TOWN OF ST. PAUL & COUNTY OF ST. PAUL

INTERMUNICIPAL STORMWATER MANAGEMENT PLAN

OCTOBER 15, 2019

INTERMUNICIPAL STORMWATER MANAGEMENT PLAN

TOWN OF ST. PAUL & COUNTY OF ST. PAUL

FIRST SUBMISSION

PROJECT NO.: 181-10286-00
DATE: OCTOBER 15, 2019

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October 15, 2019

Town of St. Paul & County of St. Paul
Town of St. Paul
5101 50th Street
St. Paul, AB
T0A 3A0

Attention: Kim Heyman, CAO

Subject: St. Paul Intermunicipal Stormwater Management Plan

Dear Mr. Heyman,

Please find attached the St. Paul Intermunicipal Stormwater Management Report, as prepared by WSP Group Canada Ltd., for your review. This report has been prepared on behalf of the Town of St. Paul and County of St. Paul.

If you should have any questions or concerns regarding the enclosed document, please do not hesitate to contact us. Thank you.

Sincerely,

Michael Nishiyama, M.A.Sc., P.Eng.
Water Resources Engineer

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FIRST SUBMISSION – OCTOBER 15, 2019

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PERMIT TO PRACTICE

PERMIT TO PRACTICE
WSP CANADA GROUP LIMITED
Signature
Date October 15, 2019
PERMIT NUMBER: P8845
The Association of Professional Engineers and Geoscientists of Alberta

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1 GENERAL

1.1 INTRODUCTION

The Town and County of St. Paul have retained WSP Canada Group Ltd. (WSP) to provide engineering services with respect to the modelling and analysis of the Town and County's stormwater management system for the preparation of an Intermunicipal Stormwater Management Plan (ISMP). The ISMP is intended to both address any deficiencies in level of service of the existing stormwater management system and to determine which upgrades may be required to address future servicing needs.

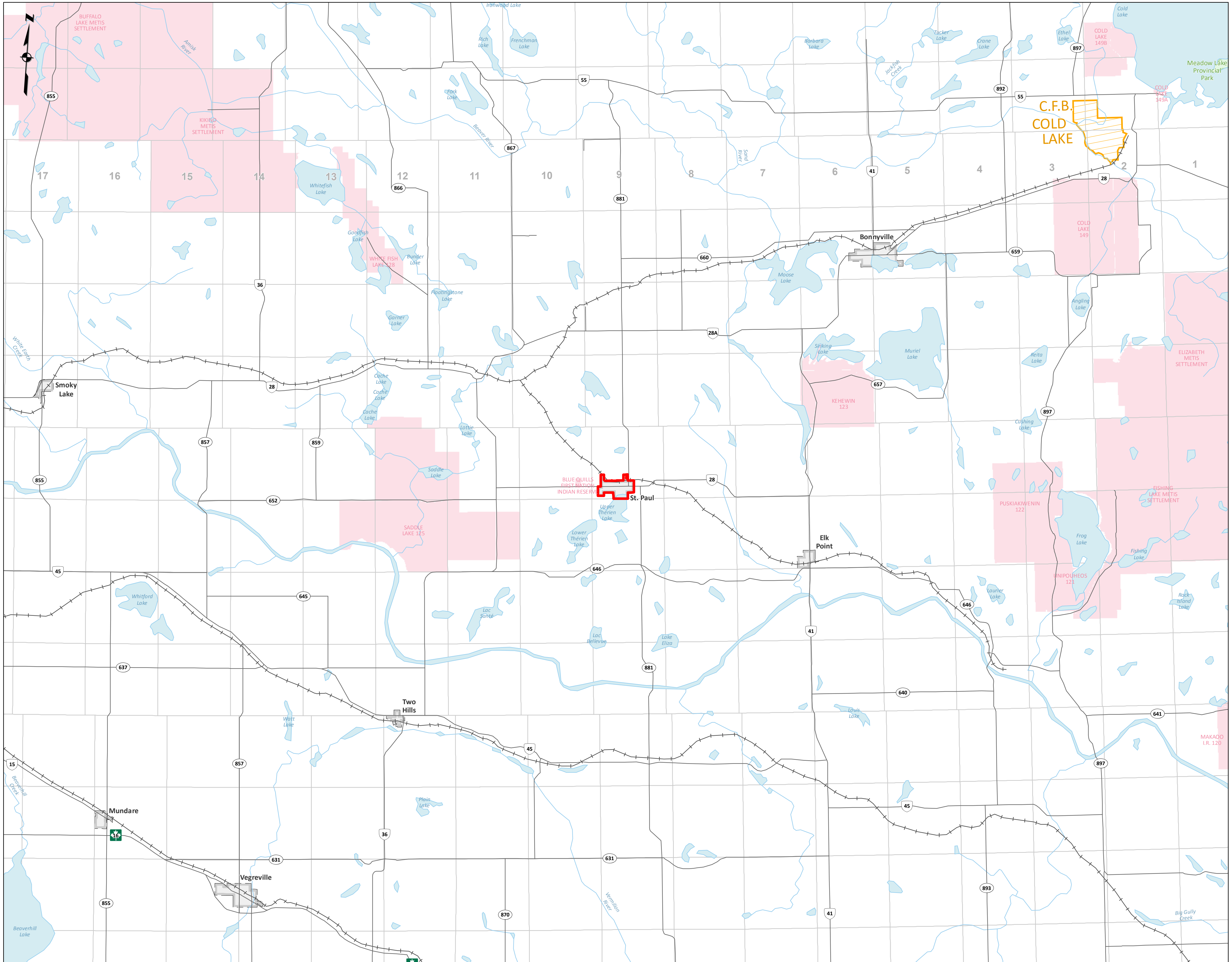
The study included the analysis of the existing stormwater management system, survey of locations of importance, climate change analysis, hydrologic and hydraulic modelling, the determination of effective remedial measures, and a capital plan. **Figure 1.1** provides an overall site plan of the project area and stormwater drainage system.

1.2 SCOPE OF WORK

The intent of this study is to address drainage as it relates to the intermunicipal boundary to the Town and County of St. Paul. The following five major phases were undertaken for the project, providing the basis for the report:

1. Initial Planning
2. Field Data Collection
3. Drainage Model Development
4. System Assessment
5. Stormwater Management Plan

The key deliverable of the conducted work is this Intermunicipal Stormwater Management Plan report, which provides a hydrologic and hydraulic model of the Town and County's stormwater management system, a capital plan, and a stormwater management plan.



Legend

- Town of St. Paul
- Provincial Roads
- Railways
- Lakes/Rivers
- River/Streams
- Township Boundary
- Urban Centre
- Military Range / Base
- First Nation
- Provincial Park

Town of St. Paul

Figure 1.1 - Location Map

Town of St.Paul

Alberta, Canada

Scale: 1:500,000

0 5 10 15 20 25 Km

Universal Transverse Mercator (Zone 12)
North American Datum (1983)

WSP

Report By: MN
Drawn by: AN
Reviewed By: JM

WSP Job #: 181-10286-00
Date: April 21, 2019
Office: Edmonton

Notes:Data provided by Altalis;Natural Resource Canada; ESRI Basemaps;GeoGratis

2 BACKGROUND

2.1 OVERALL SITE DETAILS

The Town of St. Paul is approximately 780 ha in size and is situated in east-central Alberta within the County of St. Paul No. 19. The Town is located on the northside of Upper Therien Lake, and is surrounded largely by agricultural lands. The elevations range from the approximate highest elevation in the northwest at 655.0 m to the lowest of 637.0m at Upper Therien Lake. The topography of the basin is governed by the surficial geology of the area, and has gently rolling terrain. The majority of the basin is a collection of stagnant ice moraine, and ice-thrust moraine (Alberta Geological Survey, 2013).

Drainage within the Town limits flows to either Lake Garneau, situated on the northside of town, or to Upper Therien Lake. Various amounts of runoff from the County drains through the Town into the water bodies. The general drainage direction is from the northwest to southeast. The basin area limits that effect the intermunicipal boundary of the Town and County is approximately 2200 ha's in size. **Figure 2.1** illustrates the basin limits of the intermunicipal stormwater management plan.

2.1.1 COUNTY DRAINAGE

The County consists largely of agricultural lands and generates a significant amount of runoff due to the large basin areas draining towards the major water bodies of Lake Garneau and Upper Therien Lake. The County's drainage infrastructure consists largely of roadside ditches and culverts to convey flows under roads. There are farmsteads and acreages scattered throughout the County, some of which have dugouts to manage local drainage.

Existing drainage concerns with the County generally originate from insufficient culvert sizing along natural drainage paths and roadside ditches. Runoff in the County is largely managed by naturally occurring wetlands and drainage paths to larger water bodies.

2.1.2 TOWN DRAINAGE

The Town of St. Paul consists of a mix land uses typical of most municipalities, and also has a standard minor and major stormwater system. Runoff generated from the town is conveyed via these systems to either Lake Garneau, or Upper Therien Lake. Lake Garneau is hydraulically connected to Upper Therien Lake, and drains to it under high water conditions via a control structure and minor system though town.

Existing drainage issues exist both along the boundary of the Town and within it. These issues exist for varying reasons such as large catchment areas, undersized minor system, blocked outlets, and ponding.

2.2 PREVIOUS STUDIES AND REPORTS

WSP has previously worked in the Town of St. Paul, including an assessment of the Town with engineering support regarding the flooding and downstream changes south of the Golf Course. Other previous work includes the Joint Intermunicipal ASP, East Stormwater Trunk, Future Servicing Study and Engineering Standards. The following reports were reviewed and applied to enhance the understanding and comprehensiveness of this report:

- The Town of St. Paul Area Structure Plan (March, 2009)
- The Town of St. Paul Municipal Development Plan (May, 2009)
- The Town of St. Paul and County of St. Paul No. 19 Intermunicipal Development Plan (December, 2010)
- The County of St. Paul No. 19 Municipal Development Plan (December, 2012)
- Town of St. Paul Highway 29 and 881 Industrial Area Structure Plan (October, 2015)
- St. Paul North Joint Area Structure Plan (April, 2017)

2.3 MODEL DEVELOPMENT

A 1D-2D coupled drainage model was developed using PCSWMM (Version: 2017 Professional 2D) software. This software is a Windows-based stormwater management modeling system that is capable of evaluating hydrologic and hydraulic performance. A 1D-2D model contains both 1D, or minor drainage systems, and the 2D drainage system which models major drainage. A coupled model allows for the assessment of evaluating flooding extents and its impact, and is more comprehensive than conventional drainage models that only consider the minor system.

2.3.1 METHODOLOGY

The model was developed using the available local hydrometric and meteorological data. Rainfall and design storm events were acquired from the Town of St. Paul Engineering Standard (2009). Discussions with the Town and County staff, site visit, and available data were all utilized to produce the stormwater system model. The primary sources of information for establishing the model are as follows:

- St. Paul Regional Municipal GIS database (Munisight)
- CAD drawings of existing utilities
- Previous drawings of record plans
- LiDAR data 1.0 m resolution
- NRCAN Geo Spatial Data DEM
- Aerial imagery to evaluate land use
- Town of St. Paul Minimum Engineering Design Standards
- Surficial Geology of Alberta, Alberta Energy Regulator, 2013

Design storm events that were modelled to evaluate the stormwater management system's performance were the 5 year 4 hour duration and 100 year frequency events with a 4 hour and 24 hour duration. The 4 hour events simulate a short duration event that provide peak flows, while the 24 hour events simulate long duration events, highlighting issues associated with volume concerns. The total amount of rainfall from the 100 year 24 hour event is 126.7 mm. Climate adjusted events were also applied to the model. The projected precipitation amount for the climate change adjusted 100 year 24 hour event was 133 mm.

2.3.2 HYDROLOGY

The hydrologic portion of the model was undertaken to analysis the behaviour of runoff within the basins. Results generated from the hydrologic model were then used as inputs for flow values for the hydraulic model. The runoff model within the software estimates the amount of runoff based on the catchment characteristics, and Horton infiltration parameters. The catchments were delineated using available terrain data and known hydraulic routing patterns, verified by previous documents, site visits, or desktop analysis.

A total of 439 catchments were delineated for the hydrology analysis, with an average area of 5.0 ha for the 1 m resolution LiDAR and an average area of 50.0 ha for the 10 m resolution NRCAN DEM. The catchment areas were delineated using PCSWMM's watershed delineation tool, and were assessed to ensure accuracy. These basins were then connected to the hydraulic network. The impervious percentage for each catchment was determined by examining its land use with an aerial overlay. Impervious values were an approximation of the total catchment land use type, and are conservative estimated values. The following tables outline the catchment parameters, land use and infiltration parameters.

Table 2.1 Hydrological Parameters

Manning's Coefficient	
Pervious Area	0.035
Impervious Area	0.018
Depression Storage	
Pervious Area (mm)	2.50
Impervious Area (mm)	1.30
Infiltration	
Initial Rate (mm/hr)	9.00
Final Rate (mm/hr)	2.88
Decay Factor (1/hr)	4.00

2.3.3 HYDRAULICS

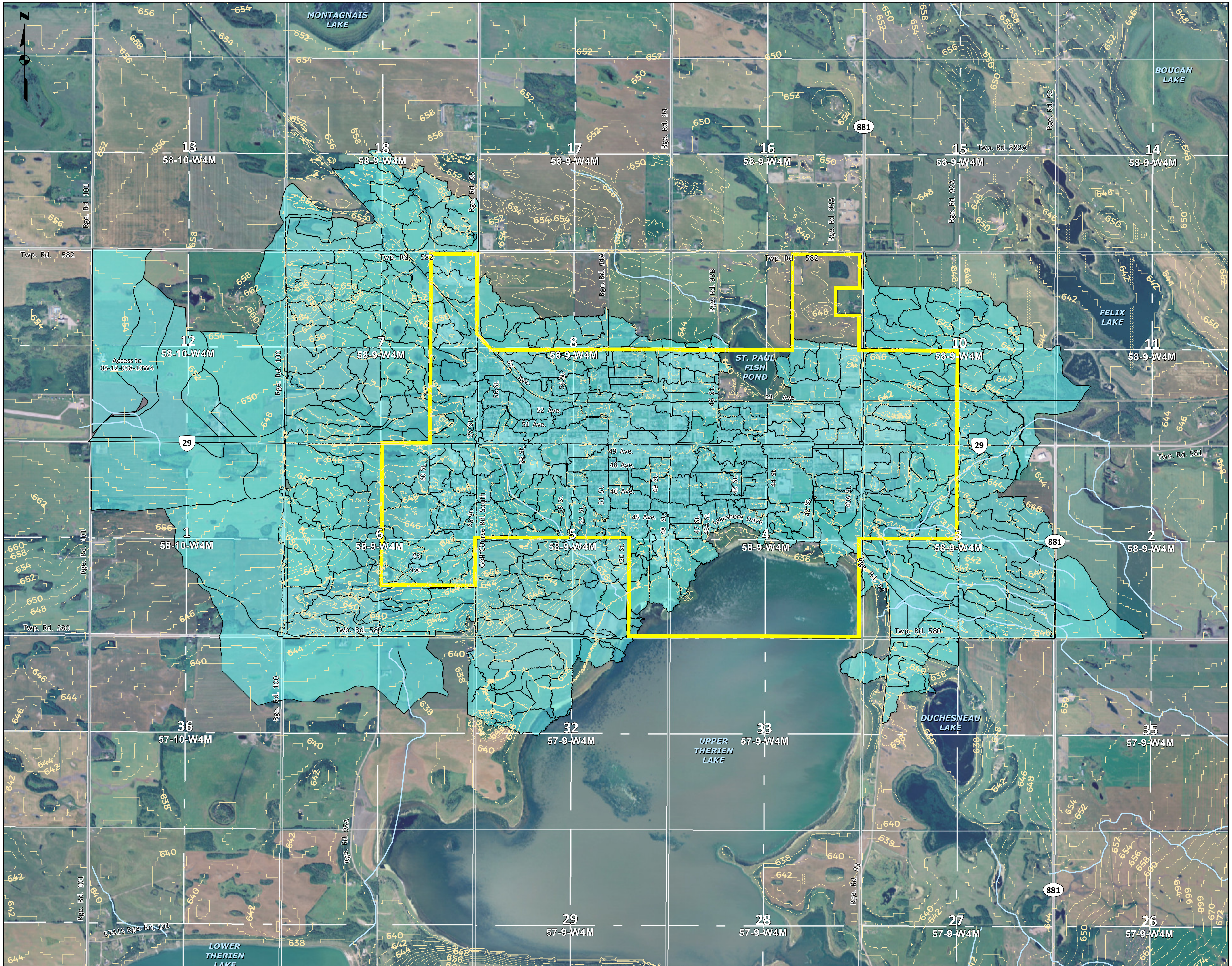
The hydraulic portion of the model was constructed of a both 1D and 2D elements. This was done to model both the behaviour of the minor system (1D) and the major system (2D). Landscape features can play a significant role in the drainage system, such as large depressions or overland flow routing. The 2D system examines these features to accurately represent flow and infiltration, as 1D modelling is limited in analyzing this behaviour. The coupled 1D-2D modelling features were created with the following approach:

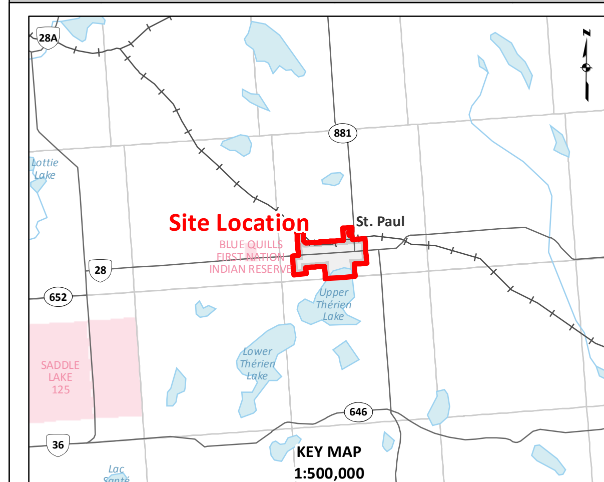
1. Drainage basin delineation
2. Build of 1D drainage components (minor system, ditches, culverts, long reaches of natural drainage courses)
3. Construction of 2D mesh from DEM
4. Integration of 1D and 2D systems
5. Connection of basins to hydraulic model
6. Analysis of system under design events

The minor system was generated from available CAD utility drawings, and the St. Paul online GIS system. A site investigation and survey was conducted for locations of likely high importance, as determined through desktop analysis and discussions with the municipalities, as to provide accurate information for those elements. Due to a limited amount of information regarding the town minor system and limited survey scope, some assumptions of pipe characteristics were made. All pipes were assumed to have a manning's coefficient of 0.013. Additional assumptions of the performance of the hydraulic system are reviewed in the section **4.3 Limitations**.

