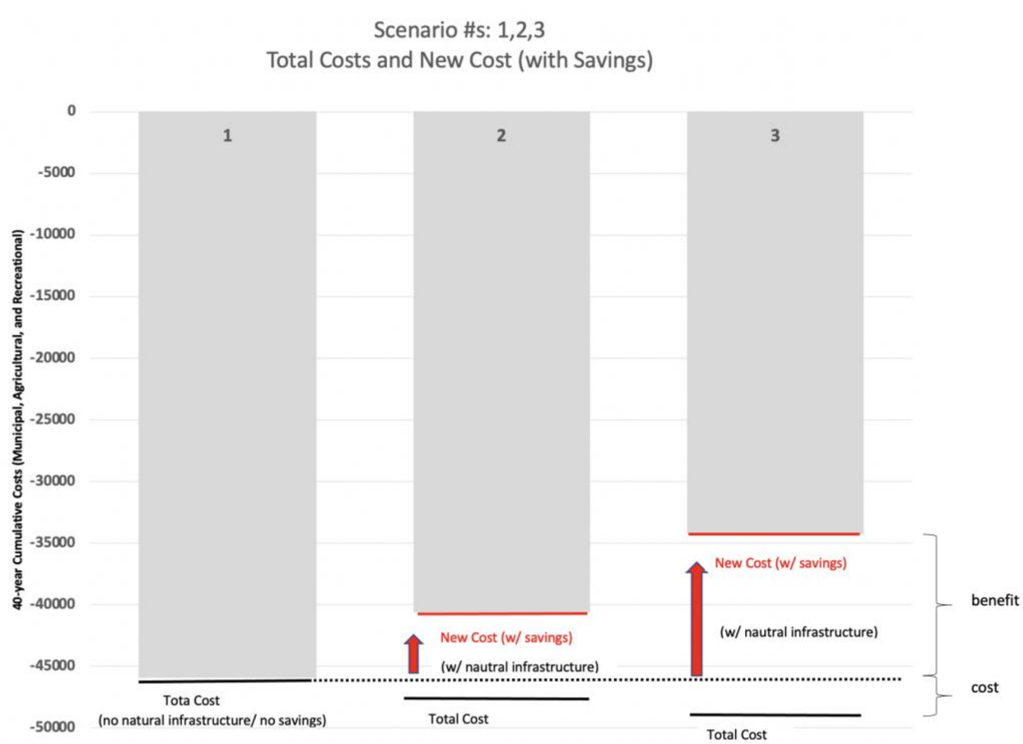
[2] Note this project does not consider co-benefits such as biodiversity or carbon sequestration.

The Economic Framework therefore accounts for different types/levels of natural infrastructure investments, and these adjustments could be modeled in IMWEBs to produce smaller or larger water quantity and quality changes.

All of the scenarios include a 40-year time horizon. Based on consultations, it is recommended to use a 40-year period, as most built infrastructure such as water treatment and wastewater treatment plant's useful life is approximately 30-40 years. With this timeframe, a CBA can compare natural infrastructure impacts on the built infrastructure. A 40-year period was also recommended in the Economic Framework as this is a common time period in which climate change impacts are modelled.

The CBA Economic Framework that has been developed can be most clearly demonstrated in a graphical format (see Figure 3 below). Since actual project data has not been collected, a fictitious dataset for the CBA has been created to demonstrate the expected costs/cost savings for each scenario. Scenario #1, demonstrates the overall expected cost outcome of a "do-nothing" scenario where wetlands and riparian areas are lost or are degraded; Scenario #2 demonstrates wetland and riparian areas "maintained"; and Scenario #3 shows wetland and riparian areas "enhanced".

Figure 3: Scenario # 1, 2, 3 Total Cost and New Cost with Savings (with fictitious data)



In order to generate the graph above, the potential costs and cost savings for each line item on an annual basis should be identified and then summed by year, to obtain a total yearly cost. Once the total yearly costs are calculated, then all of the annual costs/cost savings for the 40-year period should be added together to obtain a Total Cost for the entire scenario (i.e. do-nothing, maintain, or enhance) as shown in Figure 3 above. The Total Cost for each scenario is calculated, so that each scenario can be compared to each other to understand which provides the highest cost savings due to natural infrastructure over a 40-year period. Note that the “do-nothing” scenario will have no natural infrastructure costs, while the “maintain” and “enhance” scenarios will have natural infrastructure costs. One of the important outcomes of this CBA analysis is to understand if the natural infrastructure costs are offset by the potential cost savings that they have on managing water quantity/flows. The increased retention of water on the landscape is of particular interest because high flow events are predicted to increase in size and frequency overtime with climate change/extreme weather events. This could potentially increase operating and capital expenditures for municipal built infrastructure as well as other expenditures in the agricultural and recreation areas. Note that in addition to the actual data collection, sensitivity analyses can be conducted using Monte Carlo simulations to provide more accurate predictions of costs and cost savings.

MUNICIPAL INFRASTRUCTURE CONSULTATIONS

The project team consulted with a number of stakeholders to get their recommendations on what information and data would need to be collected in order to carry out a cost-benefit analysis for natural infrastructure. The most salient information from our consultations is provided below.

REGIONAL WATER INFRASTRUCTURE CONSIDERATIONS

The project team met with Associated Engineering (AE), a private consulting firm that works with municipalities to plan and implement drinking water, wastewater, and stormwater infrastructure (among other infrastructure) in the region. The project team engaged AE to provide background information and obtain their recommendations on water infrastructure that should be included in the CBA.

