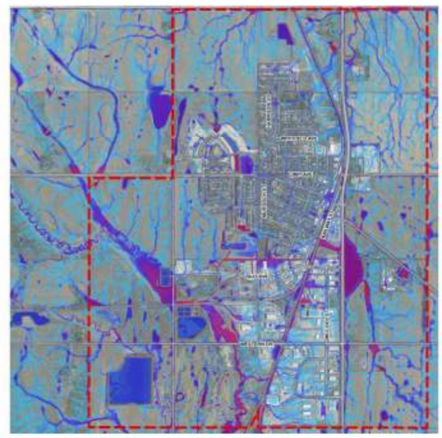

Town of Crossfield

Final Report

Stormwater Master Plan

April 2020

ISL

ISL Engineering and Land Services Ltd. is an award-winning full-service consulting firm dedicated to working with all levels of government and the private sector to deliver planning and design solutions for transportation, water, and land projects.

4015 7 Street SE, Calgary AB T2G 2Y9, T: 403.254.0544 F: 403.254.9186

April 14, 2020

Our Reference: 27309

Town of Crossfield
1005 Ross Street
Crossfield, AB T0M 0S0

Attention: Mustafa Hashini, Director, Infrastructure Operations

Dear Sir:

Reference: Crossfield Stormwater Master Plan Final Report

Enclosed is the final report for the Crossfield Stormwater Master Plan. We trust that it meets your expectations.

The Stormwater Master Plan includes an assessment of the Town's current stormwater conveyance infrastructure capacity and the Town's future needs. A robust hydrodynamic InfoWorks ICM 1D-2D model was constructed to enable the comprehensive assessment of the stormwater system. The project was initiated to ensure sound stormwater system planning. The intent of this project is to provide a road map to Town Council for assessing the capability of the infrastructure to accommodate new development in the short-term and long-term.

We sincerely appreciate the opportunity to undertake this project on behalf of the Town of Crossfield. Should you have any questions or concerns, please do not hesitate to contact the undersigned at 403.254.0544.

Sincerely,

Geoffrey Schulmeister, P.Eng., SCPM
Manager, Water and Environment

Corporate Authorization

ISL has prepared this document entitled "Stormwater Master Plan" for the use of the Town of Crossfield. It is available for use by third parties as information only. Third parties should do their own due diligence on report findings, particularly when leveraged for design purposes; ISL denies any liability whatsoever towards any third parties who make use of this document on that basis.

Krista Kruschel, E.I.T.
Engineering Support

PROFESSIONAL ENGINEER
SARAH BARBOSA
ALBERTA

2020-04-14

Sarah Barbosa, P.Eng., ENV SP
Technical Author

PERMIT TO PRACTICE
ISL Engineering and Land Services Ltd.
Signature
Date 14 April 2020
PERMIT NUMBER: P 4741
The Association of Professional Engineers and Geoscientists of Alberta

Geoffrey Schulmeister, P.Eng., SCPM
Senior Reviewer

Executive Summary

Background

The Town of Crossfield retained ISL Engineering and Land Services to complete a Stormwater Master Plan. This Stormwater Master Plan includes an assessment of Crossfield's current stormwater conveyance infrastructure capacity and Crossfield's future needs. A robust hydrodynamic InfoWorks ICM 1D-2D model was constructed to enable the comprehensive assessment of the stormwater system. The project was initiated to ensure sound stormwater system planning. The intent of this project is to provide a road map to Town Council for assessing the capability of the infrastructure to accommodate new development in the short-term and long-term.

The objectives of developing the Stormwater Master Plan include:

- Assessing existing drainage conditions and determining design criteria for the stormwater drainage system, including runoff rates and volumes.
- Providing an inventory of and analyzing existing natural drainage conveyance.
- Determining if any upgrades are required to the existing system to properly meet the needs of the municipality and to allow future growth to occur.
- Developing stormwater infrastructure plans, including stormwater management facility sizing, to manage increased and redirected runoff resulting from future development. Locations and timing may depend on:
  - Availability of sufficient servicing needs
  - Undeveloped land locations
  - District planning
- Producing a drainage basin specific stormwater management plan that uses best management practices to minimize the effect to the natural hydrological and hydro-geological regimes, and to ensure the planned stormwater management system meets regulatory authority requirements.
- Providing cost estimates related to required infrastructure upgrades, which will also provide inputs to an off-site levy bylaw.
- Commenting on possible staging options of upgrades for the most effective infrastructure implementation.

Conclusions

The Town's stormwater system consists of both major and minor drainage systems. In terms of major infrastructure, the system is comprised of a series of overland drainage routes that convey stormwater ultimately to either Crossfield Creek or Nose Creek. There are three drainage basins that convey stormwater runoff to Crossfield Creek, and two drainage basins that convey stormwater to Nose Creek. Crossfield Creek is within the Red Deer Watershed, while Nose Creek is in the Bow River Watershed. There are six notable wet/dry ponds in the Town, and two notable wetlands, as summarized below:

- Vista Crossing Wet Pond 1
- Vista Crossing Wet Pond 2
- Vista Crossing Wet Pond 3
- Vista Crossing Wetland
- Iron Ridge Wet Pond
- Westgate Dry Pond
- Fish Pond
- Black Bull Industrial Park Wetland

The minor system is comprised of gravity sewers, manholes, catchbasins, catchbasin leads, and outfalls, with the majority of this infrastructure located in newer areas of the Town. Pipe sizes range from 150 mm to 2400 mm in size. Drainage components such as culverts, gutters and roof leaders facilitate the exchange of stormwater runoff between the major and minor systems.

A coupled 1D-2D model was constructed in InfoWorks ICM to assess the Town's stormwater system. Development of the model occurred in two phases; the first was to build the minor (1D) portion of the system and the second consisted of generating a mesh to represent the major (2D) portion of the system. The process that was used to generate the model is described in detail in Section 4.0.

Design rainfall events produced from The City of Calgary's IDF parameters were utilized to assess the Town's stormwater drainage system. The minor system was assessed using a 1:5 year 1-hour Chicago rainfall distribution while the major system was assessed using a 1:100 year 24-hour Chicago rainfall distribution.