The PCSWMM 2D software is based upon the United States Environmental Protection Agency (EPA) Storm Water Management Model (SWMM) engine. The software requires a geometric discretization of the study area using a hexagonal irregular mesh, which was built by using the available LiDAR and survey data. The mesh was more discretized at locations requiring increased details and hydraulic performance. The resolution at details sections was typically 5 m and lesser so in areas of uniform topography or near boundaries, approximately 8-12 m.

Specific cells of the 2D model were connected to the minor system, which allowed for the conveyance of flows to the Town's stormwater system to designated outfalls. The model includes 28 outfalls from the 1D minor system, and 5 outfalls from the 2D system. These outfalls are the downstream boundary condition and are set as free outfalls as they discharge into either Lake Garneau or Upper Therien Lake.





Town of St. Paul

Figure 2.1
Topology and Basin
Town of St.Paul
Alberta, Canada

Scale: 1:30,000

0 0.3 0.6 0.9 1.2 1.5 Km

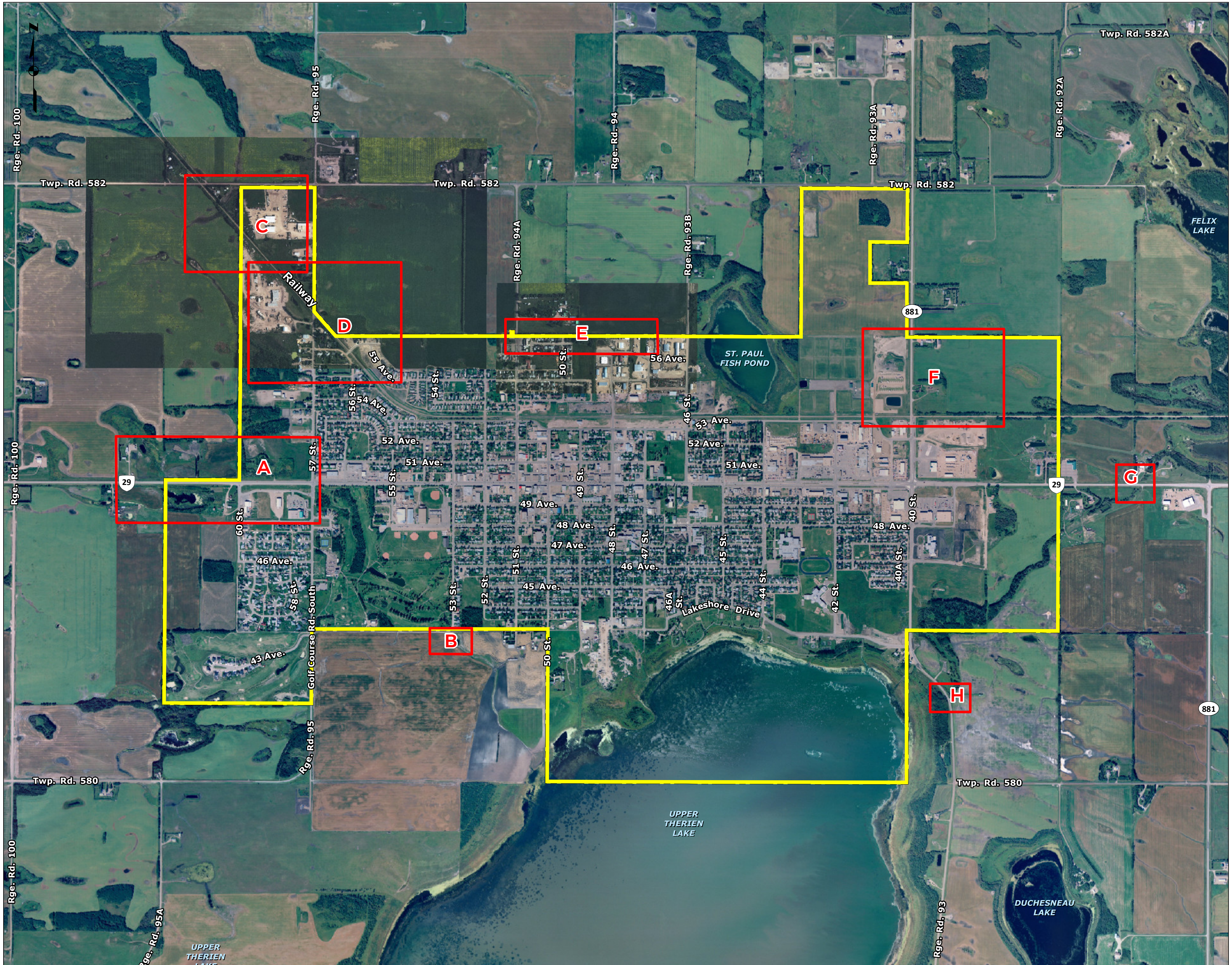
Universal Transverse Mercator (Zone 12)
North American Datum (1983)

wsp

Report By: MN
Drawn by: AN
Reviewed By: JM

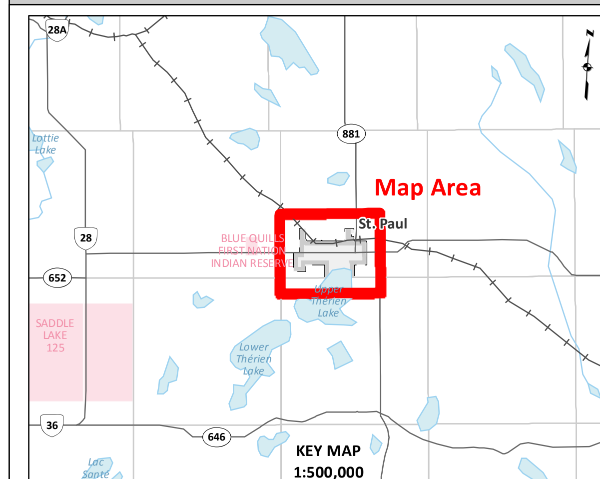
WSP Job #: 181-10286-00
Date: April 21, 2019
Office: Edmonton

Notes:Imagery Source: Valtus Imagery Service [2012]



Legend

- Modelling Areas
- Town of St.Paul



Town of St. Paul

Figure 2.2
2D Modelling Locations

Town of St.Paul

Alberta, Canada

Scale: 1:20,000

0 0.2 0.4 0.6 0.8 1 Km

Universal Transverse Mercator (Zone 12)
North American Datum (1983)

wsp

Report By: MN
Drawn by: AN
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3 CLIMATE CHANGE ANALYSIS

3.1 INTRODUCTION

An analysis was conducted to provide information about the expected changes in climate for the Town and County's territory, and their potential impacts on stormwater management. Consideration has been taken for climate change as it is likely to increase the probability and severity of extreme rainfall events bringing the community additional risks. Having conducted the climate change analysis allows for risks to be accounted for and acted upon. **Appendix A** contains the full Climatology analysis for the Town and County of St. Paul.

3.2 ANALYSIS OVERVIEW

The analysis was completed for two sections; the local climate scenarios and hydrology-oriented (IDF) curves. The general constraints for the analysis were the following:

— *Time*: The climate conditions were projected for 50-year timeslots at three steps of approximately 25 years (2006-2056; 2025-2075; 2050-2095/2100 depending on the analysis).

— *Climate scenarios*: The climate model outputs for two greenhouse gas (GHG) emission scenarios were considered: low emission (RCP 4.5: GHG emissions peak around 2040, considered optimistic) and high emission (RCP 8.5: continuous rise in GHG until the end of 21st century, considered status quo).

The Climate Atlas of Canada (CAC) is an interactive map presenting climate projections from the Pacific Climate Impacts Consortium, acquired through a statistical downscaling of 12 Global Climate Models (GCMs) projections. The downscaled data allows for the quantification of the expected changes at a scale specific to the Town and County's territory. This is then applied to generate the inter-annual precipitation changes series (minimum every 5 years or best) until 2100.

The IDF analysis was conducted using the IDF_CC tool developed by scientists at the University of Waterloo. The tool provides projected IDFs for gauged and ungauged locations across Canada, based on 33 climate models. The analysis was based on the mean of 9 downscaled models, because of their suitable resolution. The IDF_CC provides return periods (2, 5, 10, 25, 50 and 100 years) for total precipitation (mm) or intensity rate (mm/h) for 5, 10, 15, 30 minutes and 1, 2, 6, 12 and 24 hours precipitation events.

3.3 SUMMARY

The climatology report presented projections for general climate data and IDF curves for the immediate, near and far future under two GHG emission scenarios. The following conclusions were made:

- General Climate: Increase in the mean annual temperature and precipitation
    - Very high probability to witness an increase in the mean annual temperature in St. Paul in the future
    - Medium likelihood to record an increase in mean annual precipitation
    - Limitations of the Climate Atlas of Canada modelling methods do not allow for accurate projections for discrete extreme events of short duration
- IDF Curves: Increase in the magnitude of extreme precipitation events
    - Projection of an average increase in the precipitation amounts of more than 30% for 100-year return period events under the high emission scenario
- The Town of St. Paul Design Standards apply the Edmonton Municipal Airport IDF curves, which is greater than the baseline IDF for the Town. The application of the Edmonton IDF's is approximately equivalent to accounting for the 'near-future (2025-2075), low emissions' scenario.

4 RESULTS AND RECOMMENDATIONS

4.1 OVERVIEW OF MODELLING RESULTS

In existing conditions, the various drainage channels servicing the Town and County are affected by a mixture of fast response urban flows and slower response natural/agricultural basins. Potential areas of concern were identified prior to modelling, and were examined in detail with a 2D analysis. Water level depths were generated from the model, detailing areas of localized flooding and conveyance issues. It was found that drainage concerns were typically a result of insufficient hydraulic connections between the County and Town drainage systems. Results of the model are illustrated in **Figures 4.1** to **4.4**.

4.1.1 HIGWAY 29 WEST

A large portion of the land located at the west boundary of the Town and County of St. Paul is wetland. This intermunicipal boundary has a large basin area (approximately 310 ha) draining to it. These wetlands are a part of a natural drainage course that flows southeasterly through the golf course towards Upper Therien Lake. There are two major waterbodies located at the boundary, one located on the north side of the Highway, and one on the south. As these two waterbodies, plus the neighbouring wetlands are low lying topographical features they experience significant ponding. The northern waterbody has two major hydraulic connections to the Town's system; one a culvert under Highway 29 that conveys flow south to the other water body, and a second culvert at the intersection of Highway 29 and 57 Street that conveys flows south towards the golf course minor system.

Under the 100 year modelling conditions the western boundary experiences significant ponding, with potential of flooding of a couple County residential homes, and possible flooding of residential homes located on 57 Street near the Town limits. Evaluating the modelling results ponding depths reach an excess of 1.0 m, and covers an approximate area of 30 ha. Flooding conditions exist on both sides of the Highway. The major causes for the ponding include the large basin area contributing to the area, the existing natural low lying topography, and poor hydraulic conveyance along Highway 29 and flows into the Town minor system.

The following recommendations are proposed to resolve the drainage concerns:

- Improve ditch through maintenance and regrading as to provide more effective conveyance. It is key regrading is completed in the ditch leading up to the intersection of HWY 29 and 57 Street and is connected to the Town's minor system
- Replace culvert under HWY 29 at intersection with 57 St. as to improve conveyance into the minor system/ golf course.
- Inspection of existing culverts under HWY 29 to the west to verify size and capacity. Replacement is likely, and will improve the hydraulic connection between the north and south lands.
- Potential implementation of a stormwater management facility to control flow into minor system. This feature has major implications for the future land development, and should be completed in part with a planning study.
- Any future development of this area will require a form of stormwater management facility to compensate for the storage lost in the natural low lying lands, and increased runoff associated with development.

4.1.2 GOLF COURSE

The golf course consists of a large natural area with a drainage course that flows south easterly towards agricultural land, which is then conveyed to Upper Therien Lake. Overall the watercourse within the golf course is well maintained and has several larger water bodies to manage increased runoff. Two major drainage issue exists at this location including; the lack of an efficient outlet for the system, and a large contributing basin. Currently the outlet from the golf course relies upon a manhole that surcharges to surface and overflows onto the neighbouring agricultural land. This system is in place as the Town must manage flows within their property limits, as there is an ongoing dispute between the Town and the agricultural lands owner.

This outlet forces flows to surcharge to ground before it can exit the system, and as a result the golf course experiences backup in excess of an outlet discharging at a lower elevation. In addition to the outlet, the golf course has a significant basin draining through it, approximately 800 ha. The impacts of the surface outlet, and large drainage basin puts neighbouring residential homes at the boundary of the golf course and agricultural lands as risk of flooding.

The following recommendations are proposed to resolve the drainage concerns:

- Remove and replace outlet from golf course to farmland. This includes regrading lands downstream as to ensure proper conveyance. Also provide an emergency overflow path from the southernmost golf course pond to the downstream channel.
- Due to landownership concerns, the preferred drainage solution may not be possible, as such re-routing around the farmlands or alternative servicing solutions may need to be considered.

4.1.3 TOWNSHIP ROAD 582 NORTHWEST

A small parcel of residential land is located between Township Road 582 and the Ironhorse Trail. The site is located along a natural drainage path. Modelling results indicated a potential risk of flooding within the residential property, as a result of limited conveyance capacity of the culverts bounding the site. Detailed survey information of the culverts was not available, and it is recommended the sizing being confirmed, along with interviewing the residences for any know flooding concerns. Inspection of the culverts and their conveyance capability will govern the need for upgrades.

4.1.4 57 STREET NORTHWEST BOUNDARY

The northwest intermunicipal boundary consists of a mix of topography and basins. Within the existing County side exists a couple industrial facilities. The sites do not appear to have a grading plan, but do utilize onsite dugouts to manage runoff, however these facilities are limited in size and do not have any known outlets. These sites are bisected by the Ironhorse trail, which itself does not appear to have an outlet either. Within the Town side of this location exists a wetland that has a connection to the Town’s minor system. This connection appears to route the majority of flows of the County’s northwest basin into the Town’s minor system.

Within the industrial lands to the northwest there are several pockets of localized ponding, but runoff is mostly managed by the dugouts onsite and the Ironhorse’s ditch system. There does not appear to be any major flooding risks to properties. The wetland near the intersection of 57 street and 56 Avenue, provides storage and control of runoff from the northeast before it discharges into the minor system. This wetland seems to provide sufficient storage to mitigate risks of flooding of nearby homes. Ponding within this area, along the Ironhorse trail, has also been expressed by the municipality, and was indicated by the modelling results. The lack of proper conveyance and outlet are the major contributing factors to the ponding.

While there is limited risk to property, the following drainage aspects are recommended to be fixed:

- Provide proper outlet and conveyance for Ironhorse Trail both within the County and Town boundaries
- Conduct general maintenance along the trail and inspect culvert conditions.
- Conduct maintenance at the wetland and Town minor system interface to improve conveyance
- The wetland is currently providing sufficient storage and attenuation, but could possibly be upgraded for better performance, and capacity if desired.
- Future development will require a detailed stormwater management plan as to offset the increased discharges associated with it, and to incorporate a stormwater plan that does not require individual onsite storage.

4.1.5 RANGE ROAD 94A NORTH BOUNDARY

The majority of the basins to the north of the Town drains into Lake Garneau. Most of the flows of these basins are routed overland and are collected in the roadside ditches, and are eventually conveyed to Lake Garneau. There are no major defined channels near the immediate Town boundary, but there is an ephemeral channel that routes a portion of flow easterly from Range Road 94A to 93A. Modelling results indicate that there is not an immediate risk of flooding to residences along the north boundary. Flows within this area are limited, and flooding levels are shallow and away from residences. It is recommended that culverts conveying flow under Range Roads 93A and 94A be regularly inspected and maintained.

4.1.6 HIGWAY 881

The northeast boundary of the Town and County is currently agricultural lands, but has established development plans in place, Highway 29 & 881 Industrial ASP, 2015. Recent upgrades to Highway 881 (40 Street) have also incorporated an effective drainage strategy, as such there is limited drainage concerns within the area. Future development plans outline an effective stormwater management plan for the area, and are recommended to be followed.

4.1.7 WATERCOURSE AT HIGHWAY 29 EAST TO RANGE ROAD 92A

A local watercourse exists within the County to the East of Town. The watercourse drains from wetlands near Felix Lake southwest under Highway 29 towards Range road 92A and into Upper Therien Lake. Modelling results did not indicate any flooding concerns along the watercourse around any roads or properties. There are some wetlands located around the watercourse, but are naturally occurring with no residences nearby. The watercourse has two major hydraulic structures at Highway 29, and Range Road 92A. Both structures consist of duel culverts to convey flow. Neither structure experiences major backup or flooding. The largest risk to these structures is plugging either due to ice jams or poor maintenance.