Lessons Learned for Regional Water Infrastructure

- Natural infrastructure could potentially have a direct and measurable impact on the operating costs of water infrastructure (i.e. drinking and wastewater treatment plants, and storm conveyance and storage systems).
- Since our project focuses on climate change adaption over the next 40 years, it is unlikely that natural infrastructure will have a measurable direct cost savings impact on the capital costs of water infrastructure as they are typically overbuilt to handle large future weather events. Also, since a significant amount of municipal capital expenditures are funded through Federal/Provincial/Municipal cost-sharing agreements, the costs savings from natural infrastructure would need to be applied proportionally across all of the funders. Note that capital costs of water infrastructure vary depending on the size of the community it services.
- The project should focus on drinking water treatment facilities compared to other infrastructure (e.g. wastewater treatment, collection, and discharge), as these facility operational costs are directly impacted by upstream water quantity and quality, and can be changed by the presence of natural infrastructure located upstream of the water treatment facilities.
- Wastewater from a WWTP is mostly a closed loop system whereby the natural environment does not have a direct/measurable impact on the operational costs; thus, natural infrastructure will not have an impact on wastewater and therefore should not be included in our CBA. However,

understanding that the treated effluent discharge from a wastewater treatment facility will have some impact on the water quality downstream if the regulatory discharge criteria is not met.

- In a rural setting, stormwater systems can take the form of open channels, ditches, swales, culverts, and dry/wet ponds. This infrastructure is typically built to varying rainfall events and peak flows depending on the types of conveyance and storage system, however they are generally "overbuilt" to handle large events, and thus the infrastructure system may not be impacted by natural infrastructure. However, the project could consider if multiple large/high rainfall (e.g. 1-in-100 year) events occurred within our 40-year project period and what the capital cost implications could be and the thresholds surrounding those multiple events.
- In the case that capital costs of stormwater storage/conveyance systems are not impacted (as noted above) it may be important to consider the capital costs of other infrastructure that surrounds the stormwater conveyance and storage systems. For example, stormwater conveyance systems are typically built next to roadways in rural areas; the stormwater conveyance capital costs may not be impacted from a flooding event because it is "over-built", however, roadways ditches/conveyance that are not adequately sized can be impacted. Therefore, it is possible that the roadway capital costs could increase and that natural infrastructure could potentially mitigate those costs.
- It may be difficult to include ground water cost savings due to natural infrastructure for private residences in the CBA because home owners rarely test their water, and thus including changes to water quantity/quality are not likely going to decrease any private costs. It was noted by AE, however, that it may be worth looking into whether the well sites are linked to confined or unconfined aquifers; if unconfined then the water needs to be treated more and therefore pesticides/manure could seep into the ground water. In this case, natural infrastructure may be able to help mitigate seepage of pesticides and manure into the ground water.
- Surface water run-off with agricultural pesticides are "difficult and costly to treat mechanically". If natural infrastructure could pre-treat the pesticides from the stormwater run-off, it could reduce treatment costs for drinking water treatment plants.
- Discussions with AE and EPCOR suggest that a substantial increase in natural infrastructure in the region could reduce the amount of chemicals needed to treat water and thus this may be one of the potential cost savings impacts.

- Water treatment costs will also depend on: the age of the facility, the population it serves, the regulations, and water quality changes. This information will be important in determining costs for treatment.
- Climate-related expenses such as flooding, drought and emergency responses are all cost-share with federal and provincial governments and therefore any cost savings for the CBA would need to be attributed proportionally to the respective funders. Municipal cost savings therefore will be smaller than the total cost savings that would be achieved from the natural infrastructure projects.
- Lagoons, which are typical wastewater treatment facilities for rural areas and smaller communities, are discharged into the natural drainage and may impact water quality over the long-run. The water quality of the treated effluent is assessed before, during, and after the discharge and are discharged in the Spring and Fall over a 3-week period. The water quality is "sufficiently clean" to discharge, however there could be cumulative effects of the discharges over time that natural infrastructure could offset. Natural infrastructure could indirectly offset discharge into the drainage networks. There are 6 locations in the Modeste subwatershed that have both a water treatment and wastewater treatment plant with a lagoon, and there approximately 10 more locations with just a lagoon.

Regional Water Treatment Facilities Considerations

The project team is working with: a) rural municipalities to determine the *local* impacts of natural infrastructure and, b) with EPCOR to determine the *downstream* impacts on Edmonton's water treatment plant. Cost savings to the operating budgets of water treatment plants could be achieved if sufficient water quantity and quality improvements are made through natural infrastructure.

Lessons Learned for Water Treatment Facilities

The following is a list of discussions, suggestions, or recommendations that EPCOR made through a combination of project meetings and reference documents.

- EPCOR provided information from their most recent 2017 Source Water Protection Plan[3] that demonstrated that during some spring run-offs, nearly 30% of the flow in the NSR comes from Modeste Creek, which is the largest creek in the Modeste subwatershed. Spring run-off is typically when water treatment plants have the greatest operational costs due to the high amounts of organic material and suspended sediments in the water. This means that the Modeste subwatershed can have a significant influence on water quality in the North Saskatchewan River, particularly during the spring and that natural infrastructure near Modeste Creek could mitigate some of the contaminants found in spring run-off, potentially decreasing costs for EPCOR.

- The project team evaluated which water treatment plants in the region could be included in the study. Currently, there are 4 continuously operated water treatment plants within the Modeste subwatershed through to the City of Edmonton. (see Modeste and Strawberry subwatershed map in Appendix A).