Results of the piped (minor) stormwater drainage system within Crossfield under existing conditions for both the 1:5 and 1:100 year storm conditions are summarized below:

- Model results under the 1:5 year 1-hour Chicago design storm indicate that surcharging remains isolated to four locations. These locations include along Railway Street, in the easement west of Stevens Place, the sewers along Stevens Place that discharge to Westgate Dry Pond, and at the intersection of Mossip Avenue and Harrison Street. As well, various catchbasin leads throughout the Study Area are surcharged.
- Model results under the 1:100 year 24-hour Chicago design storm indicate that similar surcharging is noted as in the 1:5 year scenario, with the main difference being that surcharging extends further upstream of Westgate Dry Pond.

Results of the overland (major) stormwater drainage system within Crossfield under existing conditions for both the 1:5 and 1:100 year storm conditions are summarized below:

- Model results of the overland drainage system under the 1:5 year 1-hour Chicago design storm indicate that areas with notable water depths largely focus around ditches, creeks, and ponds.
- Model results of the overland drainage system under the 1:100 year 24-hour Chicago design storm suggest that there are a number of locations throughout Crossfield that would experience surface flooding. Nine notable areas of concern were flagged for further investigation and potential remediation measures.

A proposed stormwater system concept was developed for Crossfield. It is comprised of SWMFs, along with sewers that discharge into either Nose Creek or Crossfield Creek, or one of their tributaries. Discharge into Nose Creek is limited to a rate of 1.257 L/s/ha while the discharge rate into Crossfield Creek is 1.4 L/s/ha. These discharge rates adhere to the Nose Creek Watershed Water Management Plan (Palliser, 2008) for Nose Creek, and the past Master Drainage Plan (Stormwater Solutions Inc., 2008) for Crossfield Creek.

Volume targets have been omitted for both watersheds. This is due to the uncertainty of the criteria stipulated in the Nose Creek Watershed Management Plan (Palliser, 2008) moving forward, as stringent targets have led to delays in new developments. To provide a baseline comparison, two scenarios were developed with identical control parameters to illustrate the difference between implementing and not implementing volume targets. The results indicated that implementing volume targets to 16 mm would be approximately nine times more costly than not using these targets.

The proposed stormwater system concept was modelled in InfoWorks ICM (1D modelling only) to determine if there is adequate capacity in the system. Assessment results indicate that the conceptual network would be sufficient in managing stormwater runoff from the future developments.

Recommendations

A number of recommendations were made based on the findings of this study. This includes the findings of the existing system assessment, and development of the proposed stormwater concept for new areas.

Of the ten locations flagged as notable concerns during the existing system analysis, six locations were flagged for improvement. The proposed upgrades and associated costs for the existing system are shown in Figure 6.13 and summarized below:

- Implementation of a catchbasin on Limit Avenue, west of Harrison Street, and a tie to the existing culvert to the west.
- Upgrading the existing culvert on Ross Street to 600 mm.
- Upgrading the existing pipes on Nanton Avenue between Ross Street and Railway Street to 525 mm.
- Upgrading the existing pipe on Stevens Place, south of Smith Avenue, to 450 mm.
- Upgrading the pipe in the easement west of Stevens Place to 675 mm.
- Upgrading the pipes at the intersection of Mossip Avenue and Harrison Street to 600 mm.

The future stormwater system should be designed based on the design criteria presented in this SMP, as well as The City of Calgary's Stormwater Management and Design Manual. The future stormwater system should be constructed as denoted in Figure 7.4. The costs of these additions are shown in Table 7.10 and Figure 7.9, and amount to a total cost of $53.2 million. Future SWMFs should follow the parameters identified in Table 7.5.

Drainage to the SWMFs should be considered at the time of the subdivision application/development permit. Separate reviews should be prepared to support each subdivision application/development permit to ensure compliance with the overarching SMP.

The proposed SWMFs should be equipped with outlet control structures, while the downstream sewers should include an outfall structure at the downstream discharge location. It is recommended that stormwater outlet backflow preventers be installed at any outfall servicing catchment areas with ground or basement elevations below the local 1:100 year creek flood level. LID measures should be considered on a site-specific basis and should be reviewed by the Town to determine if their implementation is desired.

It is also recommended that the SMP should be reviewed and updated after significant periods of growth or every five years to update the hydrodynamic model and analysis with any capital upgrades completed by the Town, and the most up-to-date growth plans. This could provide clarity on the planned location of development, the density of the proposed development, and the potential corresponding upgrades. This should also be undertaken when considering densification within the established area.

Table of Contents

APPENDICES

TABLES

FIGURES

Following Page

ABBREVIATIONS

Abbreviation	Meaning
AEP	Alberta Environment and Parks
ASP	Area Structure Plan
BMP	best management practices
CBOD	carbonaceous biochemical oxygen demand
CSP	corrugated steel pipe
CMP	corrugated metal pipe
CPR	Canadian Pacific Railway
ESC	erosion and sediment control
HGL	hydraulic grade line
ICD	inlet control device
IDF	intensity-duration-frequency
LID	low impact development
MDP	Municipal Development Plan
MHR	Residential – Manufactured Home District
MSC	Meteorological Service of Canada
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
Q/Qman	peak discharge relative to sewer capacity
SMP	Stormwater Master Plan
SWMF	stormwater management facility
TLMP	Total Loading Management Plan
the Town	the Town of Crossfield
TSS	total suspended solids

1.0 Introduction

The Town of Crossfield (the Town) retained ISL Engineering and Land Services (ISL) to complete a Stormwater Master Plan (SMP). This SMP includes an assessment of the Town's current stormwater conveyance infrastructure capacity and the Town's future needs. A robust hydrodynamic InfoWorks ICM 1D-2D model was constructed to enable the comprehensive assessment of the stormwater system. The project was initiated to ensure sound stormwater system planning. The intent of this project is to provide a road map to Town Council for assessing the capability of the infrastructure to accommodate new development in the short-term and long-term.

1.1 Background

The Town's planning direction has evolved over time and thus needs to update its SMP to incorporate new documents including Area Structure Plans (ASPs), new annexed areas, and infrastructure projects. These changes need to be incorporated into the SMP to determine deficiencies in the drainage system and provide a guiding document to the Town for strategic implementation of proposed work.