4.1.8 MINOR SYSTEM

In general the minor system operates relatively effectively under the 1:5 year 4 hour design event. There are locations of flooding, but are limited to the trunk along 51 and 50 street, and 53 Avenue. The minor system infrastructure along 50 street could potentially be upsized to improve conveyance, but would require a more detailed investigation. Flows along 53 Avenue do not pose a major flooding risk as a major ditch system exists along the minor infrastructure, and overtopping flows would be directed into Lake Garneau. **Figure 4.5** illustrates the minor system and its performance. It is important to note that the analysis was focused upon the intermunicipal boundary, and as such the minor system analysis was limited to a desktop analysis. Assumptions of pipe characteristics were made, which have been reviewed in section **4.3 Limitations**.

4.2 FUTURE SCENARIO

Future development brings both an increase in runoff and potential risks of flooding, but also for the allowance of implementing stormwater infrastructure. The conversion of rural to urban will modify basin hydrology by increasing run-off volumes and place strain on the natural channels and their associated ecosystems, as such mitigative measures will be required to prevent adverse impacts upon the environment, the public, and infrastructure. This can be accomplished through the reduction or diversion of flows that currently or may in the future present a flooding risk. Climate change is also likely to increase the probability and severity of extreme rainfall events bringing the community additional risks that must be recognized and acted upon.

4.2.1 CLIMATE CHANGE ADJUSTED

As outlined in **Section 3.0** a climate change analysis was conducted, and it indicated that there would likely be an increase in the probability and severity of extreme rainfall events bringing the community additional risks. **Appendix A** contains the full Climatology analysis for the Town and County of St. Paul. The climate change analysis was implemented into the modelling results by increasing the precipitation for the 100 year 24 hour event. The new rainfall amount applied was for the 'high emissions' scenario, which had the largest increase in precipitation amount. The amount of rainfall for the climate adjusted 100 year 24 hour event was 139.42 mm. Modelling results from the climate adjusted simulation showed increased ponding depths, and flow conveyance through the system. The same problem areas exist with similar, but slightly more severe conditions.

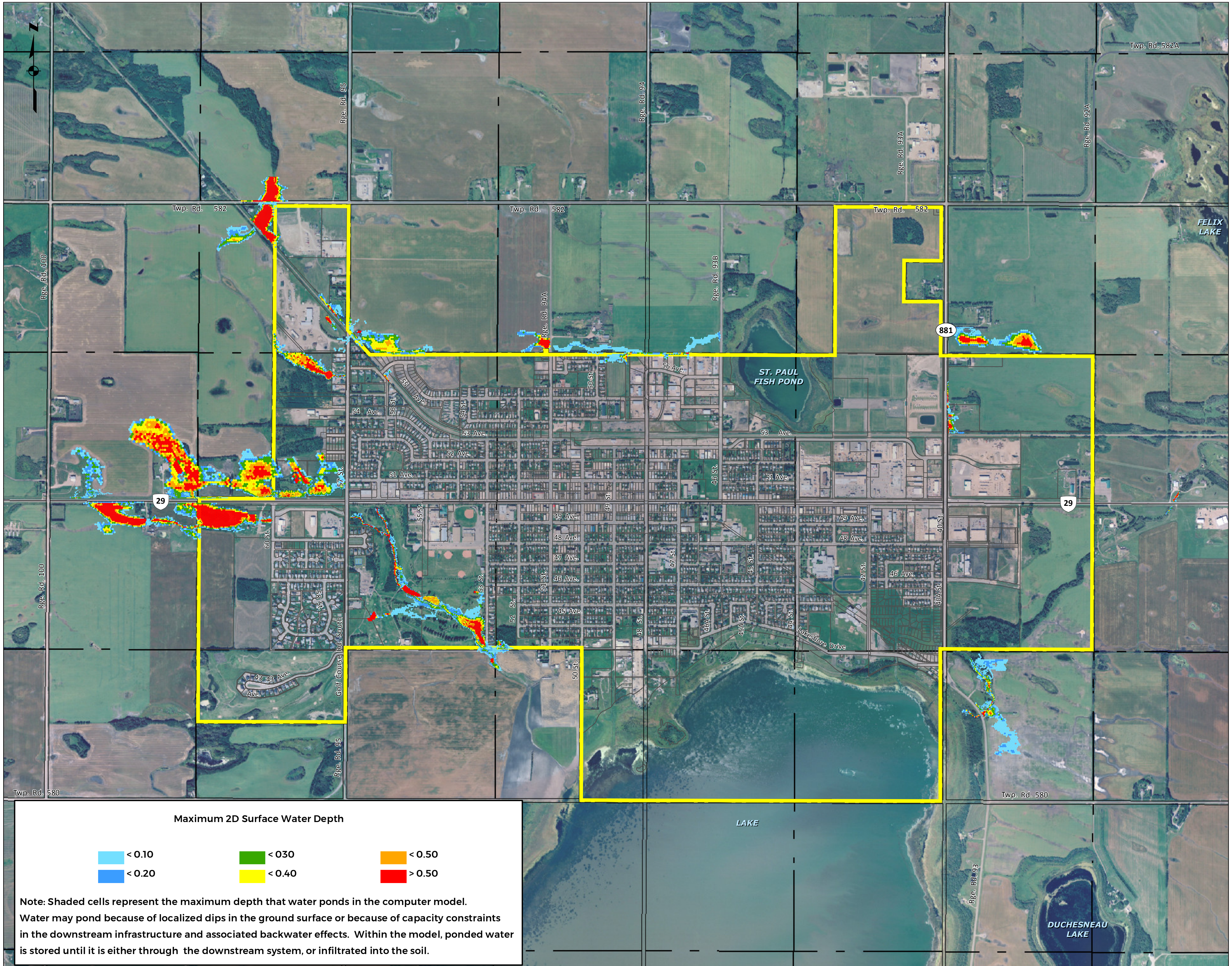
4.2.2 FUTURE DEVELOPMENT

An Intermunicipal Development Plan exists to outline a cooperative future growth framework for the resolution of planning, economic development, servicing and transportation issues that are of join interests between the Town and County. This document in conjunction with additional planning documents such as Area Structure Plans will govern the servicing recommendations for future development. As development occurs phased planning will be required as to incorporate adequate stormwater management infrastructure to properly service the area. Consideration will need to be taken to review the potential implementation of stormwater management infrastructure within future proposed developments prior to their planning phase. It may be suitable for some stormwater infrastructure to be installed on lands that are planned for long term future development lands.

4.3 LIMITATIONS

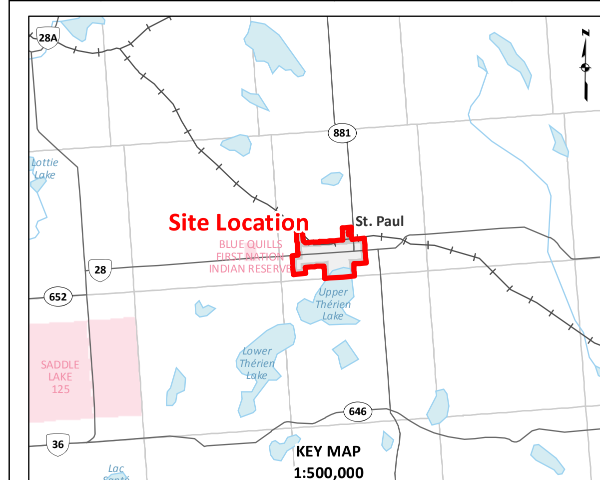
It is important to specify that limitations exist within this study that can influence the accuracy of results, including:

- Hydrologic: Limitations within the hydrologic analysis includes the assumption that basin conditions are homogenous across the delineated catchments, there is limited historical data for calibration, and the flat topography makes it challenging to delineate the basin extents. While these limitations introduce inaccuracy, methodologies were applied to ensure that conservative estimations were made.
- Hydraulic: Limitations within the hydraulic analysis includes the assumption of minor system pipe slopes, conditions and materials of pipes, the absence of analysis for the major system within the Town limits and the general discretization of the 2D cells. Design characteristics of the minor system were based off of available data from the municipalities and the online Munisight GPS database, however due to limitations of historical documents some assumptions of pipe characteristics were made. Survey was completed for critical pieces of infrastructure as to accurately represent them. The major system within the Town limits was not completed as most issue locations were not impacted by the Town's major system, and locations that are impacted have a 2-D hydraulic element incorporated into their analysis. The 2D cells were discretized to a level to represent hydraulic performance, but is still limited to maintain a balance of model usability and performance. Similar to the hydrologic limitations these items introduce inaccuracy, but methodologies were applied to ensure that conservative estimations were made.
- Other: The system has some overall assumptions including the land is dry prior to a rain event, there are no capacity constrictions or blockages, the water level of Upper Therien Lake does not limit outlet capacity from the minor system, and the water level of Lake Garneau is normal and not generating flows into the Town's minor system. These assumptions are assumed to represent the systems performance under typical operating conditions.



Legend

- Town of St.Paul
- Alberta Parcel Mapping
- Alberta Quarter Section Boundary
- Alberta Section Boundary



Town of St. Paul

Figure 4.1
5 Year 4 Hour Storm Results
Town of St.Paul
Alberta, Canada

Scale: 1:20,000

0 200 400 600 800 1,000 Metres

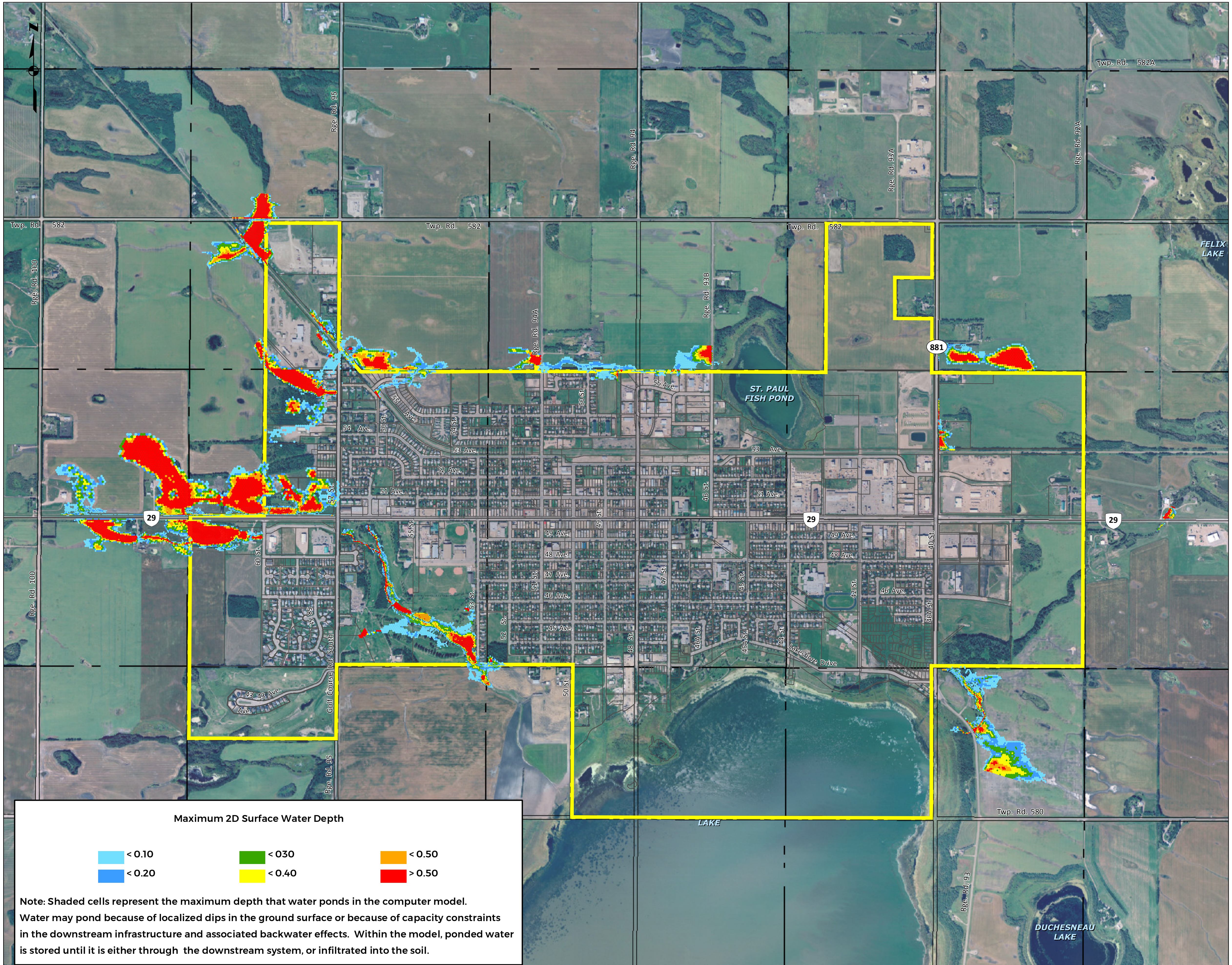
Universal Transverse Mercator (Zone 12)
North American Datum (1983)

wsp

Report By: MN
Drawn by: AN
Reviewed By: JM

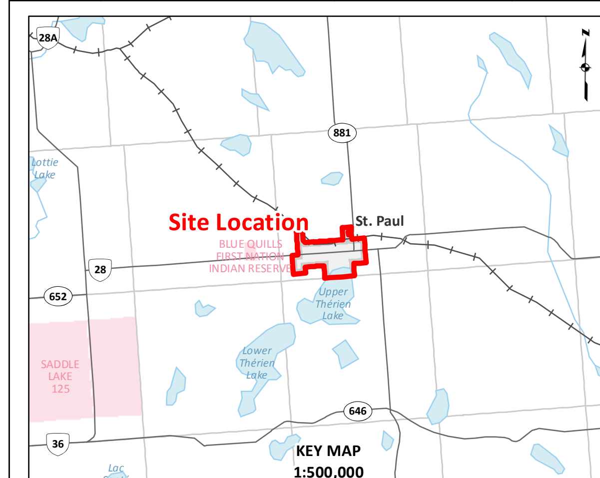
WSP Job #: 181-10286-00
Date: April 21, 2019
Office: Edmonton

Notes: Imagery Source: Valtus Imagery Service [2012]



Legend

- Town of St.Paul
- Alberta Parcel Mapping
- Alberta Quarter Section Boundary
- Alberta Section Boundary



Town of St. Paul

Figure 4.2
100 Year 4 Hour Storm Results

Town of St.Paul

Alberta, Canada

Scale: 1:20,000

0 0.2 0.4 0.6 0.8 1 Km

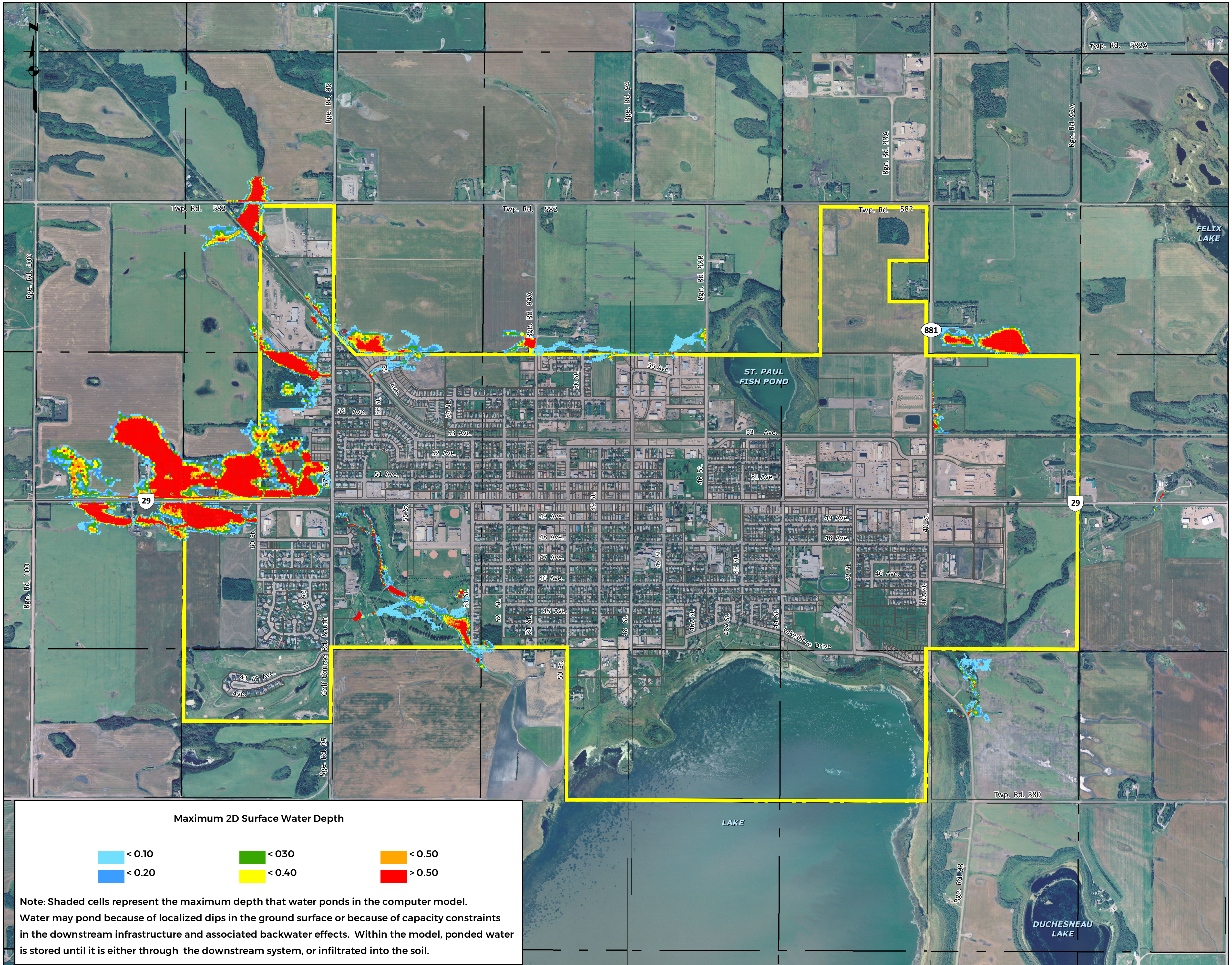
Universal Transverse Mercator (Zone 12)
North American Datum (1983)

wsp

Report By: MN
Drawn by: AN
Reviewed By: JM

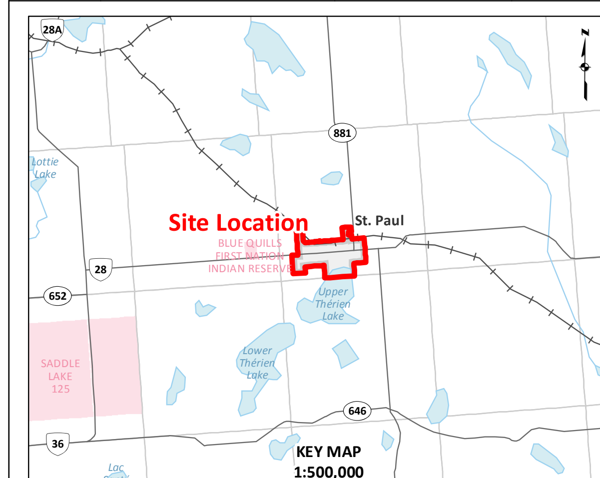
WSP Job #: 181-10286-00
Date: April 21, 2019
Office: Edmonton