  The treatment plants include:

  1) Drayton Valley
  2) Devon
  3) Edmonton (E.L. Smith plant)
  4) Edmonton (Rossdale plant)

  Ideally, the project would have a water treatment plant at the far downstream edge of the Modeste subwatershed that could capture all the benefits of the upstream water quantity quality changes of the ALUS natural infrastructure projects within its boundary. Since this is not the case, the project team needed to evaluate which drinking water treatment plants would be appropriate to include in the cost analysis. Since Drayton Valley is far upstream within the Modeste subwatershed boundary, and it has a smaller agricultural land mass surrounding it in which to implement ALUS natural infrastructure projects, it is unlikely that the drinking water treatment plant would be able to capture the majority of the benefits of

[3] 2017 Source Water Protection Plan document: https://www.epcor.com/products-services/water/Documents/source-water-protection-plan.pdf

natural infrastructure within the Modeste subwatershed. Thus, it was agreed that the project would not include the Drayton Valley drinking water treatment plant.

Drayton Valley is the only continuously running water treatment plant located in the Modeste subwatershed. However, further downstream is the Town of Devon's water treatment plant which lies in between the Modeste subwatershed and the City of Edmonton. This water treatment plant could be considered for the cost analysis. EPCOR noted, however, that there is likely no substantial difference between the water quantity/quality between the Devon water treatment plant and the next downstream water treatment plant in Edmonton (E.L. Smith). Since there is not a substantial difference in water quantity/quality, then the project team and EPCOR decided that it would be best to include a review of the operating cost impacts of the natural infrastructure on the E.L. Smith plant rather than the Devon water treatment plant. The E.L. Smith water treatment plant is also significantly larger than Devon's water treatment plant as EPCOR's water treatment plants provide water not only to Edmonton, but to a number of surrounding communities.

- The ability to map the changes in water quantity and quality due to the natural infrastructure projects would be important to determine the changes in cost for Edmonton's E.L. Smith water treatment plant. It was discussed that obtaining these water quantity/quality changes from IMWEBs would help EPCOR to determine the cost impacts. It was agreed that the IMWEBs data that corresponds to the various scenarios that are included in the CBA could be provided to EPCOR. EPCOR would then be able to provide a parameter (after consulting internally) for a cost impact for the different scenarios. An example for a cost impact could be a reduction in chemicals being used to treat the water.
- EPCOR suggested that specific past extreme event dates be provided to them and then they could review their costs before/during/after an event that occurred upstream (as described in the municipal section below).
- EPCOR's 2017 Source Water Protection Plan highlights some important information about the land-use in the Modeste that is relevant for this project.
    - The Modeste, relative to the rest of the North Saskatchewan River Watershed, has the highest amount of manure per square km and grassland and pasture/forage are the predominant crop.

- The tributaries in the Modeste subwatershed in general have higher than average colour, turbidity, and *E. coli* relative to the other tributaries in the watershed, and elevated levels of nitrate, total ammonia, and total phosphorus. Increased levels of these parameters are due in part to the natural ecoregion and geology of the Modeste subwatershed; however, these parameters are also likely elevated beyond their natural range due to changes in land use. This supports the idea that the Modeste subwatershed may benefit from natural infrastructure projects to improve water quality and mitigate water quality treatment costs.

MUNICIPALITY DISCUSSIONS

The project team held a workshop with municipal staff from the region to discuss the potential costs and benefits from investments in natural infrastructure to municipal infrastructure. The workshop was intended to help identify current and future cost savings and how they could be tracked within municipal processes. It focused on the management of water quantity and quality under flood and drought scenarios.

Lessons Learned from Rural Municipality Discussions

- Extreme events, particularly flooding can cause damage to roads and bridges. It would be important to quantify the damage costs of extreme events to road infrastructure maintenance and repair, as well as to quantify how natural infrastructure such as wetlands and riparian buffers can reduce operating costs by mitigating these extreme events.
- Extreme events such as flooding and drought negatively affect the function of drainage networks including culverts, catch basins and stormwater ponds. It would be important to quantify the damage costs of extreme events to drainage infrastructure maintenance and repair and also quantify how natural infrastructure such as wetlands and riparian buffers can reduce operating costs by mitigating these extreme events.
- In order to estimate the costs that extreme events have on municipal infrastructure, it is important to identify a time period when the impacts occurred to the municipal budget. It was recommended to look at a budget before/during/after an event so that cost impacts can be

estimated. Note that municipalities cannot provide a cost parameter due to a certain amount of increased or decreased water volume from a flood or drought and thus the before/during/after approach must be used to estimate costs.