The goal of stormwater management has changed as technology has improved and the environment has become a larger concern in our society. The Town recognizes the need to consider environmental, social, and economic factors when planning for existing and future developments. Upgrades must balance the impacts of cost, operation and maintenance, existing and future developments, and environmental protection. Risks must be considered to prioritize upgrades and ensure the Town's budget is respected.

1.2 Purpose of Study

The objectives of developing the SMP include:

- Assessing existing drainage conditions and determining design criteria for the stormwater drainage system, including runoff rates and volumes.
- Providing an inventory of and analyzing existing natural drainage conveyance.
- Determining if any upgrades are required to the existing system to properly meet the needs of the municipality and to allow future growth to occur.
- Developing stormwater infrastructure plans, including stormwater management facility (SWMF) sizing, to manage increased and redirected runoff resulting from future development. Locations and timing may depend on:
  - Availability of sufficient servicing needs
  - Undeveloped land locations
  - District planning
- Producing a drainage basin specific stormwater management plan that uses best management practices to minimize the effect to the natural hydrological and hydro-geological regimes, and to ensure the planned stormwater management system meets regulatory authority requirements.
- Providing cost estimates related to required infrastructure upgrades, which will also provide inputs to an off-site levy bylaw.
- Commenting on possible staging options of upgrades for the most effective infrastructure implementation.

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2.0 Study Area

2.1 Location

Crossfield is situated in southern Alberta in Rocky View County, approximately 43 km north of The City of Calgary. The Town is within the Calgary-Edmonton Corridor, north of the City of Airdrie and south of the Town of Olds. The Town was founded in 1892 as a result of its location along the Calgary to Edmonton line of the Canadian Pacific Railway (CPR) and was incorporated as a town in 1980. Its prime location between Calgary and Edmonton has led to a fair amount of growth throughout the years.

Crossfield is bounded by the Queen Elizabeth II Highway to the east, Highway 72 to the south, Range Road 13 to the west, and Township Road 290 to the north. Highway 2A transects the Town in a north-south direction along the east end.

The overall Study Area of the SMP includes all developments that are serviced within the Town boundary, as well as any considered annexed land for future growth considerations. Figure 2.1 highlights the area that was considered as part of the SMP while Figure 2.2 illustrates the lands that are being considered for annexation. The Study Area encompasses over 1,185 ha within the previous boundary plus 1,765 ha of proposed annexed lands for a total Study Area of approximately 2,950 ha.

The Town's elevation ranges between 1064 m in the northeast near Highway 2A, and 1131 m in the southeast also near Highway 2A. There is a ridge that divides the northeast portion of the town from the southwest. In the northeast, topography generally falls from the southwest to northeast while in the southwest, topography generally falls from the northeast to southwest. A topographical map is provided in Figure 2.3.

Crossfield is situated in the South Saskatchewan River watershed; part of the Nelson-Churchill (Hudson Bay) continental drainage basin. Within the South Saskatchewan River watershed, Crossfield is located in Regions 05BH and 05CE. 05BH represents a reach of the Bow River while 05CE represents a reach of the Red Deer River. There are two notable creeks; the Nose Creek Watershed is in 05BH while the Crossfield Creek Watershed is in 05CE. A map of the watershed boundaries is shown in Figure 2.4.

2.2 Existing Land Use

In terms of current land use classifications, Crossfield is divided into land use district groupings including: residential, commercial/business, industrial, municipal or urban holdings/open space areas. The development type influences stormwater runoff coefficients / imperviousness values and roughness coefficients, therefore obtaining an appropriate classification was vital to achieve an accurate representation of stormwater runoff. These land use types are shown in Figure 2.5.

2.3 Growth Horizons

For the SMP, one future horizon was considered, around 2040. This was done to be in line with the TMP, also by ISL. The future land use was based on the approved ASPs within the Town and the future annexation area, and the 2018 Municipal Development Plan (MDP). The ASPs that were considered as part of this project are shown in Figure 2.6.

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Legend

Study Area

Credits:Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

FIGURE 2.1
STUDY AREA
CROSSFIELD STORMWATER
MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.

ISL

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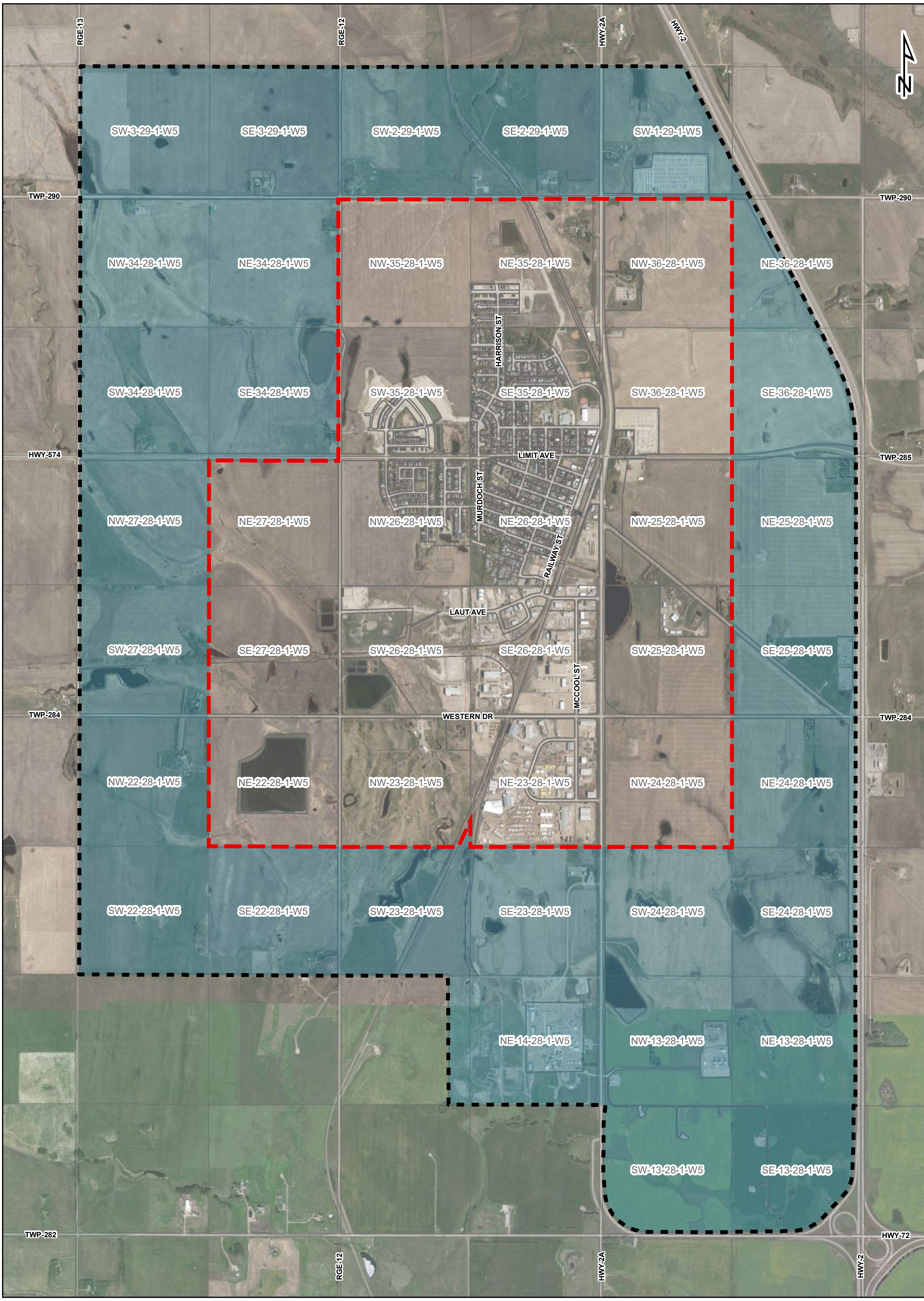