Notes:Imagery Source: Valtus Imagery Service [2012]



Legend

Town of St.Paul
Alberta Parcel Mapping
Alberta Quarter Section Boundary
Alberta Section Boundary



Town of St. Paul

Figure 4.3
100 Year 24 Hour Storm Results

Town of St.Paul

Alberta, Canada

Scale: 1:20,000

0 0.2 0.4 0.6 0.8 1 Km

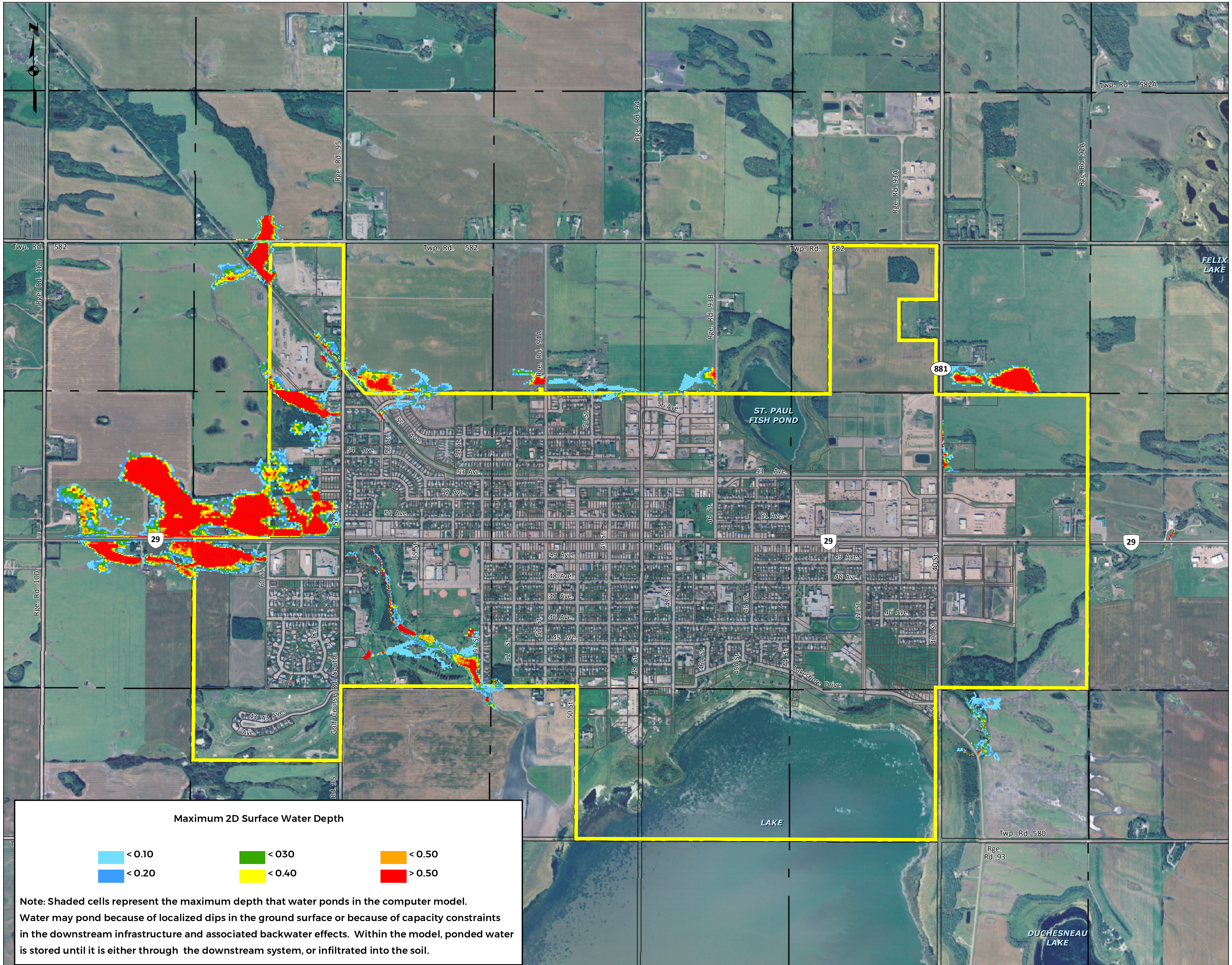
Universal Transverse Mercator (Zone 12)
North American Datum (1983)

wsp

Report By: MN
Drawn by: AN
Reviewed By: JM

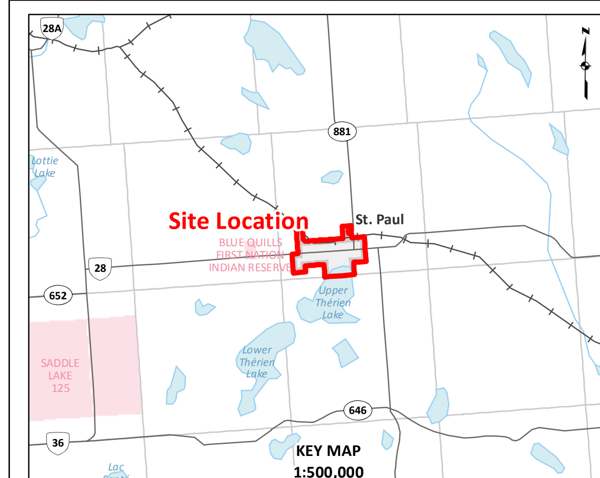
WSP Job #: 181-10286-00
Date: April 21, 2019
Office: Edmonton

Notes:Imagery Source: Valtus Imagery Service [2012]



Legend

- Town of St.Paul
- Alberta Parcel Mapping
- Alberta Quarter Section Boundary
- Alberta Section Boundary



Town of St. Paul

Figure 4.4
100 Year 24 Hour Climate Change Storm Results

Town of St.Paul

Alberta, Canada

Scale: 1:20,000

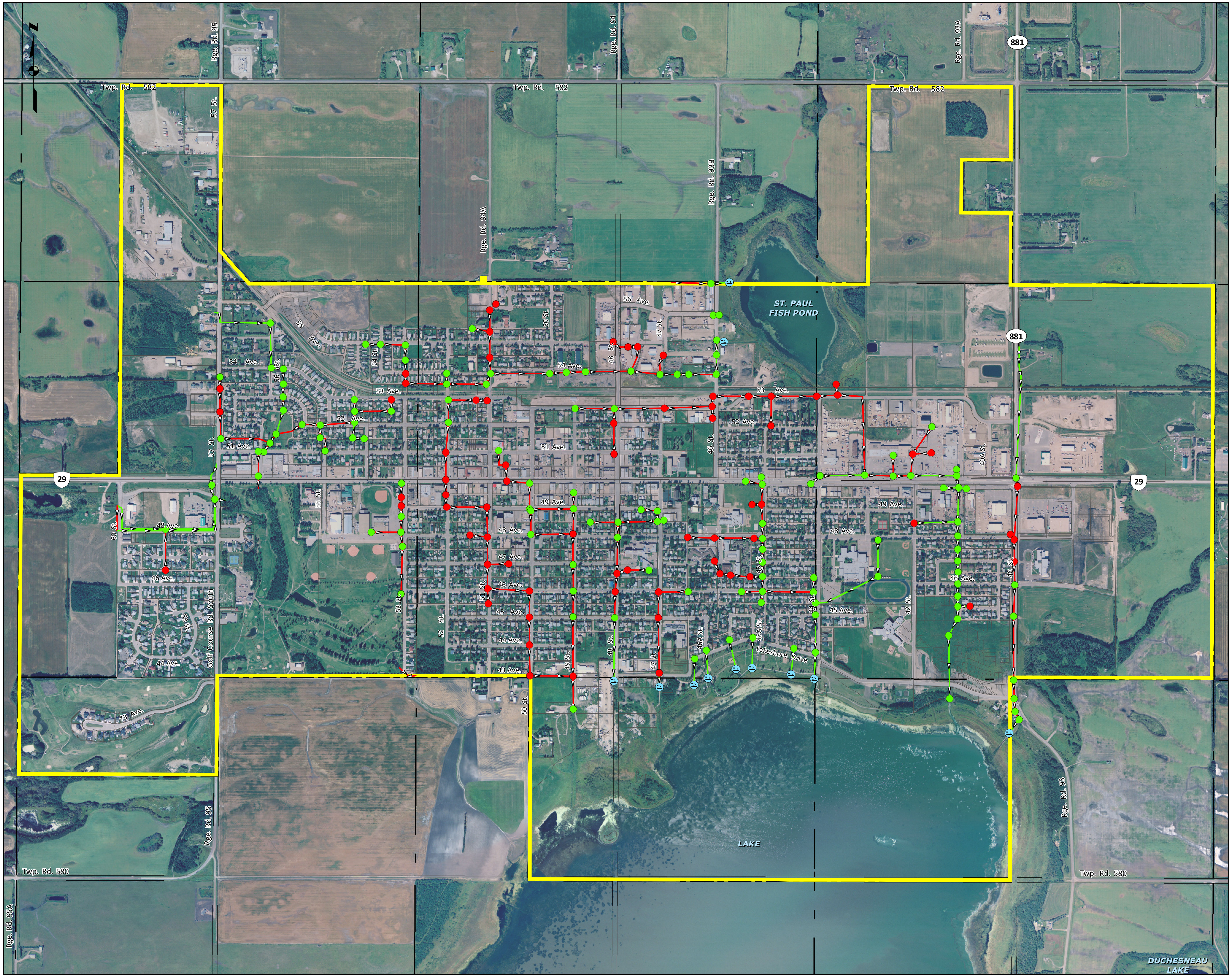
0 0.2 0.4 0.6 0.8 1 Km

Universal Transverse Mercator (Zone 12)
North American Datum (1983)

Report By: MN
Drawn by: AN
Reviewed By: JM

WSP Job #: 181-10286-00
Date: April 21, 2019
Office: Edmonton

Notes:Imagery Source: Valtus Imagery Service [2012]



Legend

- Alberta Parcel Mapping
- Alberta Quarter Section Boundary
- Alberta Section Boundary
- Outfalls

Junction

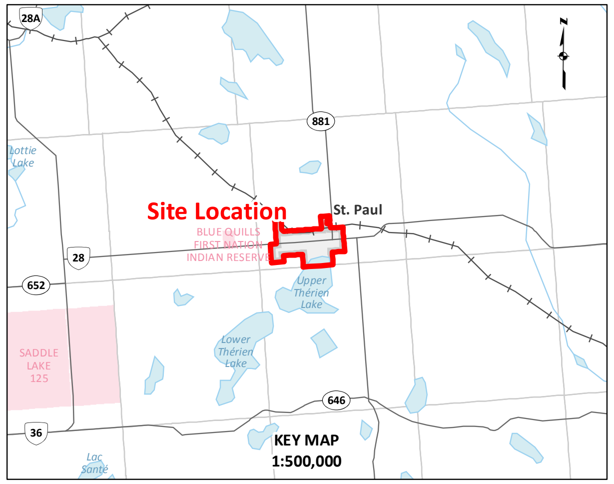
Maximum Ponded Depth

- =< 0.01m
- > 0.01m

Conduits

Max/Full Depth

- <1 m
- =>1 m
- Town of St.Paul



Town of St. Paul

Figure 4.5 Minor System Routing and 1:5 year 4 Hour Performance

Town of St.Paul
Alberta, Canada

Scale: 1:2,000

0 0.15 0.3 0.45 0.6 0.75 Km

Universal Transverse Mercator (Zone 12)
North American Datum (1983)

wsp

Report By: MN
Drawn by: AN
Reviewed By: JM

WSP Job #: 181-10286-00
Date: April 21, 2019
Office: Edmonton

Notes: Imagery Source: Valtus Imagery Service [2012]

5 CAPITAL PLAN

5.1 CAPITAL WORKS OPTIONS AND COST ESTIMATES

Table 5.1 Proposed upgrades summary

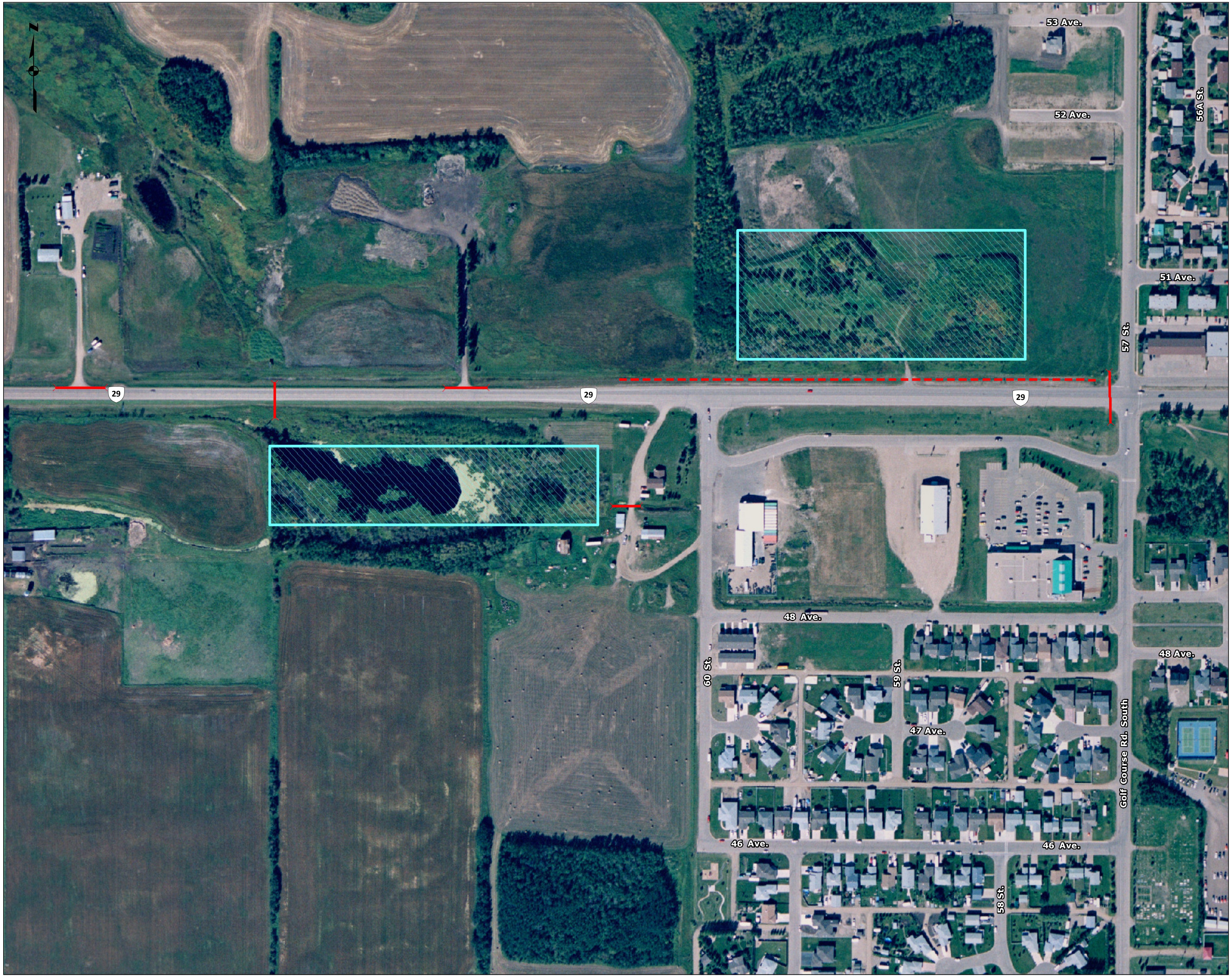
ID	LOCATION	ISSUE	RECOMMENDATION	COSTS	Priority
A	Highway 29 (West Boundary)	Localised flooding in low lying areas and wetlands. Poor conveyance in ditches and from low lying land into minor system.	Improve ditches along HWY 29 through maintenance and regrading. Culvert upgrades under HWY 29. Potential facility to manage flooding lands.	$1,000,000	High
B	Golf Course	Known flooding concerns at outlet of Golf Course due to lack of a sufficient outlet.	Install a proper outlet system, including upsized structure, and proper grading for emergency overflow. Alternative solutions of re-routing the outlet are dependent upon dispute resolution. Temporary solution could involve berming along the residential side.	$220,000	High
C	Township Road 582 (Northwest County)	Potential risk to rural residential property due to limited conveyance capacity of culverts.	Inspect culvert condition and potentially upgrade.	$135,000	Medium
D	57 Street (Northwest Boundary)	Localised pockets of ponding, but no major risk to neighbouring properties. Area would benefit from an upgraded system, and will require attention in future development.	Conduct general maintenance along Ironhorse trail ditch, and inspect culvert conditions. Provide proper outlet system for Ironhorse trail ditch. Conduct maintenance at wetland interface with Town's minor system. Incorporate stormwater management plan into future business development.	$425,000	Medium
E	Range Road 94A (North Boundary)	No immediate risk of flooding to residences. Area would benefit from a culvert upgrade under Range Road 94A.	Upgrading culvert under Range Road 94A would assist with conveyance. Continued general maintenance and inspection recommended.	$80,000	Low
F	Highway 881 (Northeast Boundary)	Effective drainage plan already in place, stormwater management plans in place from the Highway 29 & 881 Industrial ASP should be followed.	Follow plans in place for future development.	N/A	Low
G	Highway 29 (East County)	No expected flooding concerns to residences near the watercourse by the Highway 29 culverts. Watercourse has natural low areas and wetlands that may experience flooding during extreme events.	Ensure general maintenance and inspection occurs annually for culverts.	$1,500	Low
H	Range Road 93 (Southeast Boundary)	No expected flooding concerns for the watercourse near the Range road 93 culverts. Watercourse has natural low areas and wetlands that may experience flooding during extreme events.	Ensure general maintenance and inspection occurs annually for culverts.	$1,500	Low