- As noted above, a specific time period for an event needs to be used to estimate costs, however it was mentioned that estimating costs for a drought will be much more difficult than a flood. Since a drought is by nature a long-term event, the costs would be more difficult to derive in a before/during/after approach. It was also mentioned by municipal staff that droughts can actually save costs as there is less wear-and-tear on the infrastructure, and thus it was recommended to not include drought for the above reasons.
- When a time period is chosen, based on flood events, then the 4 municipalities in the Modeste subwatershed could provide operating costs before/during/after an event. The cost increase could be compared to "normal" expenditure ranges (the 'baseline"), and then that cost increase could be utilized in the CBA. The cost increase could be considered the "cost savings" in the CBA as these costs would theoretically not occur with the presence of natural infrastructure.
- Identifying the time periods to include for the municipal budget analysis is important. Two methods were suggested for identifying the time period:
    - Some municipal staff recalled certain flood events that were common across multiple areas in the Modeste subwatershed. Those time periods could be used for the budget analysis across all of the Modeste municipalities.
    - Another approach that was recommended was to look at agricultural crop payouts for floods as these could indicate when flooding events occurred (discussed in a subsequent section).
    - An important caveat to both of the above-mentioned approaches is that extreme flooding events may impact a large portion of the subwatershed, or it could affect a smaller geographic area; if it is a large geographic area then many municipalities will have budget impacts whereas a smaller area will indicate fewer municipalities (one or two). The CBA would need to take into account the scale of the impacts. Since a watershed approach is being taken in this project, a larger scale impact would be preferred.
- As noted above, the scale of the event is important for the CBA. Geographically smaller events may be of interest as well as, as these can have relatively large impacts on the local infrastructure. Although subwatershed-scale impacts are desired, costs of localized impacts can also be collected.

For example, municipalities in the workshop mentioned that there are hotspots on the landscape that they know in advance will almost always be impacted with an extreme event. The project may consider scenarios that take into account localized versus subwatershed scales, or the cumulative effect of localized issues.

- Localized impacts and the costs associated with those could be collected for the CBA. To support the analysis on localized impacts, IMWEBs has the capacity to model and identify where potential hot spots are located on the landscape and also where specifically natural infrastructure could be located to create the largest impact on water quantity and quality. Municipalities would then need to model the infrastructure maintenance and repair costs for the identified hot spots. It was discussed in the workshop that the municipalities would be interested in utilizing IMWEBs modeling to help with planning as nothing formal is currently utilized to help them identify hotspots (other than those identified anecdotally through senior staff members). The municipalities were interested in comparing the IMWEBs-predicted hotspots to those that the municipalities have identified through staff experience. More specific information regarding the municipalities' interests in IMWEBs is provided below.

Suggestions on IMWEBs modelling tool development:

- Provide the tool to municipalities to try out and drill down the tool.
- Provide costs and benefits of individual BMPs and assess which BMPs have more impacts.
- Provide flow outputs in volume rather than probability criteria (such as 1 to 100-year events). Small events with high volume may cause local damage.

Suggestions on applying the IMWEBs modelling tool:

- Use IMWEBs simulated flow to evaluate a stormwater management plan (for municipal asset management).
- Use IMWEBs modelling results to examine triple bottom lines including social, financial, and environmental effects.
- Use existing BMPs (such as wetlands) and assessment results in IMWEBs modelling to confirm previous or future planning decisions.

- Use the IMWEBs modelling tool to support multiple levels of planning such as Intermunicipal Development Plans, Municipal Development Plans, and Area Structure Plans as well as the integration of these processes.
- Use the IMWEBs modelling tool to identify environmentally sensitive areas (ESAs).
- Use the IMWEBs modelling tool to correlate and compare the costs of natural versus built infrastructure.
- Use the IMWEBs modelling tool to identify gaps in restoration and prioritization of natural infrastructure/ BMPs.
- Use IMWEBs modelling to identify/examine natural infrastructure initiatives to mitigate flood and drought (provide scientific support).
- Use IMWEBs modelling to support the integration of recreational plans, stormwater plans, and corridor plans.
- Use IMWEBs modelling to support high resolution detailed planning.

AGRICULTURAL INSURANCE

Background — Agricultural Insurance Data

The natural infrastructure in this project takes place on private farm land. Since natural infrastructure has the potential to mitigate the impacts of flood and drought on farmland, this project intended to review if the presence of natural infrastructure could reduce insurance payouts from crop insurance programs that insure against flood and drought effects.

As discussed in the previous section, following the Municipal workshop discussion, it was decided that the project should analyze specific dates that were known to have been a drought/flood period and map municipal increases or decreases in expenditures to potential crop payouts. For example, if there was excessive rain and the municipality experienced higher costs due to flood (or drought conditions) then our project team would also review the same time periods for insurance payouts. The reverse could be true as well; the insurance payouts could also indicate which periods an extreme event may have occurred, and then a request to the municipalities to pull cost data before/during/after that specific event could also be applied. As described below, however, municipal and agricultural floods and droughts are more difficult to map together than expected. Data was requested for the Modeste subwatershed boundary for the most recent 10 years (2009-2019).

Lessons Learned from Agricultural Insurance

The Agriculture Financial Services Corporation (AFSC), the largest crop insurer in Alberta, notes that the insurance payouts related to flooding (i.e. "excess moisture") are only related to flooding that impacts a farmer's ability to seed their land *before* the crop is grown; once the land is seeded, the insurance payouts for floods would be paid as a result of a "production shortfall" and paid only after a harvest. As such a production shortfall payout can be due to many reasons and drought and flooding are only two of them. Note that AFSC does not track drought or flooding payouts after seeding because all production losses are lumped together, so it is difficult to identify specifically if a payout was made for a flood or drought. Also, the flooding ("excessive moisture") payments would only be related to pre-planting conditions typically during the months of May through June (depending on the crop). It was noted that AFSC does have a moisture deficiency payment (for drought) that uses rainfall as an index, but that is *only* used for pasture or silage and not all crops. Thus, tracking insurance payouts due to flood and drought is difficult; flooding can only be tracked before seeding and drought can only be tracked for silage/pasture. Including agricultural insurance payouts in the CBA may be challenging unless we are interested in focusing on specific time periods or specific crops.