Date: 4/1/2020 Document: H:\27309 - Supplemental\02_CADD\251_Figures\01_Report Figures\2.0 Study Area\Figure2.2_Annexation_Boundaries.mxd

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Legend

- Annexation Lands
- Annexation Boundary
- Pre-Annexation Boundary

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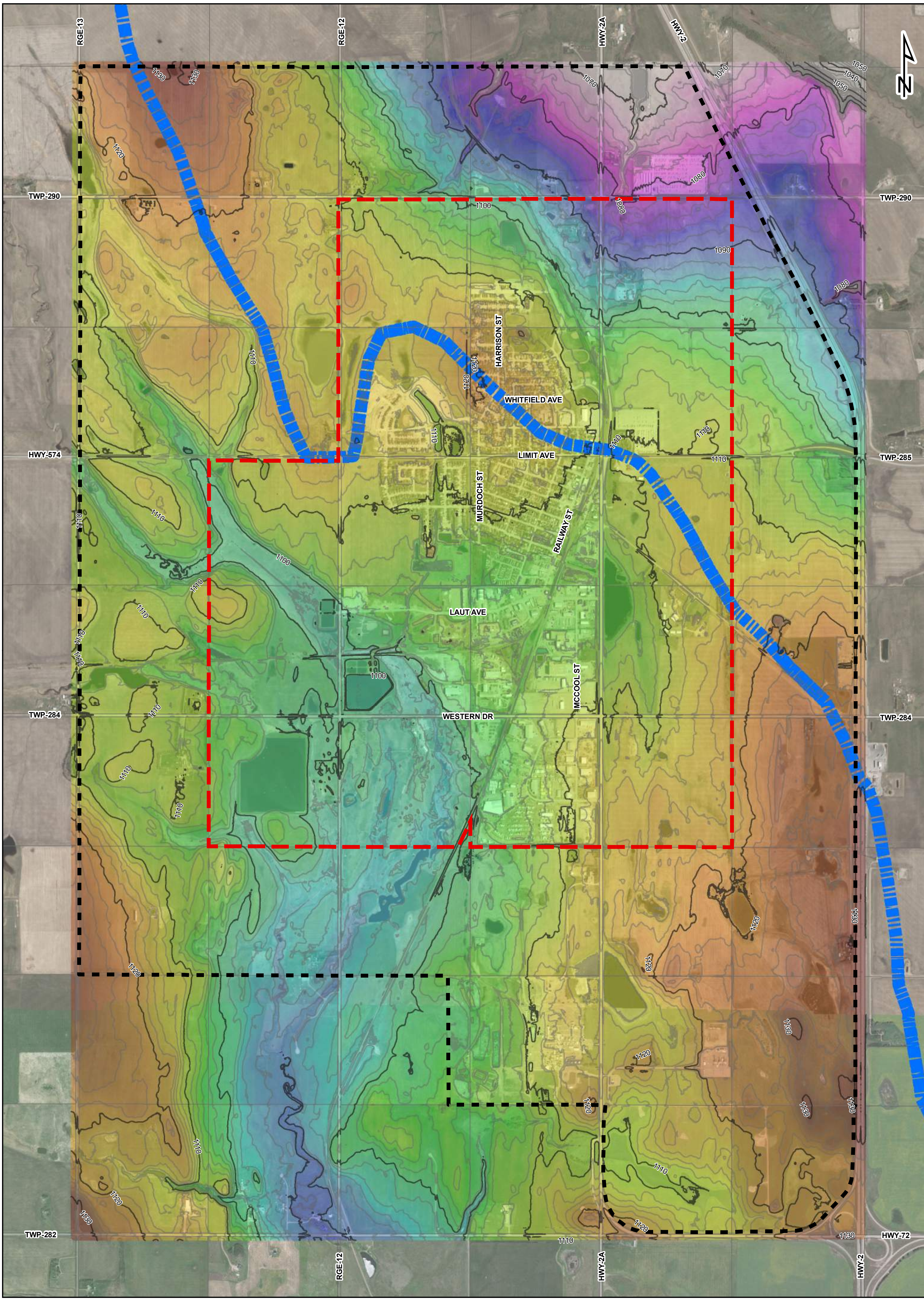
FIGURE 2.2
ANNEXATION LANDS
CROSSFIELD STORMWATER MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.