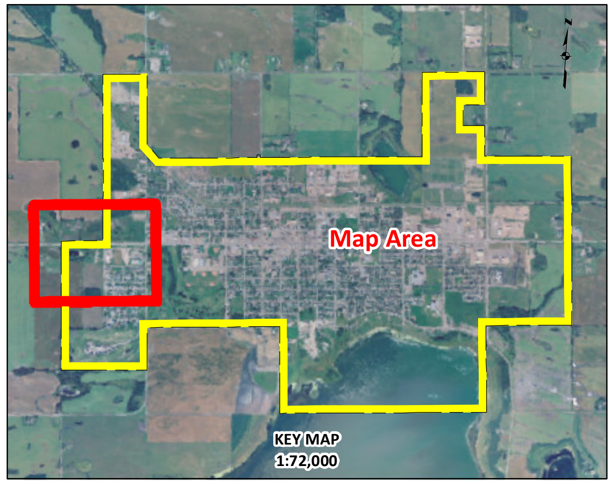
5.2 OPERATION AND MAINTENANCE

Along with these upgrades it is recommended that maintenance be a focus as to maintain performance in the stormwater system. The primary focus of maintenance should be culverts and ditches along the intermunicipal boundary. A yearly maintenance plan should be carried out at the beginning of spring along priority drainage pathways including:

1. Drive along the road looking out for and removing any large obstructions to drainage in the ditch.
2. Repairing or re-defining any sections of ditching that have eroded since the previous year.
3. Monitor each culvert and ensure the culvert is clear of debris and vegetation.
4. If required, dig out any soil that has blocked the culvert.
5. If a culvert has been significantly damaged over the previous year, replacing the culvert with the County's standard minimum sized culvert where possible should be considered.

On a regular basis, ditches should be mowed to ensure proper conveyance. Other sections should be cared for on a case by case basis as required or as issues are brought forward.





Town of St. Paul

Figure 5.1 - 2D Modelling Area A Proposed Upgrades

Town of St.Paul

Alberta, Canada

Scale: 1:3,500

0 0.035 0.07 0.105 0.14 0.175 Km

Universal Transverse Mercator (Zone 12)

North American Datum (1983)

wsp

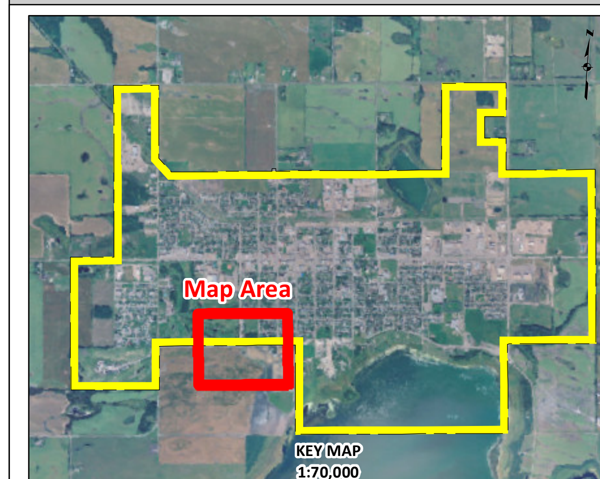
Report By: MN
Drawn by: AN
Reviewed By: JM

WSP Job #: 181-10286-00
Date: April 21, 2019
Office: Edmonton

Notes:Imagery Source: Valtus Imagery Service [2012]

Legend

- Regrading Required
- Culvert(s) to be Upgraded



Town of St. Paul

Figure 5.2 - 2D Modelling Area B Proposed Upgrades

Town of St.Paul

Alberta, Canada

Scale: 1:2,500

0 0.025 0.05 0.075 0.1 0.125 Km

Universal Transverse Mercator (Zone 12)
North American Datum (1983)

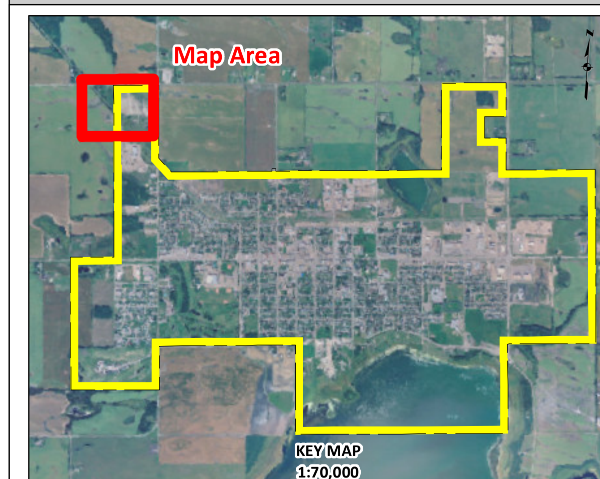
Report By: MN
Drawn by: AN
Reviewed By: JM

WSP Job #: 181-10286-00
Date: April 21, 2019
Office: Edmonton

Notes:Imagery Source: Valtus Imagery Service [2012]

Legend

- Culvert(s) to be Upgraded
- Re-Define Ditch



Town of St. Paul

Figure 5.3 - 2D Modelling Area C Proposed Upgrades

Town of St.Paul

Alberta, Canada

Scale: 1:2,000

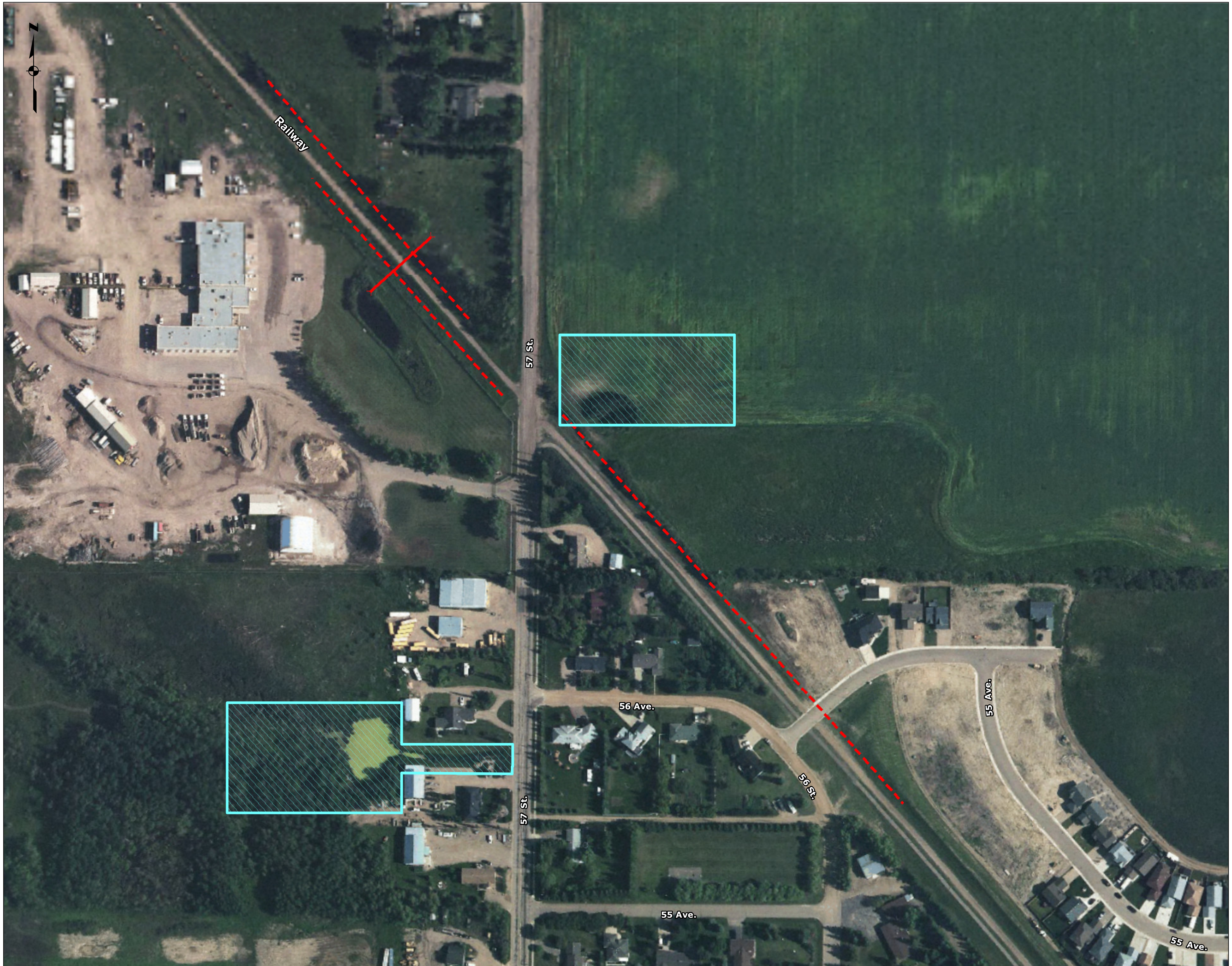
0 20 40 60 80 100 Metres

Universal Transverse Mercator (Zone 12)
North American Datum (1983)

Report By: MN
Drawn by: AN
Reviewed By: JM

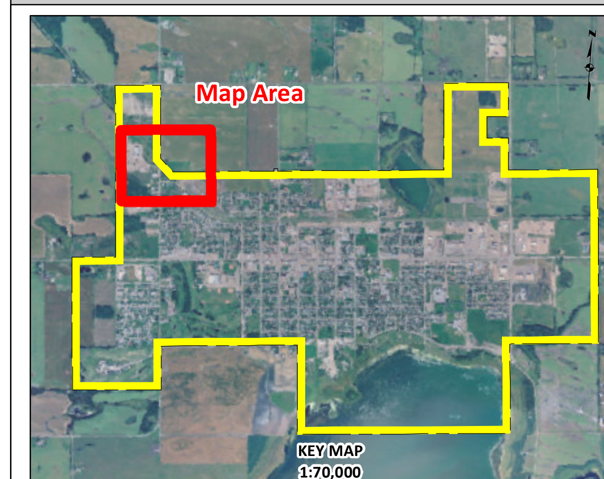
WSP Job #: 181-10286-00
Date: April 21, 2019
Office: Edmonton

Notes:Imagery Source: Valtus Imagery Service [2012]



Legend

- Maintenance and Upgrades Areas
- Culvert(s) to be Upgraded
- Re-Define Ditch



Town of St. Paul

Figure 5.4 - 2D Modelling Area D Proposed Upgrades

Town of St.Paul

Alberta, Canada

Scale: 1:2,500

0 25 50 75 100 125 Metres

Universal Transverse Mercator (Zone 12)
North American Datum (1983)

WSP

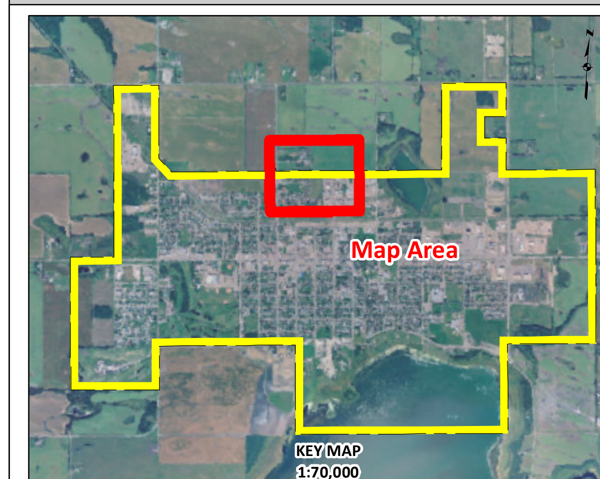
Report By: MN
Drawn by: AN
Reviewed By: JM

WSP Job #: 181-10286-00
Date: April 21, 2019
Office: Edmonton

Notes:Imagery Source: Valtus Imagery Service [2012]

Legend

- Culvert(s) to be Upgraded
- Re-Define Ditch



Town of St. Paul

Figure 5.5 - 2D Modelling Area E Proposed Upgrades

Town of St.Paul

Alberta, Canada

Scale: 1:2,500

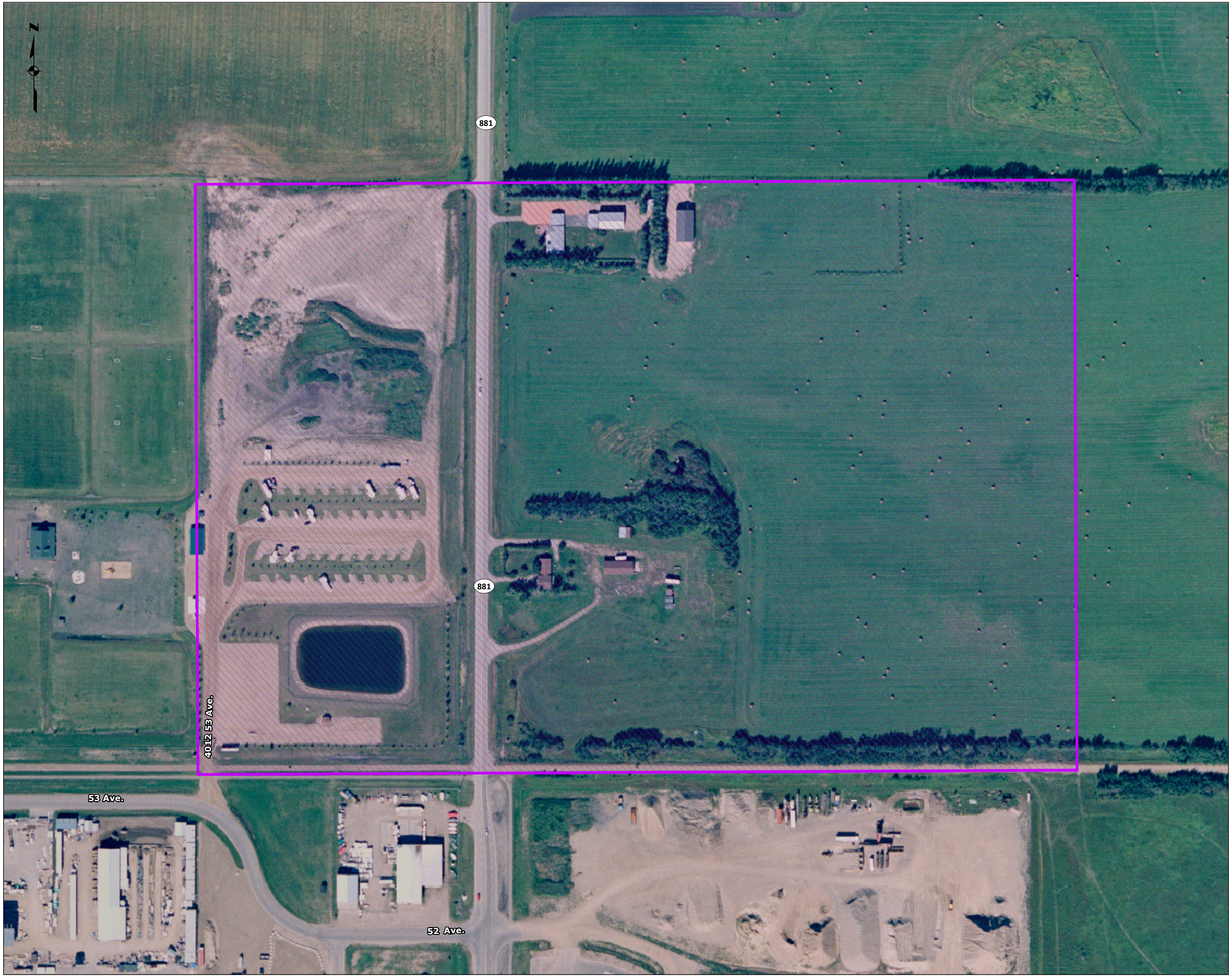
0 25 50 75 100 125 Metres

Universal Transverse Mercator (Zone 12)
North American Datum (1983)