Preliminary data from AFSC suggests that the highest excessive moisture (or flooding) payouts in the pre-seeding phase were in 2011, 2017, 2019; and the highest payouts for drought (for pasture/silage) was in 2009, 2015, 2018. Since the crop insurance payouts would represent flood and drought on a larger landscape scale, it may be important to choose some of these years to consider in the municipal data collection for the CBA, as it is likely that if crop insurance payouts were made that municipalities were also affected at the same time.

Since floods are only specified in the seeding stage of production, and drought is only specified for hay/silage, then agricultural insurance payouts may be difficult to use as a starting point for defining the time periods for the municipal cost analysis. For example, if the flooding time period is used in conjunction with the agricultural insurance payouts, then the municipal costs would need to be collected for May and June only; conversely if agricultural payout time periods for drought are used, then municipal cost data would span from July to September. Since this project is focusing on flooding, and not drought (for reasons provided earlier in the report), then flooding that occurred during the Spring could be a good time period to utilize for the municipal cost analysis.

When the crop insurance and the cost scenarios are developed, this project could assume that certain percentages of payouts would be reduced because of the presence of natural infrastructure. For example, the CBA could incorporate a reduced crop insurance payout by 10%, 30%, and 50% and include those as a cost savings into the CBA. Also, since payouts are paid in different parts of the growing season, the CBA could incorporate additional scenarios with different season impacts. For example, the costs savings could be considered during the planting season (May-June) and a separate analysis during the growing/harvest season (Jun-Sept). This type of analysis would also correspond to different water management timelines, for example, during spring run-off when snow melt is occurring in the early spring, and then other times throughout the year such as in the summer and fall. Further information would need to be collected from AFSC, however, to understand how agricultural crop insurance payouts and potential cost savings could be incorporated into a CBA.

RECREATION LANDOWNERS

BACKGROUND—RECREATIONAL DATA

The economic CBA in this project considers recreational impacts in addition to the municipal and agricultural impacts. Recreation is included in the CBA as these areas can be directly impacted by the presence of natural infrastructure.

Lessons learned from Recreation Data

Recreational activities can be included in the CBA in two different ways: either as a benefit generated when a project is implemented (e.g. improved water quality leads to more site visits), or as a cost when the absence of a natural infrastructure project leads to site closures and reduced recreational activity. Two of the potential ecosystem services provided by projects of this nature are the potential for flood mitigation (through increased retention of stormwater) and, improvements in water quality (either blocking or reducing flow of excess nutrients and sediment to water bodies). Flooding events, in particular, can have major impacts on recreationists through site closures and infrastructure damage.

Although the natural infrastructure would primarily impact municipalities through the cost side of the ledger, recreational impacts can be measured in both costs savings and/or increased revenues. This would mean that the cost savings in the CBA from recreation areas could be included in the total cost savings summation provided in the earlier examples; or the additional revenues from increased site visits due to increased water quality can be added to the analysis. For example, the additional revenues could be included as a benefit in Figure 3, along with the other cost saving benefits.

The cost-benefit estimates can be generated from campsite data in the Modeste subwatershed. Estimates could be based on a willingness-to-pay (WTP) per trip to recreation areas with various amenities, activities, and natural attributes. A benefit-transfer model, based on past utilization of recreation areas in the Modeste, could be generated by creating a recreation demand for camping trips (based on usage for 4 months, May through August). This method allows values to be generated from a primary study in one area and applied to another, and is used when the available data is not sufficient for a primary study, or there are insufficient resources to undertake a primary study. Benefit transfer can be a valid method of obtaining economic values, provided that care is taken to ensure that both the goods/services and the population of beneficiaries are comparable (Johnston et al., 2015).

Further research could also be conducted to estimate increases in revenue due to improve water quality. If recreation areas have improved water quality, they may attract more recreationist to the same site and increase revenues, or a new clean waterway could open and attract brand new revenue sources. Natural infrastructure has the capacity to improve water quality and thus future data analysis could be done to include this type of analysis. For example, in a preliminary analysis of another study, it was found that a blue-green algae warning for a lake, typically issued when blooms of cyanobacteria are observed, reduces trip values to the adjacent campgrounds.

CONCLUSION

A preliminary Economic Framework for a cost-benefit analysis was developed in this project to understand how natural infrastructure could reduce municipal, agricultural, and recreation costs in the Modeste subwatershed and downstream. The municipal costs were considered from the local perspective where the natural infrastructure projects were being implemented on the ground, as well as the benefits that could accrue to the downstream water utility (EPCOR) for the City of Edmonton. The cost savings for agricultural and recreational areas were based locally in the Modeste subwatershed.

The Economic Framework in this project considered the cumulative costs for municipalities and agricultural and recreational areas over a 40-year period and scenarios for “with” and “without” natural infrastructure. Scenario #1 was built without natural infrastructure and is considered the baseline scenario with wetland and riparian loss over the 40-year period. Scenarios #2 and #3 were built with natural infrastructure. Scenario #2 assumes that natural infrastructure will be “maintained” or no-net loss to the current state with potential new or increased maintenance costs, and Scenario #3 assumes that the natural infrastructure would be “enhanced” over time with new and/or large improvements to the current state. Scenarios #2 and #3 assumes that water quantity and quality would improve and thereby decrease costs. Scenario #1 would have the highest costs as natural infrastructure would not be in place to mitigate costs and therefore no benefits would accrue. Scenarios #2 and #3 would both achieve cost savings, however, the more natural infrastructure there is, the more cost savings that can be achieved. Scenario #2 would have additional costs with the increased or implementation of maintenance to current natural infrastructure compared to Scenario #1 (with no natural infrastructure), however the natural infrastructure costs are offset by the additional cost savings (or benefits) that are achieved. Likewise, Scenario #3 has higher additional costs of enhanced natural infrastructure but there are also higher cost savings that are achieved compared to Scenarios #1 or #2.