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Legend

- Major Contour -10m Interval
- Minor Contour - 2m Interval
- Annexation Boundary
- Pre-Annexation Boundary
- Watershed Boundary

Elevation (m)
High : 1134.13
Low : 1039.09

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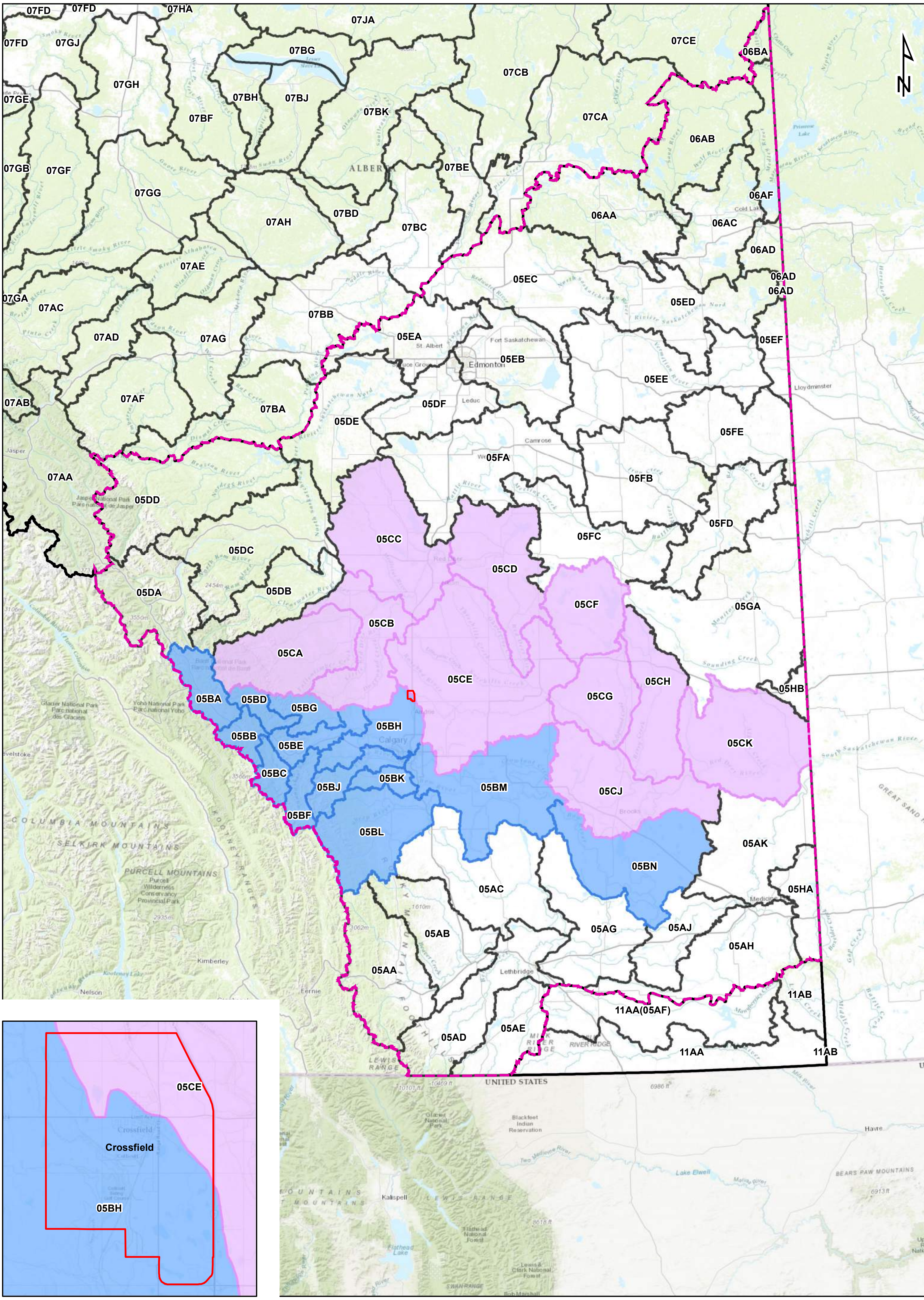
FIGURE 2.3
TOPOGRAPHY
CROSSFIELD STORMWATER MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.



Credits:Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

0 21,500 43,000 86,000 129,000 172,000 Metres

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Legend

Study Area

Continental Drainage Basins

Nelson-Churchill (Hudson Bay)

Mackenzie (Arctic Ocean)

Mississippi (Gulf of Mexico)