Report By: MN
Drawn by: AN
Reviewed By: JM

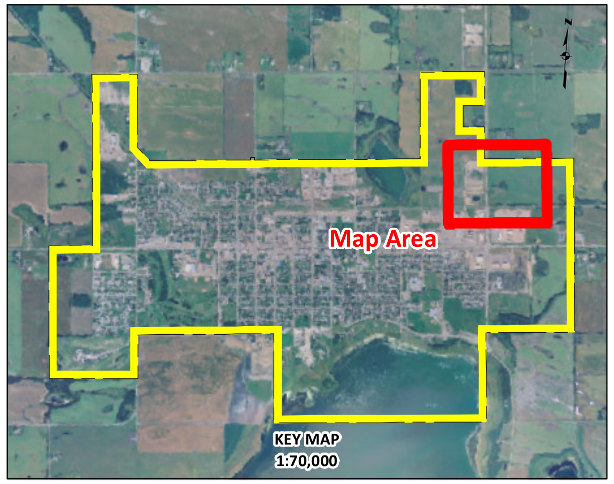
WSP Job #: 181-10286-00
Date: April 21, 2019
Office: Edmonton

Notes:Imagery Source: Valtus Imagery Service [2012]



Legend

Future Development



Town of St. Paul

Figure 5.6 - 2D Modelling Area F Proposed Upgrades

Town of St.Paul

Alberta, Canada

Scale: 1:2,750

0 25 50 75 100 125 Metres

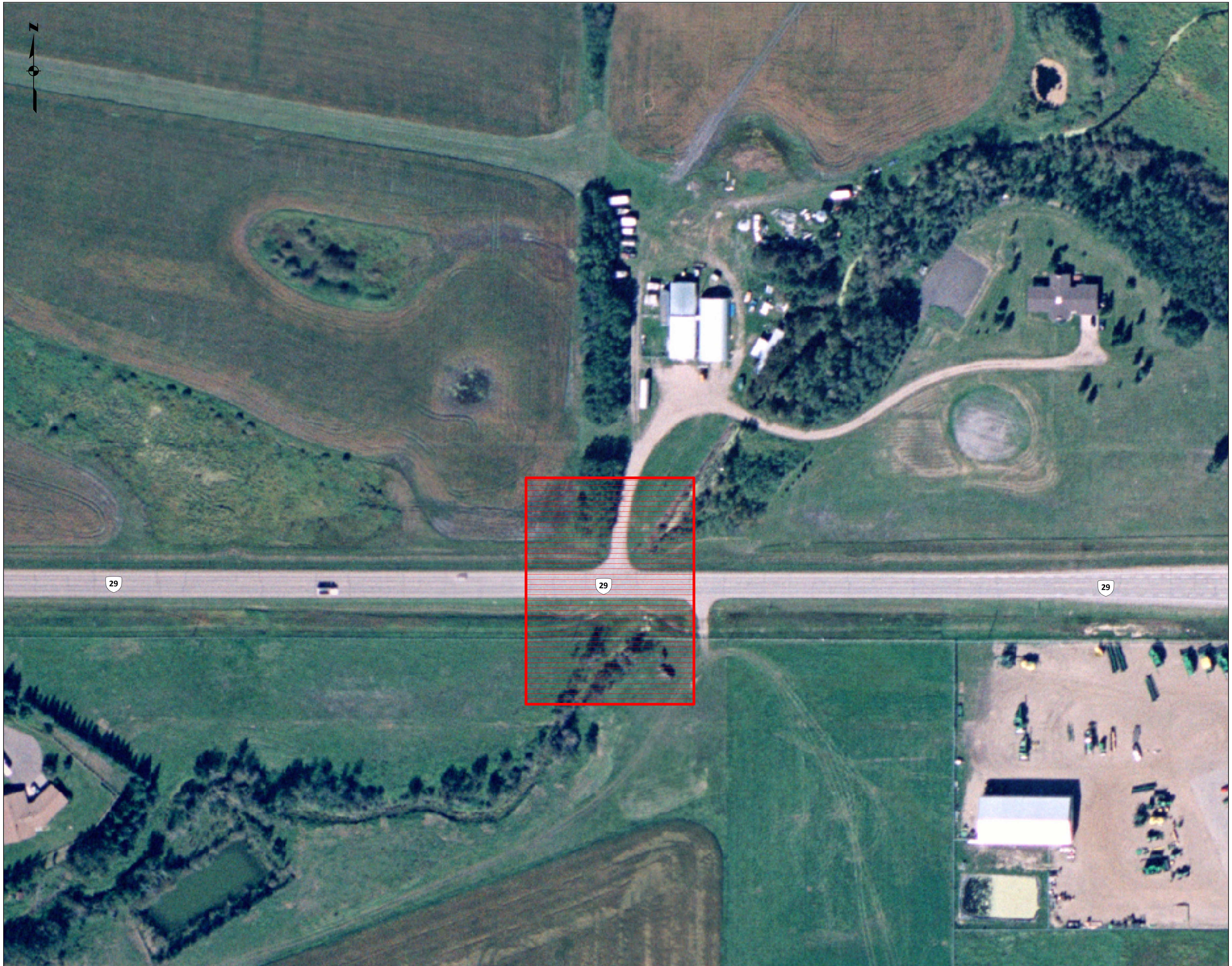
Universal Transverse Mercator (Zone 12)

North American Datum (1983)

Report By: MN
Drawn by: AN
Reviewed By: JM

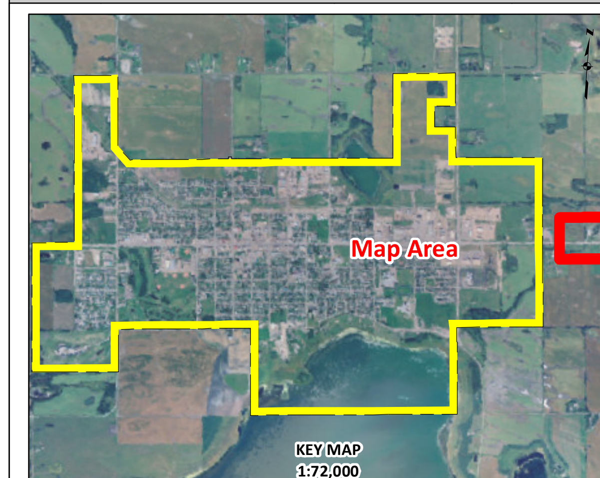
WSP Job #: 181-10286-00
Date: April 21, 2019
Office: Edmonton

Notes:Imagery Source: Valtus Imagery Service [2012]



Legend

General Maintenance



Town of St. Paul

Figure 5.7 - 2D Modelling Area G Proposed Upgrades

Town of St.Paul

Alberta, Canada

Scale: 1:1,500

0 10 20 30 40 50 Metres

Universal Transverse Mercator (Zone 12)

North American Datum (1983)

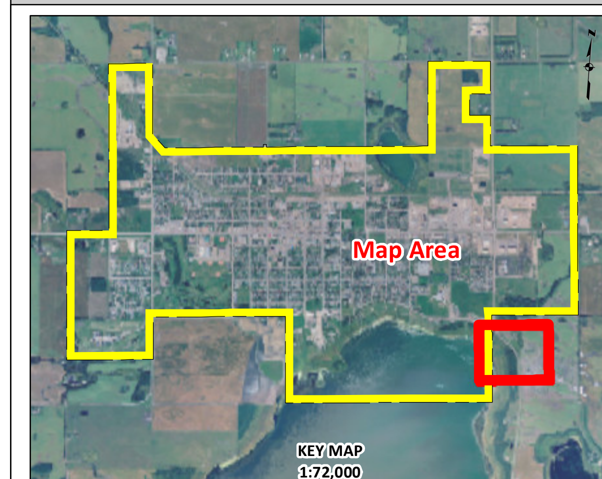
Report By: MN
Drawn by: AN
Reviewed By: JM

WSP Job #: 181-10286-00
Date: April 21, 2019
Office: Edmonton

Notes:Imagery Source: Valtus Imagery Service [2012]

Legend

General Maintenance



Town of St. Paul

Figure 5.8 - 2D Modelling Area H Proposed Upgrades

Town of St.Paul

Alberta, Canada

Scale: 1:2,000

0 20 40 60 80 100 Metres

Universal Transverse Mercator (Zone 12)
North American Datum (1983)

Report By: MN
Drawn by: AN
Reviewed By: JM

WSP Job #: 181-10286-00
Date: April 21, 2019
Office: Edmonton

Notes:Imagery Source: Valtus Imagery Service [2012]

6 CONCLUSION

WSP Canada Group Limited was retained by the Town of St. Paul and County of St. Paul to undertake the preparation of an Intermunicipal Stormwater Management Plan. This report has provided information that is intended to address any deficiencies in the level of service of the existing stormwater management system and to determine which upgrades may be required to address existing and future servicing needs. The report includes an analysis of the existing stormwater management system, survey of locations of importance, climate change analysis, hydrologic and hydraulic modelling, remedial recommendations, and a capital plan.

The assessment of the system included the evaluation of the existing servicing scenarios for a 100 year 24 hour design event, and future scenario with a climate adjusted 100 year 24 hour design event. This return event and duration present a severe long term event that will generate the most runoff and critical flooding conditions for the intermunicipal boundary.

The study has determined the following key conclusions and recommendations:

- The stormwater management system is performing satisfactory overall, and has limited risks to residences. There are notable areas that can be improved to mitigate concerns, and future development will require the implementation of additional stormwater management infrastructure. Annual general maintenance is key in maintaining an efficient and effective system.
- The main area of concern for the Town and County is the golf course and its upstream contributing basin. Upgrades are recommended to ensure an efficient outlet is provided from the golf course, and that future development within that basin ensures appropriate control is provided to manage runoff.
- The climate change analysis presented an increase in rainfall in the future, however the current St. Paul guidelines indicate the use of the City of Edmonton’s Municipal Airport IDF. This IDF data is greater than the expected baseline for the Town of St. Paul, and would be approximately equivalent to accounting for a ‘near-future (2025-2075), low emissions’ scenario as outlined in the Climate Change report.

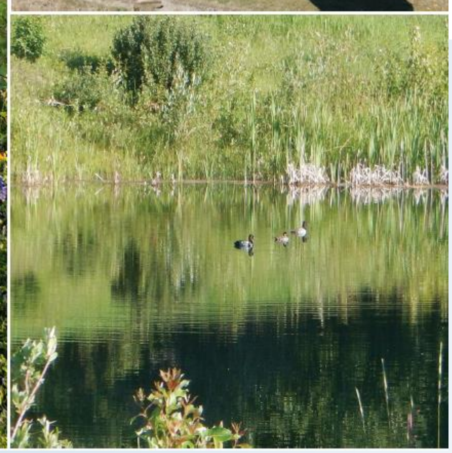
APPENDIX

A

CLIMATE CHANGE REPORT

Intermunicipal Stormwater Management Plan: Town of St. Paul & County of St. Paul

Phase 1: Project Initiation and Data Gathering: Climatology



November 2018

Project number: 181-10286-00_100_102

wsp

Prepared by

Jean-Philippe Martin, Ph.D. Env. Sci.

Climate change specialist, WSP Canada (Environment - Quebec)

TABLE OF CONTENT

CONTEXT

The various drainage channels servicing the St. Paul Town & County are operated under a complicated network of surficial channel, which is generally collected and conveyed to the southeast, into Upper Therian Lake. Climate change is likely to increase the probability and severity of extreme rainfall events bringing the community additional risks that must be recognized and acted upon. Therefore, this report presents a climatological perspective on the region, to be integrated into the Stormwater Management Plan.

METHODOLOGY

The general constraints were the following:

— *Time*: The climate conditions were projected for 50-year timeslots at three steps of approximately 25 years (2006-2056; 2025-2075; 2050-2095/2100 depending on the analysis).
— *Climate scenarios*: The climate model outputs for two greenhouse gas (GHG) emission scenarios were considered: low emission (RCP 4.5: GHG emissions peak around 2040, considered optimistic) and high emission (RCP 8.5: continuous rise in GHG until the end of 21st century, considered status quo).

Then, the analysis contains two sections: local climate scenarios and hydrology-oriented (IDF) curves.

I. LOCAL CLIMATE SCENARIOS

To provide specific information about the expected changes in climate for the Town and County's territory, and their potential impacts on stormwater management, the projected trends in climate are presented at the local scale. A set of 8 climate indices relative to temperature and precipitation changes was selected:

1. Mean annual temperature (°C);
2. Mean annual precipitation (mm);
3. Mean spring precipitation (mm);
4. Heavy precipitation days >10 mm (nb);
5. Heavy precipitation days >20 mm (nb);
6. Very cold days <-30 °C (nb);
7. Frost-free season (days);
8. Freeze-thaw cycles (nb).

The dataset was extracted from the Climate Atlas of Canada, which presents statistically downscaled data from Global Climate Models (also called GCMs). Further methodological details are presented in the section.

II. HYDROLOGY-ORIENTED CLIMATE ANALYSIS

Second, a hydrology-oriented analysis allowed to produce climate adapted intensity-duration-frequency (IDF) precipitation curves. These curves consist in adjusting existing (historically-based) curves by considering expected changes in precipitations. The aim of climate adapted IDFs is to design hydraulic components based on future water regimes instead of relying solely on past data. Further methodological details are presented in the section.

Then, the potential of regional climate models and uncertainties are discussed, before concluding with recommendations.

LOCAL CLIMATE SCENARIOS FROM STATISTICAL DOWNSCALING: THE CLIMATE ATLAS OF CANADA

DATA AND ANALYSIS

The Climate Atlas of Canada[1] (CAC) is an interactive map presenting climate projections from the Pacific Climate Impacts Consortium, acquired through a statistical downscaling of 12 Global Climate Models (GCMs) projections. Climate projections are available for approximately 130 km x 130 km gridpoints or as point-values for different cities. The watershed being small (48.23 km^2) and centered around the municipality of St. Paul, data from St. Paul were extracted for the analysis. The CAC provides annual projections for climate and extreme weather variables under two different GHG emission scenarios (low: RCP4.5 or high: RCP8.5). For each year, the CAC provides the user with the minimum, the average and the maximum outputs from the different model iteration.

The general legend of the levels of likelihood of change for a climate variable is presented in Table 1. Classes are from the Climate Change Lens (Resilience assessment) Guidelines from Infrastructure Canada (2018). We added a confidence level to likelihood, which qualifies the homogeneity of the 12 overall models in relation to the historical distribution. This level of confidence allows to appreciate the uncertainty related to the variability of climate models.

Table 1 Legend of the climate trend analysis

LEVEL	LIKELIHOOD[1]	CONFIDENCE
1 Very low	**1- Very low** *Not likely to occur in period *Unlikely to become critical/beneficial in period	**Low** The interval of the ensemble of models presents a variability opposite to the trend relative to current mean
2 Low	**2- Low** *Likely to occur once between 30-50 yrs *Likely to become critical/beneficial between 30-50 yrs	
3 Moderate	**3- Moderate** *Likely to occur once between 10-30 yrs *Likely to become critical/beneficial between 10-30 yrs	**Medium** The interval of the ensemble of models presents a single limit opposite to the trend relative to current mean
4 High	**4- High** *Likely to occur at least once in a decade *Likely to become critical/beneficial in a decade	**High** The interval of the ensemble of models presents a good coherence with the trend relative to the current mean
5 Very high	**5- Very high** *Likely to occur at least once or more annually *Likely to become critical/beneficial within several years	
[1]**Source : Infrastructure Canada (2018)** Climate Change Lens**.**		

[1] http://climateatlas.ca

RESULTS

The climate trends applicable to the Town of St.Paul are detailed in Table 2.

HIGHLY LIKELY WARMER TEMPERATURES

The mean annual temperatures are expected to rise from 1.8-2.1 °C to more than 3 °C, for immediate future and far future respectively. This is also consistent with rising winter minimum and summer maximum temperatures, but also fewer very cold days (>10 less days with temperatures below -30 °C per year in the far future), reduced number of freeze-thaw cycles and a shorter winter (increased number of frost-free days).

In terms of data quality, the likelihood and confidence levels are very high and high for all the temperature-related variables.

LIKELY MORE PRECIPITATION

According to the Climate Atlas data, the precipitation regime is likely to change overall, but there appears to be a great variability among the climate models. Overall, the mean annual change corresponds to more than 40 to 50 mm per year over the far future, respectively for low and high carbon emission scenarios. The maximum increase would occur during spring season (an increase of 23-32 mm per year). There does not appear to be a trend for the summer season (data not presented). In terms of data quality, the high variability across the models attenuates the ensemble mean, which only provides a moderate likelihood and a medium confidence about the trends.

UNCERTAINTIES ABOUT EXTREME PRECIPITATION EVENTS

In terms of extreme events, the mean would rise about 1 additional day with more than 10 mm or 20 mm of liquid precipitation, but the variability between models ranges significantly (the most pessimistic scenario would be up to +5 days / year). This data should not be considered reliable, as described in the next section. We also identified a data gap about the atmospheric instability conditions, like thunderstorms, which can influence the hazards related to heavy rain.