In summation, the cost of the natural infrastructure is expected to be significantly offset by the cost savings that can be achieved by improving water quantity and quality in the region. This cost-benefit analysis is important, especially when considering the baseline scenario where natural infrastructure is being lost and costs to municipal, agricultural and recreational assets are therefore expected to increase over time. Since the benefits of natural infrastructure are expected to largely outweigh the costs, then natural infrastructure should be considered as a tool to reduce costs for municipalities, agricultural producers, and recreational landowners while also increasing resilience to extreme weather events. For example, municipalities could benefit from lower costs to manage water quantities such as flood damages to roads and other critical infrastructure as well as water treatment plant costs; agricultural areas could benefit from lower agricultural insurance payouts from reduced flood risk; and recreation areas could benefit from improved water quantity and quality and thereby increase site visits.

Since natural infrastructure is a low-cost option to manage water quantity and quality it also becomes important when considering alternative built engineered options. For example, a water treatment plant is expensive to upgrade in the short-term; expensive to replace in the long-term; and once these engineered structures are built, they begin to depreciate over time. Alternatively, natural infrastructure generally *appreciates* and improves water quantity and quality management over time.[4] Natural Infrastructure should therefore be considered a compliment to the engineered structures as they are expected to decrease infrastructure capital and maintenance costs and at the same time improve other co-benefits such as carbon sequestration and increase biodiversity.

In order to carry out a cost-benefit analysis of natural infrastructure for municipalities and agricultural and recreational areas, scenarios need to be built around available data and assumptions. This project created an Economic Framework for a cost-benefit analysis that could be further modified with future data collection. The following is a summary of the suggested scenarios and future data collection.

Municipalities: In order for a municipality to provide cost data that represents capital and operating impacts of managing water, the municipality would need dates that are tied to a specific weather event. It is recommended to obtain a date range in which an event's impacts occurred and then request specific data for before, during, and after the event to evaluate the cost impact. This approach could reveal the cost impacts since municipalities do not necessarily keep track of expenditures according to weather events. It is important to note, however, that the impacts could be localized in a small area or they could span across a large area of land; both of which can be costly depending on the severity of the event. When considering a multi-jurisdictional cost-benefit

[4] Ozmet, S., DiFrancesco, K., Garter, T. (2015). *The role of natural infrastructure in the water, energy, and food nexus,* Nexus Dialogue Synthesis Papers. Gland, Switzerland: IUCN.

analysis such as at a subwatershed scale, it could be that a severe weather event could impact only one municipality or it could impact multiple municipalities, and the impacts could affect adjacent municipalities or they may be more sporadic across the landscape.

Also, when considering a municipal water utility downstream, such as EPCOR, in this project, it is useful to identify when water quality impacts the cost of the water treatment plant. For example, EPCOR monitors the tributaries in the watershed upstream that impact the water quantity/quality changes in the mainstem during different times of the year. Changes in the water quantity/quality can indicate a higher cost to treat particularly during spring run off when contaminants loads are highest. This project identified a major tributary in the Modeste subwatershed that contributed significantly to spring run-off, which could indicate that natural infrastructure on this tributary could potentially mitigate costs for the water treatment plant downstream.