Watersheds

Bow River

Red Deer River

Remaining Watershed Regions

FIGURE 2.4
WATERSHED BOUNDARIES
CROSSFIELD STORMWATER MASTER PLAN

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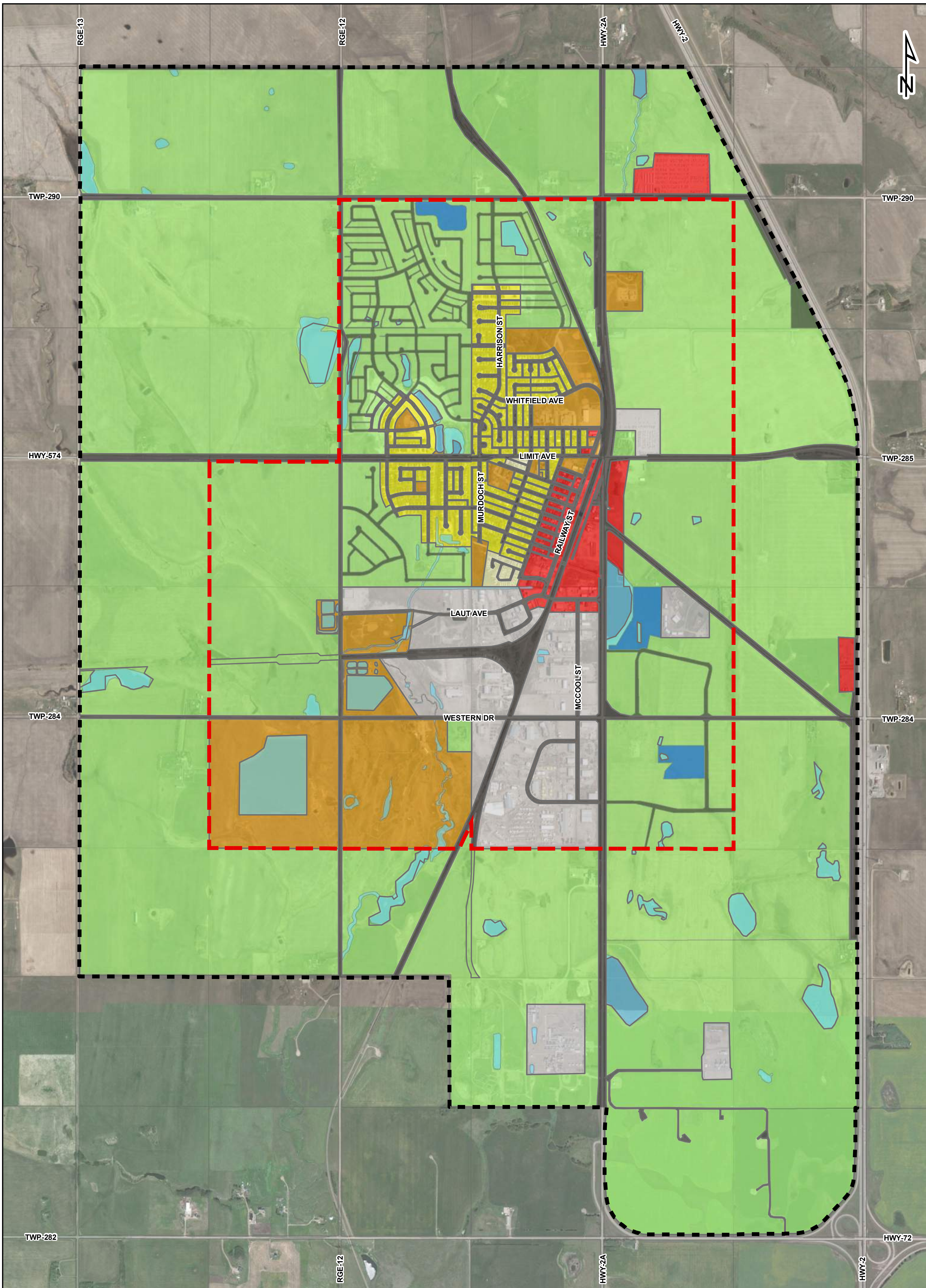

Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Metres
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Legend

- Residential
- Commercial
- Industrial
- Manufactured Home Residential
- Municipal
- Urban Holdings
- Road
- SWMF
- Waterbody
- Annexation Boundary
- Pre-Annexation Boundary

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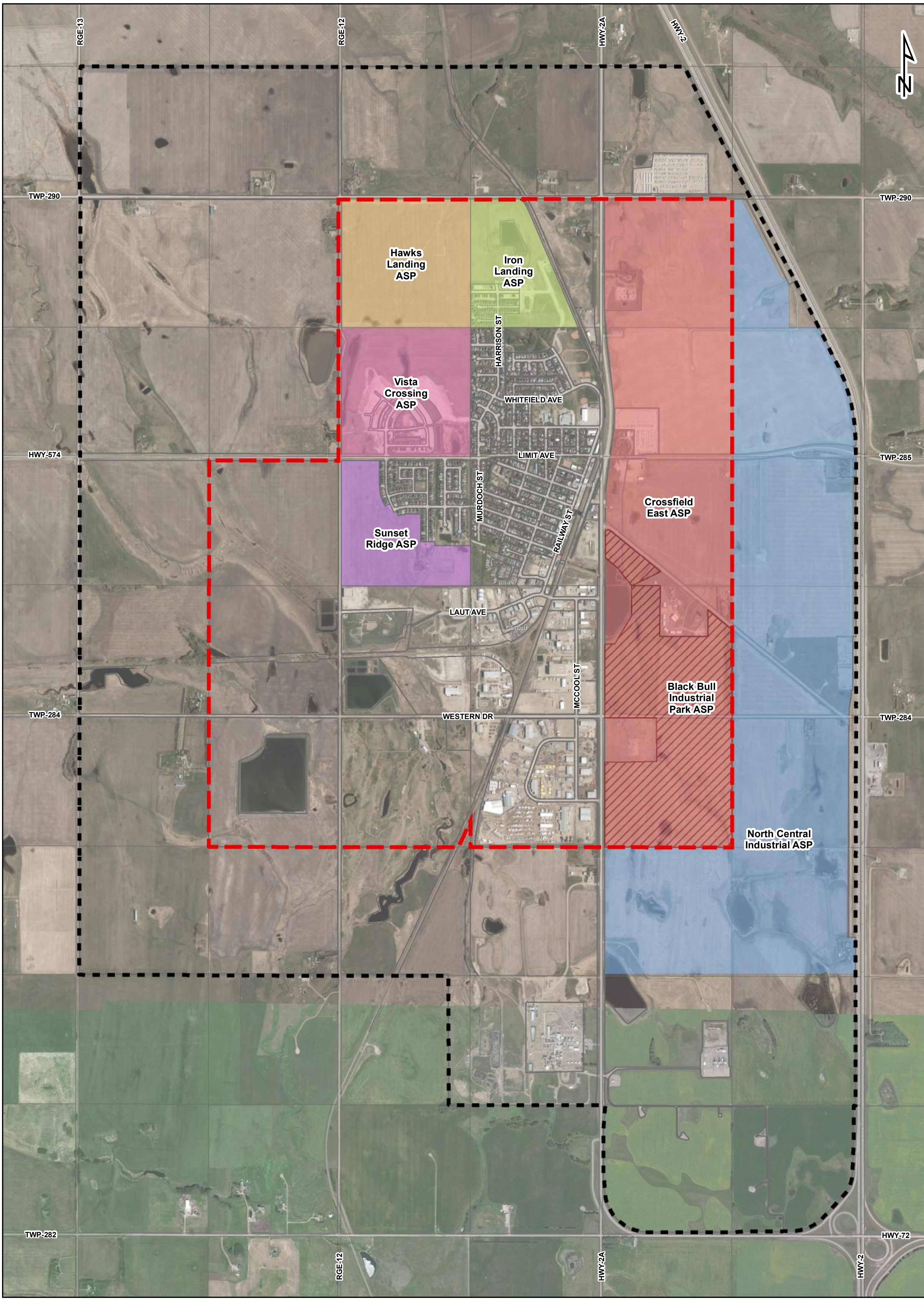
FIGURE 2.5
EXISTING LAND USE
CROSSFIELD STORMWATER MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.