Moreover, the statistical downscaling of the Atlas may attenuate some high precision dynamics on a spatial scale (such as topography and surface roughness), or temporal scale (monthly balance and cumulative series of storms affecting the watershed given the timing of spring freshet). This is supported by a global rise in extreme events intensity, may it be drought or heavy rain (IPCC, 2012)[2]. These are critical for extreme flow dimensioning. This estimate for precipitation change is therefore considered conservative. Further modelling is required about those climate variables under future conditions. Dynamical downscaling (other said regional climate modelling) may be of interest to reduce this uncertainty. See last section for more details.

[2] https://www.ipcc.ch/pdf/special-reports/srex/SREX_Full_Report.pdf

Table 2 Likelihood and confidence about climate trends for the immediate, near and far future according to two climate scenarios

CLIMATE VARIABLE	BASELINE 1950-2005	IMMEDIATE FUTURE 2006-2056		NEAR FUTURE 2025-2075		FAR FUTURE 2050-2095		LIKELIHOOD / *CONFIDENCE*
Mean [min;max]		**Low carbon (RCP 4.5)**	**High carbon (RCP 8.5)**	**Low carbon (RCP 4.5)**	**High carbon (RCP 8.5)**	**Low carbon (RCP 4.5)**	**High carbon (RCP 8.5)**	
1. Mean annual temperature (°C)	1.2	3	3.3	3.8	4.5	4.5	6.0	**Very high**: The mean and the intervals are rising at all seasons under both scenarios. This change will be critical in the near future. Despite a slight uncertainty among the model, the future intervals are significantly distinct from the current conditions.
	[-0.6;2.9]	[0.9;5.0]	[1.2;5.2]	[1.6;5.8]	[2.2;6.7]	[2.3;6.6]	[3.4;8.6]	*High confidence*
2. Mean annual precipitation (mm)	429	453	450	461	467	468	479	**Moderate**: In both scenarios, the mean trend and the intervals are rising. However, a reduction is expected for summer. Those changes will be more evident in the far future. The intensity of the changes only represents a slight proportion of the total, and the models involve a great variability that could go against the general trend.
	[311;553]	[321;605]	[317;593]	[323;614]	[326;623]	[327;628]	[332;645]	*Medium confidence*
3. Mean spring precipitation (mm)	81	94	94	98	103	104	113	**High**: Spring is the season where the precipitations are expected to increase the most, in both scenarios. The mean and the intervals are rising under both scenarios, but the intervals are very large and overlap from present to far future conditions.
	[41;135]	[50;162]	[46;168]	[51;168]	[50;186]	[54;184]	[55;209]	*Medium confidence*
4. Heavy precipitation days >10 mm (nb)	9.2	10.2	10.1	10.4	10.6	10.4	10.9	**Low**: the slight increase in the number of heavy precipitation days is insignificant compared to the width of the confidence intervals.
	[4.2;15.0]	[4.5;17.0]	[4.3;16.5]	[4.7;17.0]	[4.6;17.3]	[4.6;17.0]	[5.0;18.0]	*Low confidence*

CLIMATE VARIABLE	BASELINE 1950-2005	IMMEDIATE FUTURE 2006-2056		NEAR FUTURE 2025-2075		FAR FUTURE 2050-2095		LIKELIHOOD / *CONFIDENCE*
5. Heavy precipitation days >20 mm (nb)	1.9	2.3	2.3	2.4	2.5	2.5	2.7	**Low**: the slight increase in the number of heavy precipitation days is insignificant compared to the width of the confidence intervals.
	[0.2;4.7]	[0.4;5.7]	[0.3;4.9]	[0.4;5.6]	[0.4;5.4]	[0.4;5.8]	[0.5;6.2]	*Low confidence*
6. Very cold days <-30 °C (nb)	14.5	7.4	6.7	5.2	3.4	3.8	1.9	**Very high**: The mean and the intervals are decreasing. The changes will be obvious in the near future. The future intervals are significantly distinct from the current conditions.
	[5.8;30.1]	[1.7;22.4]	[2.0;22.6]	[1.1;18.0]	[0.9;17.8]	[0.6;17.4]	[0.4;13.5]	*High confidence*
7. Frost-free season (days)	102.8	122.1	128.4	128.1	138.6	134.1	147.7	**Very high**: The mean and the intervals are increasing. The changes will be obvious in the near future. The future intervals are significantly distinct from the current conditions.
	[82.7;119.3]	[97.2;142.9]	[103.8;144.0]	[105.6;149.9]	[114.8;155.6]	[110.3;152.2]	[129.3;170.9]	*High confidence*
8. Freeze-thaw cycles (nb)	81.8	76.4	74.7	74.0	70.1	73.6	65.5	**High**: The mean and the intervals are rising under both scenarios, but the intervals are very large and overlap from present to far future conditions.
	[61.4;99.4]	[55.3;94.9]	[52.9;91.0]	[53.5;91.5]	[49.3;85.2]	[52.4;90.4]	[46.6;79.0]	*Medium confidence*

Results for the historical period and 2006-2056 are computed from 12 CMIP5 global climate models, statistically downscaled to 10 km x 10 km pixels and then averaged at the scale of the National Topographic Service's (NTS) 1:250,000 map grids. Point-value data for the Town of St. Paul was computed using nearest-neighbor analysis. The low emission scenario (RCP 4.5) suppose a stabilisation of GHG emissions prior to 2100. The high emission scenario (RCP 8.5) suppose an increase of GHG emissions until 2100. The intervals represent the minimum and maximum outputs from the various models.

OPPORTUNITIES AND LIMITATIONS

The data from the Climate Atlas of Canada is easily available. The annual resolution of the projections allows for analysis on the time span and the time steps that fit the needs of the project. However, the statistical downscaling algorithm used in the Atlas is relatively simple. It uses historical datasets to simulate the daily variability in the monthly projected data. This means that the projected data reflect the changes in monthly, seasonal or annual means, but does not reflect the changes in daily climate variability. As a result, the authors acknowledge that "the data is not well suited for many water management and engineering applications that require daily inputs"[3].

For example, the Climate Atlas projects little change in heavy precipitation days, as illustrated in Table 2. However, there is a high level of consensus amongst the scientific community regarding an increase in extreme precipitation events. Therefore, the authors of the Climate Atlas have low confidence in the heavy precipitation day values.

[3] https://climateatlas.ca/important-data-notes-and-limitations

HYDROLOGY-ORIENTED CLIMATE INFORMATION: IDF CC TOOL

DATA AND ANALYSIS

The IDF_CC tool[4] was developed by scientists at the University of Waterloo. They provide projected IDFs for gauged and ungauged locations across Canada, based on 33 climate models (9 bias-corrected, statistically downscaled models at the 10-km x 10-km scale or 24 GCM datasets). We based our analysis on the mean of the 9 downscaled models, because of their more appropriate resolution. These updated IDFs are estimated in three steps, by (i) establishing a statistical relationship between annual maximum precipitation (AMPs) of the base period GCM and the future period GCM, (ii) establishing a statistical relationship for the IDF of the baseline period and (iii) update the IDF curves for future periods.

The IDF_CC provides return periods (2, 5, 10, 25, 50 and 100 years) for total precipitation (mm) or intensity rate (mm/h) for 5, 10, 15, 30 minutes and 1, 2, 6, 12 and 24 hours precipitation events. Data are available for the historical period and for any periods of 50 years from 2006 to 2100. Emission scenarios available are RCP 2.6 (GHG emissions peak around 2010-2020, very optimistic), RCP 4.5 (GHG emissions peak around 2040, optimistic) and RCP 8.5 (continuous rise in GHG, or status quo).

RESULTS

The projected changes in maximum annual precipitations are presented in Tables 3, 4 and 5 for the immediate, near and far futures, respectively. Table 6 and Figure 1 summarize the increase in extreme precipitation events for low and high emission scenarios.

HIGHLY LIKELY INCREASE IN THE INTENSITY OF EXTREME PRECIPITATION EVENTS

Low-frequency precipitation events will likely witness the highest increase in their intensity. For example, on average, the projected intensity of 100-year return period precipitation events under the high emission scenario is up to 30% higher than the baseline value, based on historical data. For the most catastrophic scenario (maximum projection under the high emission scenario), the increase in intensity of the 100-year return period precipitation events can be 86% higher than the baseline value .

In terms of data quality, the likelihood and the confidence of witnessing an increase in extreme precipitation events are very high. For example, figure two presents the uncertainties in 100-year return period projected precipitation intensities under high emission scenario, based on the distribution of the 9 model outputs. For 1440-minute precipitation events (which corresponds to 24 hours), only the minimum (102.58 mm) is under the historical value (106.63 mm).

THE INCREASE IN THE INTENSITY OF EXTREME PRECIPITATION COULD BE HIGHER

The analysis above is based on the mean output of the 9 downscaled models. However, the uncertainty around this mean value is high. For the 100-year return period, 1440-minute precipitation projected intensity under high

[4] https://www.idf-cc-uwo.ca

emission scenario, the maximal output of the model is 198.25 mm, which represents an increase of 85.9% compared to the baseline data.

In that regard, a conservative approach to climate change-induced risk related to stormwater would be to add a security margin when calibrating the stormwater drainage infrastructures of St. Paul on the average IDF under high emission scenario.

Table 3 Projected precipitation amount (mm) for St. Paul at different timesteps and return periods for the period 2006-2056 under 2 GHG scenarios

Time (min)	Return periods																	
	2-year			5-year			10-year			25-year			50-year			100-year		
	B	**L**	**H**	**B**	**L**	**H**	**B**	**L**	**H**	**B**	**L**	**H**	**B**	**L**	**H**	**B**	**L**	**H**
5	5.23	5.67	5.76	7.81	8.52	8.51	9.71	10.86	10.73	12.34	13.79	14.28	14.49	15.90	17.39	16.82	18.30	20.95
10	8.41	9.13	9.28	12.60	13.73	13.72	15.37	17.20	16.99	18.87	21.10	21.83	21.48	23.56	25.77	24.07	26.18	29.98
15	10.23	11.10	11.28	15.36	16.75	16.73	18.68	20.90	20.65	22.81	25.50	26.39	25.84	28.35	31.00	28.84	31.37	35.92
30	12.10	13.13	13.34	18.40	20.07	20.04	22.84	25.55	25.24	28.81	32.21	33.33	33.56	36.82	40.26	38.60	41.99	48.07
60	14.24	15.45	15.70	22.55	24.59	24.56	30.24	33.84	33.43	43.50	48.63	50.32	56.80	62.31	68.14	73.92	80.41	92.07
120	18.11	19.65	19.97	26.85	29.28	29.24	34.94	39.10	38.63	48.93	54.70	56.61	62.99	69.11	75.57	81.15	88.27	101.06
360	26.96	29.25	29.73	38.68	42.17	42.12	48.06	53.78	53.12	62.16	69.49	71.91	74.53	81.76	89.41	88.68	96.47	110.45
720	33.29	36.12	36.70	48.65	53.05	52.98	60.70	67.92	67.09	78.40	87.65	90.71	93.53	102.62	112.22	106.63	116.00	132.81
1440	40.57	44.01	44.72	55.47	60.48	60.41	66.32	74.21	73.31	81.34	90.93	94.10	96.53	102.62	112.22	106.63	116.00	132.81

B: baseline L: low emission (RCP4.5) H: high emission (RCP8.5)

Table 4 Projected precipitation amount (mm) for St. Paul at different timesteps and return periods for the period 2025-2075 under 2 GHG scenarios

Time (min)	Return periods																	
	2-year			5-year			10-year			25-year			50-year			100-year		
	B	**L**	**H**	**B**	**L**	**H**	**B**	**L**	**H**	**B**	**L**	**H**	**B**	**L**	**H**	**B**	**L**	**H**
5	5.23	5.50	5.97	7.81	8.39	8.95	9.71	10.83	11.57	12.34	14.11	15.60	14.49	16.79	18.44	16.82	19.25	21.99
10	8.41	8.85	9.62	12.60	13.52	14.44	15.37	17.15	18.32	18.87	21.58	23.86	21.48	24.88	27.32	24.07	27.54	31.47
15	10.23	10.76	11.69	15.36	16.49	17.61	18.68	20.85	22.27	22.81	26.08	28.83	25.84	29.93	32.87	28.84	33.00	37.70
30	12.10	12.73	13.83	18.40	19.75	21.09	22.84	25.49	27.22	28.81	32.95	36.42	33.56	38.88	42.69	38.60	44.17	50.47
60	14.24	14.98	16.28	22.55	24.21	25.85	30.24	33.75	36.04	43.50	49.75	54.99	56.80	65.80	72.25	73.92	84.58	96.65
120	18.11	19.05	20.70	26.85	28.82	30.77	34.94	39.01	41.65	48.93	55.96	61.85	62.99	72.98	80.13	81.15	92.85	106.10
360	26.96	28.36	30.82	38.68	41.51	44.33	48.06	53.64	57.28	62.16	71.09	78.58	74.53	86.35	94.81	88.68	101.47	115.95
720	33.29	35.02	38.05	48.65	52.22	55.76	60.70	67.75	72.34	78.40	89.67	99.12	93.53	108.37	118.99	106.63	122.01	139.42
1440	40.57	42.67	46.37	55.47	59.53	63.57	66.32	74.03	79.04	81.34	93.02	102.82	96.53	108.37	118.99	106.63	122.01	139.42

B: baseline L: low emission (RCP4.5) H: high emission (RCP8.5)

Table 5 Projected precipitation amount (mm) for St.Paul at different timesteps and return periods for the period 2050-2100 under 2 GHG emission scenarios

Time (min)	Return periods																	
	2-year			5-year			10-year			25-year			50-year			100-year		
	B	L	H	B	L	H	B	L	H	B	L	H	B	L	H	B	L	H
5	5.23	5.68	6.24	7.81	8.69	9.60	9.71	11.33	11.92	12.34	13.94	15.21	14.49	16.62	17.95	16.82	19.60	20.91
10	8.41	9.14	10.05	12.60	14.01	15.47	15.37	17.94	18.87	18.87	21.32	23.26	21.48	24.63	26.60	24.07	28.05	29.92
15	10.23	11.12	12.23	15.36	17.09	18.87	18.68	21.81	22.94	22.81	25.77	28.11	25.84	29.64	32.00	28.84	33.60	35.85
30	12.10	13.15	14.46	18.40	20.47	22.60	22.84	26.66	28.04	28.81	32.55	35.50	33.56	38.50	41.57	38.60	44.98	47.98
60	14.24	15.48	17.02	22.55	25.08	27.70	30.24	35.30	37.13	43.50	49.16	53.60	56.80	65.15	70.35	73.92	86.14	91.89
120	18.11	19.69	21.64	26.85	29.86	32.98	34.94	40.79	42.91	48.93	55.28	60.30	62.99	72.25	78.02	81.15	94.56	100.87
360	26.96	29.31	32.22	38.68	43.02	47.51	48.06	56.10	59.01	62.16	70.23	76.60	74.53	85.48	92.31	88.68	103.34	110.24
720	33.29	36.18	39.78	48.65	54.11	59.76	60.70	70.85	74.53	78.40	88.58	96.62	93.53	107.28	115.85	106.63	124.26	132.55
1440	40.57	44.09	48.48	55.47	61.69	68.13	66.32	77.41	81.44	81.34	91.89	100.23	96.53	107.28	115.85	106.63	124.26	132.55
B: baseline L: low emission (RCP4.5) H: high emission (RCP8.5)																		

Table 6 Average increase in extreme precipitation events under 2 GHG emission scenarios

Return periods	Low emission scenario			High emission scenario		
	Immediate future 2006-2056	Near future 2025-2075	Far future 2050-2100	Immediate future 2006-2056	Near future 2025-2075	Far future 2050-2100
2-year	8.5%	5.2%	8.7%	10.3%	14.3%	19.5%
5-year	9.0%	7.3%	11.2%	8.9%	14.6%	22.8%
10-year	11.9%	11.6%	16.7%	10.5%	19.2%	22.8%
25-year	11.8%	14.4%	13.0%	15.7%	26.4%	23.2%
50-year	9.3%	15.5%	14.3%	19.6%	26.8%	23.4%
100-year	8.8%	14.4%	16.5$	24.6%	30.7%	24.3%