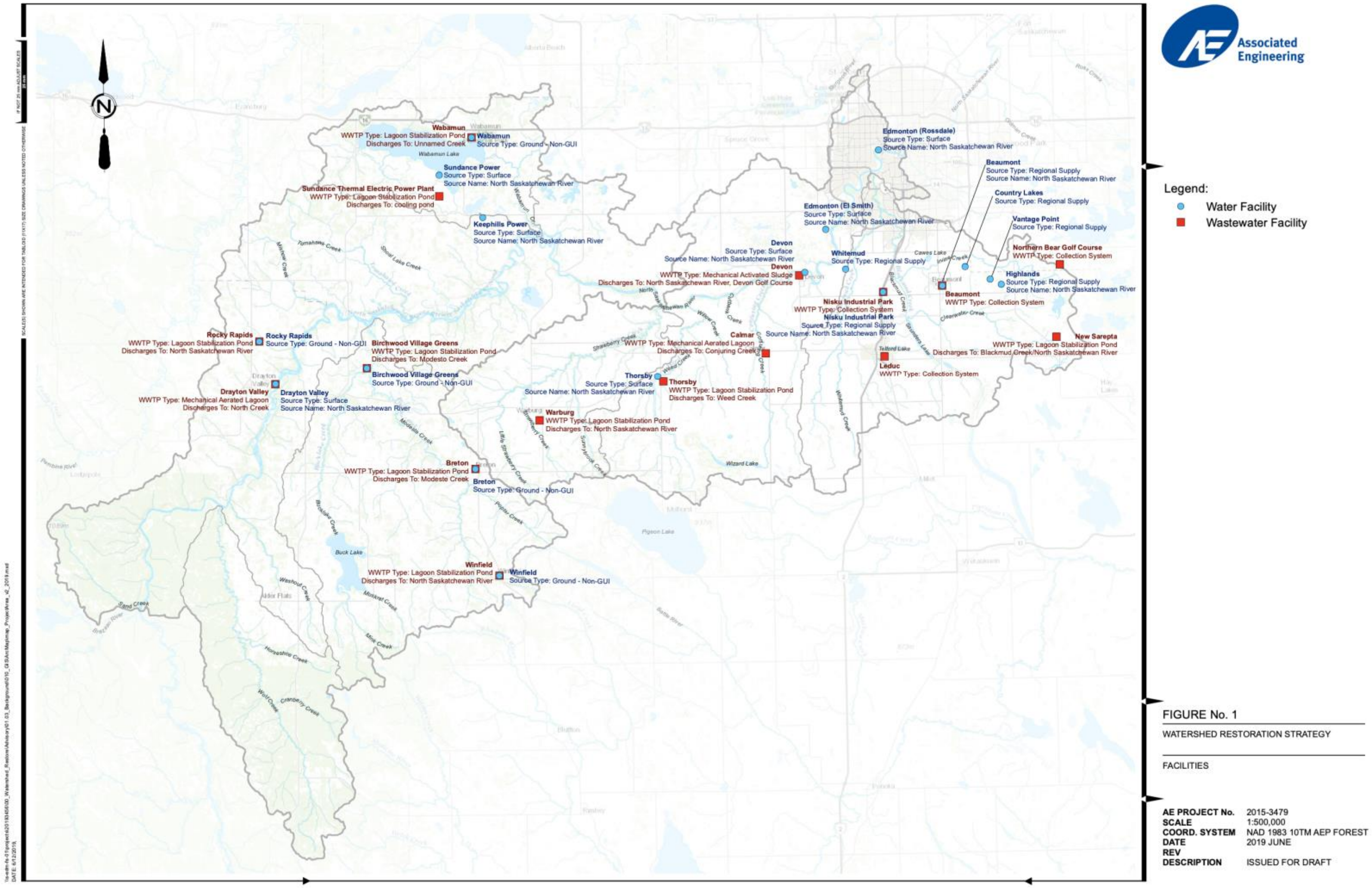
Agricultural: In order to obtain agricultural insurance data to understand the potential cost savings from natural infrastructure, it is important to identify what payouts are made and when. For example, agricultural insurance payouts are made during pre-planting/seeding and after harvest. For the federal agricultural insurance program, only pre-planting payouts are made specifically for a severe weather event such as flooding. All other payouts are made after harvest, with the reasons for the payout being lumped together and defined as a "production shortfall." Thus, it is not possible to know if a production shortfall was due to, for example, a pest infestation or to a flooding event. As such, understanding the impacts of specific severe weather events on agricultural payouts would need to be targeted in either the pre-planting stage from May-June for flooding (i.e. "excess moisture") and/or droughts (i.e. "moisture deficiency") for only silage and pasture crops. If agricultural payouts are incorporated into the cost-benefit analysis then a project could assume a 10%, 30%, and 50% decrease in insurance payouts due to natural infrastructure and then build cost scenarios round those amounts.

Recreation: Recreational areas have been identified as one place that costs could decrease as well as revenues could increase due to the presence of natural infrastructure. Recreational areas are also measurably impacted by both water quantity and quality changes. Recreational areas such as lakes and rivers can reduce costs if natural infrastructure is placed such that it cleans water and manages water quantities such as flooding. Also increased revenues can be generated from increases site visits due to improved water quantity and quality. For example, the cost-benefit analysis could include scenarios that indicate cost savings measures such as fewer blue-green algae warnings and also increase revenues with increased camping visits, if recreational areas are included in the analysis.

Natural Infrastructure Projects: Natural infrastructure project scenarios could be based on actual projects (ALUS projects in this case) on the ground, as well as future projects that increase in value/function and/or in number over time. Scenarios could be built around low, medium, and high value/function of the natural infrastructure as well as for the number of natural infrastructure projects on the ground. This analysis, combined with watershed modeling, could provide at what scale the natural infrastructure projects need to be in order to have an impact on the cost for municipal, agricultural and recreational areas.

Utilizing all or part of the additional scenarios described above in the cost-benefit analysis could lead to a more accurate prediction of the impacts of natural infrastructure on municipal, and agricultural and recreation areas of the economy. The key to a more robust cost-benefit analysis, however, will depend on availability and access to additional data sources.

APPENDIX A—MAP OF MAJOR WATER & WASTEWATER FACILITIES IN THE REGION



APPENDIX B – STAKEHOLDER ORGANIZATIONS ENGAGED

For this project, more than 100 stakeholders were engaged from 44 distinct organizations. A list of the organizations is provided below.

Organization Name
Al-Terra Engineering
ALUS Canada
Alberta Innovates
Alberta Real Estate Foundation
Alberta Water Council
Associated Engineering
City of Airdrie
City of Calgary
City of Courtenay, BC
City of Edmonton
City of Lethbridge
City of West Vancouver, BC
City of Vancouver, BC
Credit Valley Conservation
Ducks Unlimited Canada
EPCOR
Government of Alberta, Agriculture and Forestry
Government of Alberta, Environment and Parks
Infrastructure Asset Management Alberta
Insurance Bureau of Canada
Land Stewardship Centre
Miistakis Institute
Municipal District of Brazeau County
Municipal District of Clearwater County
Municipal District of Leduc County
Municipal District of Parkland County
Municipal District of Red Deer County
Municipal District of Rockyview
Municipal Natural Asset Initiative
North Saskatchewan Watershed Alliance
Town of Chestermere
Town of Cochrane
Town of Devon
Town of Drayton Valley
Town of Gibsons, BC
Town of Okotoks
Town of Taber
University of Alberta
University of Guelph
Urban Development Institute
Urban Systems
Watrecon Consulting

APPENDIX C – MUNICIPAL NATURAL INFRASTRUCTURE PROJECT

THE MODESTE NATURAL INFRASTRUCTURE PROJECT

WHAT IS NATURAL INFRASTRUCTURE?