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Legend

Area Structure Plan (ASP)

- Black Bull Industrial Park
- Crossfield East
- Hawks Landing
- Iron Landing
- North Central Industrial
- Sunset Ridge
- Vista Crossing
- Annexation Boundary
- Pre-Annexation Boundary

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FIGURE 2.6
AREA STRUCTURE PLANS
CROSSFIELD STORMWATER MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.

Date: 4/1/2020 Document: H:\27309 - Supplemental\02_CADD\251_Figures\01_Report Figures\2.0 Study Area\Figure2.6_Pr_ASP_Areas.mxd

3.0 Existing Stormwater System

Within Crossfield, the stormwater consists of both major and minor drainage systems. The major system consists of any overland drainage and conveys stormwater runoff that is in excess of the minor system. The minor system includes any underground infrastructure, including the pipe network and any of its associated structures.

The major system consists of the following types of drainage components:

- Surface (overland) drainage
- Roads
- Ditches
- Swales
- Escape routes
- Storage facilities
- Wet/dry ponds
- Traplows

The minor system consists of the following types of drainage infrastructure:

- System operating under gravity conditions
- Catchbasins, inlets and leads
- Manholes and junctions
- Outfalls

Drainage components such as culverts, gutters and roof leaders are considered to be part of both systems as these features facilitate an exchange of stormwater runoff between the overland (major) and piped (minor) systems. In addition, some drainage in undeveloped or open areas is achieved by uncontrolled overland drainage. These definitions are in line with those stipulated in Calgary's Stormwater Management and Design Manual document (City of Calgary, 2011).

Drainage in most developed newer areas is curb and gutter drainage with collection to storm sewer systems, usually discharging ultimately to a tributary of either Nose Creek or Crossfield Creek. In older parts of Crossfield, drainage is a combination of surface drainage along streets to either limited storm sewer pickup locations or to ditches/swales where runoff is ultimately discharged to downstream drainage courses via existing culverts.

3.1 Stormwater Conveyance System

Crossfield's minor (piped) stormwater system detailed with regards to size is illustrated in Figure 3.1 and summarized below in Table 3.1. It is noted that limited information was available pertaining to the minor system (for example, pipe material, installation year, and in some cases pipe size). The assumptions that were made regarding data gaps is proved in Section 4.0.

Table 3.1: Minor Stormwater System Summary – Sewer Size

Size	Total Length	Percent of Total
mm	m	%
150	23	0%
200	821	7%
250	1,684	14%
300	1,389	12%
350	245	2%
375	504	4%
400	248	2%
450	1,931	16%
500	313	3%
525	205	2%
600	1,029	9%
675	815	7%
700	63	1%
750	284	2%
800	161	1%
900	1,315	11%
1000	193	2%
1050	218	2%
1200	297	2%
1700	16	0%
1800	106	1%
2400	23	0%
Total	**11,881**	**100%**

3.2 Existing Drainage Patterns

As mentioned above, Crossfield is transected by a ridge, which divides the northeast from the southwest. The portion of the Town in the northeast drains towards tributaries of Crossfield Creek, while the portion of the Town in the southwest drains towards tributaries of Nose Creek.

Within the current Town boundary, existing drainage patterns generally define five drainage basins, noting that these basins are confined to within the Town's boundary for illustration purposes. These basins can be seen in Figure 3.2 and are described as follows:

Drainage Basin 1 – this drainage basin is located within the Red Deer River watershed, in the northwest corner of the Town. The basin drains towards the north, where it confluences at a tributary of the Crossfield Creek. With an area of approximately 81 ha, this basin includes all of the Hawks Landing ASP and a portion of the Vista Crossing ASP.

Drainage Basin 2 – this drainage basin is the largest of the three basins located in the Red Deer River watershed, at an area of 247 ha. The basin includes the north portion of the Town's existing development, plus the Iron Landing ASP, a portion of the Crossfield East ASP, and the area between Highway 2A and the Canadian Pacific Railway. The tributary of the Crossfield Creek that this drainage basin connects to is within the Town's existing boundary.

Drainage Basin 3 – this drainage basin is also in the Red Deer Watershed, converging with a tributary of the Crossfield Creek that is further downstream than Drainage Basins 1 and 2. It covers a small portion of the Crossfield East ASP, and has a total area of 24 ha.

Drainage Basin 4 – this drainage basin is within the Bow River Watershed and flows to a tributary of Nose Creek. Drainage Basin 4 is the largest basin within the Town, consisting of an area of 728 ha. This includes the majority of the built-up residential and industrial areas. The Sunset Ridge ASP, Black Bull Industrial Park ASP and most of the Vista Crossing ASP are within this basin, as well as a portion of the Crossfield East ASP.

Drainage Basin 5 – this drainage basin is located in the southwest corner of the Town is situated within the Bow River Watershed. The basin drains towards Nose Creek and consists of a total area of 105 ha. A large portion of this basin is the Town's effluent storage cell, while the remaining land is undeveloped.

There are also several notable ponds/wetlands within Crossfield's limits, as summarized below and shown in Figure 3.3:

- Vista Crossing Wet Pond 1
- Vista Crossing Wet Pond 2
- Vista Crossing Wet Pond 3
- Vista Crossing Wetland
- Iron Ridge Wet Pond
- Westgate Dry Pond
- Fish Pond
- Black Bull Industrial Park Wetland

The list provided above accounts for the named waterbodies within the Town's boundary. There are also a number of unnamed wetlands that are shown on Figure 3.3. The locations of these wetlands were digitized using aerial and topographical data to provide input into the 2D model.