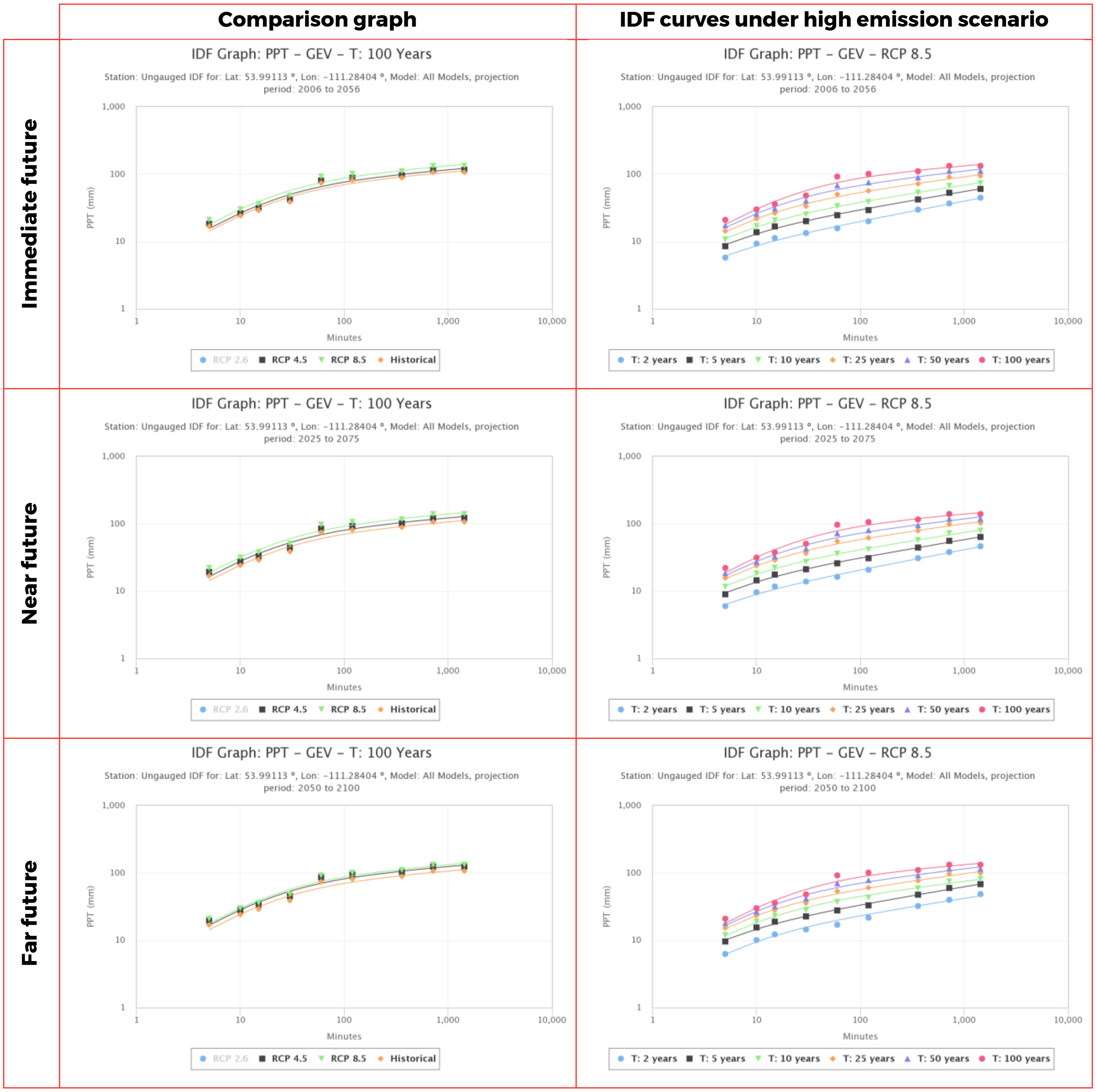


Figure 1 Projected IDF curves for the immediate, near and far futures. The lefthand column compares the IDFs under the two emission scenarios for 100-year return period events. The graphs in the righthand column compares the precipitation intensity for different return periods under high emission scenario

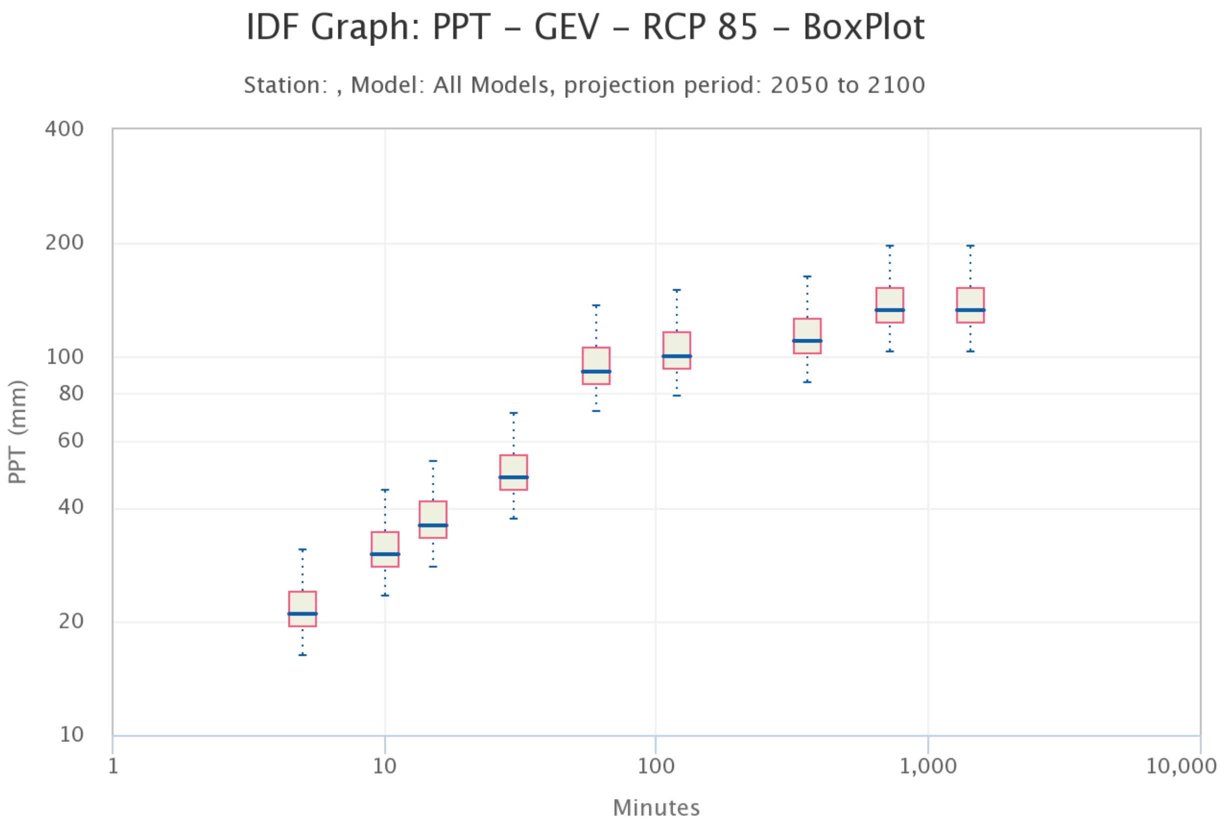


Figure 2 Boxplot of the distribution of the outputs from the 9 models for the projected intensity of 100-year return period precipitation events in the far future under high emission scenario

OPPORTUNITIES AND LIMITATIONS

The IDF_CC tool provides ready-to-use IDFs. However, the discussion regarding the limitations of statistical downscaling in the previous section is also relevant to the IDF_CC tool. Since they use 10-km x 10-km grid points, there would be an opportunity to gather more data from the county, compared to data from the Climate Atlas of Canada. We carried out a sensitivity analysis at the scale of the watershed. The variation in the projected IDF curves for different points in the watershed was less than 2 mm for 100-year 24-hour precipitation events, which was considered insignificant.

As the tool requires a 50-year period for projections, there are limitations in the future periods that we can project as well. This limits our ability to calculate IDFs calibrated on the lifespan of the different components of the stormwater drainage infrastructures.

REGIONAL CLIMATE MODELS (DYNAMICAL DOWNSCALING): ESCER DATASET

OPPORTUNITIES AND LIMITATIONS

ESCER, a research lab at UQAM, could provide regional climate model, which is physics-based downscaling of GCMs instead of being statistically-based. These data should comprise fewer uncertainties in the projected changes in extreme events of short duration. The spatial resolution of the data is either 50-km x 50-km, 25-km x 25-km or 10-km x 10-km, whether there is a need for a more local or regional overview. Data outputs from this model can be hourly in the best of cases, or 3 hours otherwise.

We could therefore provide time series of projected annual maximum precipitations for 3, 6, 12 and 24 hours, from which we might be able to extrapolate the IDFs for shorter time spans based on historical data.

UNCERTAINTIES

Various sources of uncertainties were discussed in each of the above sections. We dealt with the three main sources of uncertainty identified in the best practices relative to climate information (Charron, 2014):

— *Global emissions*: the information was considered for both RCP 4.5 (optimistic) and 8.5 (status quo) emission scenarios;
— *Climate models*: our analysis is based on 9 GCMs
— *Downscaling techniques*: the quality and gaps between the Climate Atlas and IDF_CC tools were assessed; the potential from regional climate modelling was also acknowledged.

CONCLUSIONS AND RECOMMENDATIONS

This report presented projections for general climate data and IDF curves for the immediate, near and far future under two GHG emission scenarios.

INCREASE IN THE MEAN ANNUAL TEMPERATURE AND PRECIPITATION

Data from the Climate Atlas of Canada suggest a very high probability to witness an increase in the mean annual temperature in St. Paul in the future. This increase could be quite severe (as much as +6.4 °C in the far future) and will be accompanied with a decrease in winter conditions in terms of cold days and length of the winter season. The level of confidence in this data is very high.

The likelihood to record an increase in mean annual precipitation is medium. This increase should be more pronounced for spring precipitation and non-existent for summer precipitation.

In terms of stormwater drainage infrastructure, the focus is mostly on extreme events. From the account of the Climate Atlas of Canada, their modelling methods do not allow accurate projections for discrete events of short duration.

INCREASE IN THE MAGNITUDE OF EXTREME PRECIPITATION EVENTS

The IDF_cc tool projects an average increase in the precipitation amounts of more than 30% for 100-year return period events under the high emission scenario compared to the baseline data. The likelihood to record and increase is very high, as much of the lower bracket of the uncertainty on the projected IDF curves are superior than the baseline data.

RECOMMENDATIONS TO MANAGE THE UNCERTAINTIES

The statistical downscaling methods used by the two climatic tools used in the present report could underestimate the extreme values and have important uncertainty intervals. For example, some models of the IDF_cc tool project the increase in the magnitude of 100-year return period 24-hour precipitation events to be as much as 85.9% above the present-day IDF data. It is therefore our recommendation to adopt a conservative approach to this data and add a security margin and/or perform sensitivity analysis (at least +10%) to account for this uncertainty in the calibration of the stormwater drainage planning.

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APPENDIX

B COST ESTIMATES

St. Paul Intermunicipal Stormwater Management Plan
Budget Level Cost Estimation

Project:	**St. Paul SWM Plan**	Made by: Cole Gerber
Client:	**Town of St. Paul**	Approved by: Michael Nishiyama
WSP #:	**181-10286-00**	Date: April 10, 2019

ITEM NO.	DESCRIPTION OF WORK	UNIT	QUANTITY	UNIT PRICE	COST
A.	*Highway 29 (West Boundary)*				
	1. 900 mm Culvert under access road	l.m.	60	$ 802.64	$ 48,158.40
	2. Ditch regrading to intersection	l.m.	170	$ 70.00	$ 11,900.00
	3. 750 mm Culvert under HWY 29 (West)	l.m.	60	$ 690.78	$ 41,446.80
	4. 750 mm Culvert under HWY 29 (50 Ave - HWY 29)	l.m.	100	$ 690.78	$ 69,078.00
	5. SWMF for future Commercial Development	cu.m.	10000	$ 50.00	$ 500,000.00
	6. 600 mm Culvert under access road near 50 Street	l.m.	30	$ 482.80	$ 14,484.00
	7. Highway repair	sq.m.	240	$ 90.00	$ 21,600.00
				Subtotal	$ 706,667.20
				Engineering/Administration/Testing (15%)	$ 106,000.08
				Contingency (25%)	$ 176,666.80
				Total	**$ 989,334.08**
B.	*Golf Course (South Boundary)*				
	1. 800 mm Culvert at 53 Street	l.m.	60	$ 584.99	$ 35,099.40
	2. Regrading at outlet	cu.m.	2000	$ 50.00	$ 100,000.00
	3. Emergency overflow / Road regrading	cu.m.	300	$ 70.00	$ 21,000.00
				Subtotal	$ 156,099.40
				Engineering/Administration/Testing (15%)	$ 23,414.91
				Contingency (25%)	$ 39,024.85
				Total	**$ 218,539.16**
C.	*Township Road 582 (Northwest County)*				
	1. 750 mm Culvert under Township Road 582	l.m.	70	$ 690.78	$ 48,354.60
	2. 750 mm Culvert under Ironhorse Trail	l.m.	40	$ 690.78	$ 27,631.20
	3. Ditching along Ironhorse Trail	l.m.	300	$ 70.00	$ 21,000.00
				Subtotal	$ 96,985.80
				Engineering/Administration/Testing (15%)	$ 14,547.87
				Contingency (25%)	$ 24,246.45
				Total	**$ 135,780.12**
D.	*57 Street (Northwest Boundary)*				
	1. 750 mm Culvert under Ironhorse Trail	l.m.	40	$ 690.78	$ 27,631.20
	2. Ditching along Ironhorse Trail West of Range Road 95/ 57 St	l.m.	200	$ 70.00	$ 14,000.00
	3. Ditching along Ironhorse Trail East of Range Road 95/ 57 St	l.m.	100	$ 70.00	$ 7,000.00
	4. Maintenance at 57 Street inlet	Bulk	1	$ 1,000.00	$ 1,000.00
	5. Pond at Ironhorse Trail	cu.m.	5000	$ 50.00	$ 250,000.00
	6. Wetland evaluation and maintenance	Bulk	1	$ 5,000.00	$ 5,000.00
				Subtotal	$ 304,631.20
				Engineering/Administration/Testing (15%)	$ 45,694.68
				Contingency (25%)	$ 76,157.80
				Total	**$ 426,483.68**
E.	*Range Road 94A (North Boundary)*				
	1. 600 mm Culvert under Rainge Road 94A	l.m.	40	$ 482.80	$ 19,312.00
	2. Ditching along north boundary	l.m.	450	$ 70.00	$ 31,500.00
	3. Road Repair (Range Road 94A , paved)	sq.m.	60	$ 100.00	$ 6,000.00
				Subtotal	$ 56,812.00
				Engineering/Administration/Testing (15%)	$ 8,521.80
				Contingency (25%)	$ 14,203.00
				Total	**$ 79,536.80**
F.	*Highway 881 (Northest Boundary)*				
	1. Follow HWY 29 & 881 Industrial ASP				$ -
				Subtotal	$ -
				Engineering/Administration/Testing (15%)	$ -
				Contingency (25%)	$ -
				Total	**$ -**
G.	*Highway 29 (East County)*				
	1. General ditch/creek/culvert maintenance	Bulk	1	$ 1,000.00	$ 1,000.00
				Subtotal	$ 1,000.00
				Engineering/Administration/Testing (15%)	$ 150.00
				Contingency (25%)	$ 250.00
				Total	**$ 1,400.00**
H.	*Range Road 93 (Southeast Boundary)*				
	1. General ditch/creek/culvert maintenance	Bulk	1	$ 1,000.00	$ 1,000.00
				Subtotal	$ 1,000.00
				Engineering/Administration/Testing (15%)	$ 150.00
				Contingency (25%)	$ 250.00
				Total	**$ 1,400.00**
				Overall Total	**$ 1,852,473.84**

Notes:

A.3	Evaluation of current culvert size prior to installation
A.5	Stormwater management plan required for future planned commercial. SWMF, connection to minor system etc.
A.6	Interim upgrades to wetland prior to commercial development (Potential major SWM item, To be planned w/ ASP)
D.5	Stormwater management plan for future business development. SWMF, connection to minor system, and Ironhorse Trail maintenance
D.6	Consideration of upgrading wetland for drainage performance or into SWMF
E.2	Could maintain existing conditions, as there is limited flooding and low risk to residence

Prices taken from Alberta Transportation Unit Price Averages for North Central Alberta (2019, then 2018, 2017, 2016) where possible else Provincial average for 3 lowest bids since 2016

APPENDIX

C

SITE INSPECTION PHOTOS

Site Inspection Photo Locations

P (1)

P (2)

P (3)

P (4)

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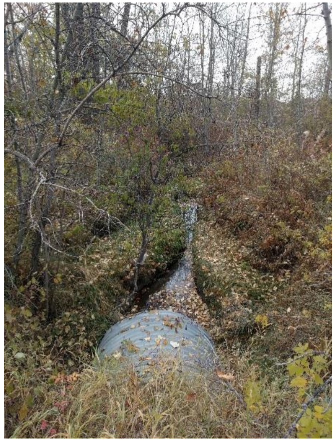
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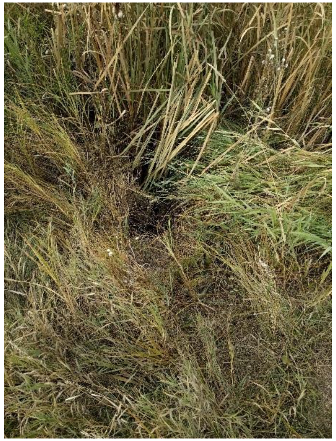

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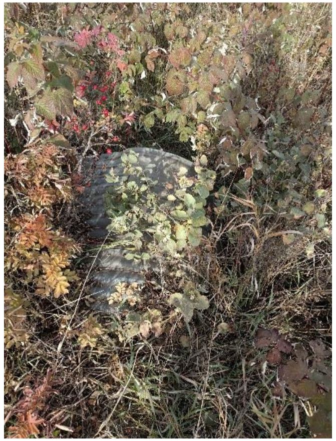

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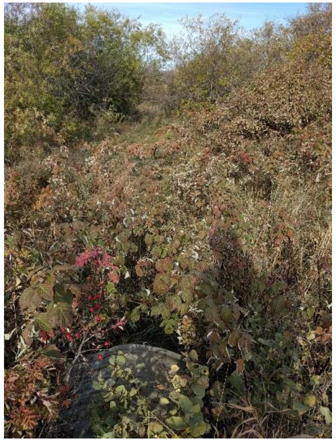

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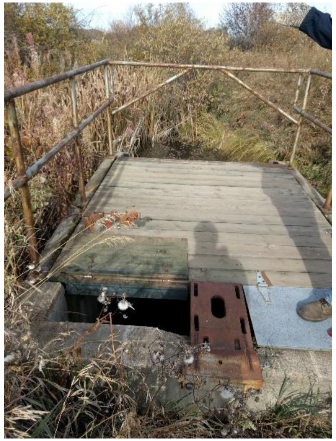

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