Sometimes referred to as "green infrastructure" or "natural assets," natural infrastructure consists of landscape features—such as wetlands, riparian buffers and forests —that improve water quality and lower the risk of flooding and drought.

The benefits of natural infrastructure include carbon sequestration, wildlife habitat, recreation and protection from severe weather events. By retaining and filtering water, wetlands reduce overland flooding and replenish groundwater supplies.

Natural infrastructure also extends the life of built, "grey" infrastructure, such as floodways, culverts, bridges, and water-treatment plants.

Researchers have begun to financially quantify these many benefits to society, and to understand the costs when natural infrastructure is lost.

THE MODESTE NATURAL INFRASTRUCTURE PROJECT

The Modeste Natural Infrastructure Project will evaluate the financial benefits of conserving and enhancing natural infrastructure on agricultural lands in the Modeste Creek watershed in Alberta, Canada.

Experts from the University of Guelph, InnoTech Alberta, and ALUS will work with local communities to understand how restoring natural infrastructure will improve water quality and reduce the impact of flood and drought.

Using modelling, they will evaluate scenarios where natural infrastructure is restored, enhanced and conserved to meet the needs of local and downstream communities.

A cost-benefit analysis comparing different combinations of natural infrastructure with built infrastructure will help create a knowledge base and value proposition for natural infrastructure investment from the public and private sector.

The Modeste Natural Infrastructure Project will also contribute to the creation of natural infrastructure. Through the ALUS program, 263 hectares (650 acres) of wetland and riparian areas will be restored or enhanced in the Modeste watershed.

ABOUT THE PROJECT AREA

The Modeste watershed is a sub-basin of the North Saskatchewan River basin, and is located upstream of Alberta's Capital Region.

The Government of Alberta has identified the Modeste watershed as a priority for flood and drought mitigation, as well as an important area affecting water quality in the province.

The Modeste was chosen for this project because of the support provided by the North Saskatchewan Watershed Alliance's Headwaters Alliance—a water-focused intermunicipal collaboration group established in 2014. Each of the five counties in the Alliance has a program to engage farmers and ranchers in the enhancement and protection of natural infrastructure: Parkland, Brazeau, Leduc and Wetaskiwin Counties administer the ALUS program, while Clearwater County administers the LandCare Program.

THE MODESTE CREEK WATERSHED

THE MODESTE NATURAL INFRASTRUCTURE PROJECT

Project Partners

ALUS Canada

ALUS Canada is a federally-registered charity that partners with communities and farmers to restore and enhance natural ecosystems on agricultural lands. ALUS communities in the Modeste watershed—ALUS Wetaskiwin-Leduc, ALUS Parkland and ALUS Brazeau—will restore and enhance wetlands and riparian areas as a part of this project.

Contact: Lara Ellis, Vice-President, Policy and Partnerships: lellis@alus.ca

ALUS.CA

Department of Geography, Environment and Geomatics, University of Guelph

Dr. Wanhong Yang's research program integrates economic, hydrologic, and GIS modelling to examine the cost effectiveness of agricultural conservation programs, with a mission to develop modelling tools for agricultural BMP assessment at both field and watershed scales. Modelling projects using his IMWEBs tool have taken place in Canada and the U.S.

Contact: Dr. Wanhong Yang, Professor and Chair, Department of Geography, Environment and Geomatics: wayang@uoguelph.ca

UOGUELPH.CA

InnoTech Alberta

InnoTech Alberta's primary focus is to facilitate the conversion of applied research to economic, social and environmental benefits. InnoTech links basic research and commercial outcomes, in accordance with strategic directions set out by the Government of Alberta, by delivering specialized services for its government and industry clients.

Contact: Dr. Marian Weber, Principal Researcher: Marian.Weber@innotechalberta.ca

INNOTECHALBERTA.CA

North Saskatchewan Watershed Alliance

As a Watershed Planning and Advisory Council, the NSWA is a multi-stakeholder organization that seeks to improve the management of water quality, water quantity and the health of aquatic ecosystems by developing and sharing knowledge and facilitating partnerships and collaborative planning processes. The NSWA will contribute watershed data and advice toward this project.

Contact: Mary Ellen Shain, Watershed Planning and Management Coordinator: Maryellen.shain@nswa.ab.ca

NSWA.AB.CA

Parkland County

Parkland County, located just west of the City of Edmonton, is a vibrant and robust community that is proud of its leadership toward sustainability and its long-time support of stewardship on both public and private lands.

Contact: Krista Quesnel, Community Sustainability Manager: krista.quesnel@parklandcounty.com

PARKLANDCOUNTY.COM

ALUS participants will restore and enhance wetlands and riparian areas in the Modeste Creek watershed.

Funding Partners

The primary funder of the project is Alberta Environment and Parks' Watershed Resiliency and Restoration Program (WRRP). This project is funded in part through Natural Resources Canada's Climate Change Adaptation Program. Additional funding is supplied by the City of Edmonton, EPCOR and the McConnell Foundation.

The Green Marble

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