3.3 Wetland Conservation and Protection

Generally, ISL recommends retention of reasonably permanent, large, and/or complex wetlands due to the potential landscape hydrologic impact. Typically, these basins have limited anthropogenic disturbance resulting in native plant communities, high potential for rare species, and stable wildlife habitat for waterfowl, shorebirds, amphibians, and invertebrate species. Additionally, these basins typically hold more water than other wetlands and may be significant to catchment hydrology. To infill them during development would not only displace this water, but also likely impact the overland flow dynamics, which could lead to flooding and/or spring melt and stormwater management issues.

It should also be noted that less permanent wetlands also provide important wetland functions such as stormwater retention, sediment and nutrient retention, as well as wildlife habitat. The impact of their disturbance is however anticipated to be less since there is a greater chance that they have been historically disturbed by cultivation. ISL recommends that during development, conservation of these wetlands be considered.

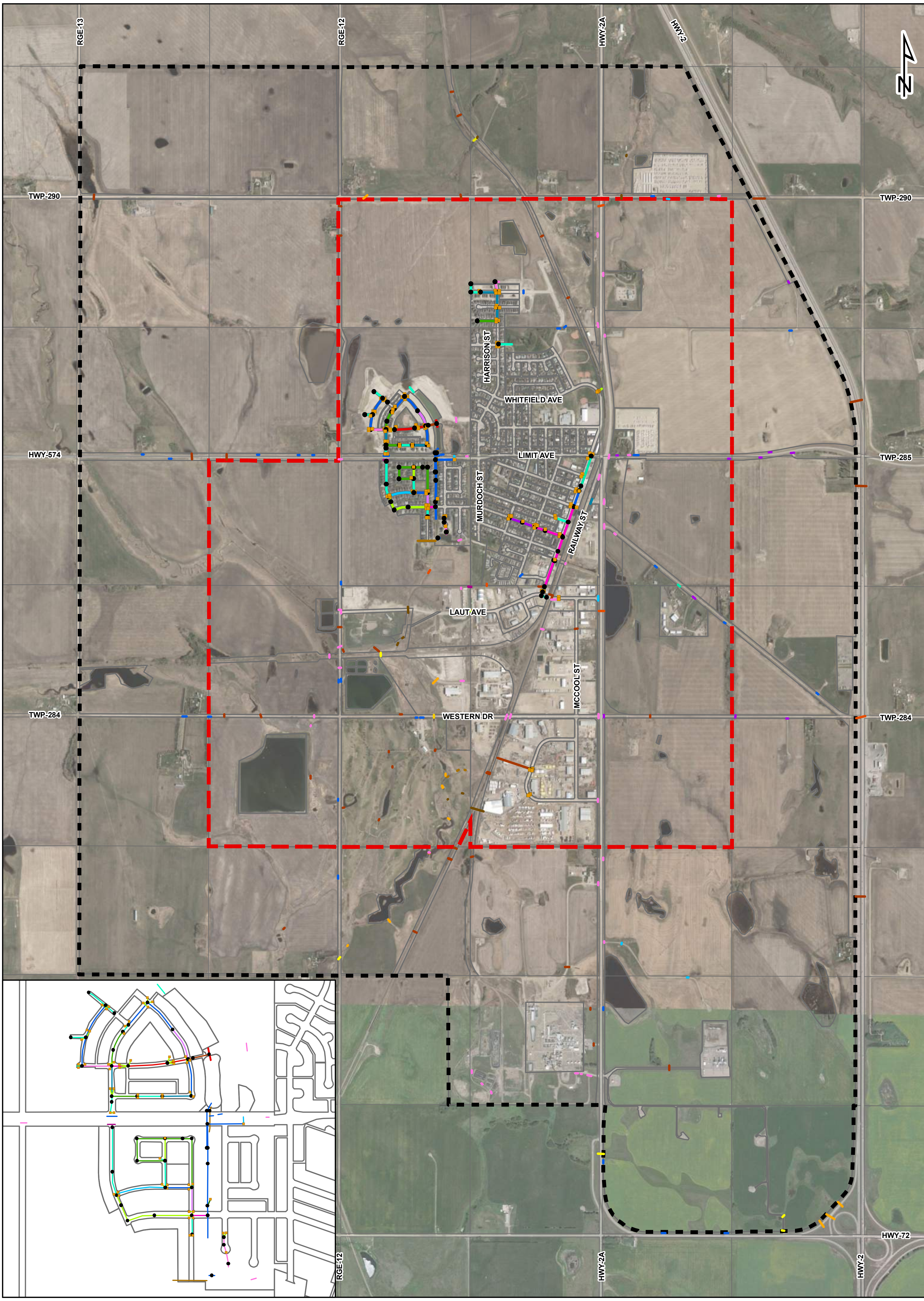
3.3.1 Setbacks

Wetland setbacks are important to consider for development planning. Setbacks provide a buffer of vegetation and help to filter water and other inputs, provide habitat for wildlife, and help protect the wetland from disturbance.

The Alberta government recommends 20 m for glacial till or 50 m for coarse textured sands and gravels adjacent to Class III (Stewart and Kantrud, 1971) and above wetlands as well as lakes, rivers, streams, seeps and springs (AESRD, 2012b). Class II wetlands (Stewart and Kantrud, 1971) have a recommended 10 m setback (AESRD, 2012b).

3.3.2 Recommended Areas to Retain

ISL primarily recommends retention of crown-claimed wetlands. Additionally, ISL recommends that other intact wetlands and their connections, be retained into the future and have a 50 m setback applied. A 20 m setback is recommended for other intact waterbodies that have low disturbance and/or high potential for habitat.



Date: 4/1/2020 Document: H:\27309 - Supplemental\02_CADD\251_Figures\01_Report Figures\3.0 Existing Stormwater System\Figure3.1_Ex_Pipe_Diameter.mxd

Legend

- Manhole
- Catchbasin
- Annexation Boundary
- Pre-Annexation Boundary

Pipe Diameter (mm)

150	350	600	1000
200	375	675	1050
250	400	700	1200
300	450	750	1700
	500	800	1800
	525	900	2400

FIGURE 3.1 PIPE DIAMETER CROSSFIELD STORMWATER MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.

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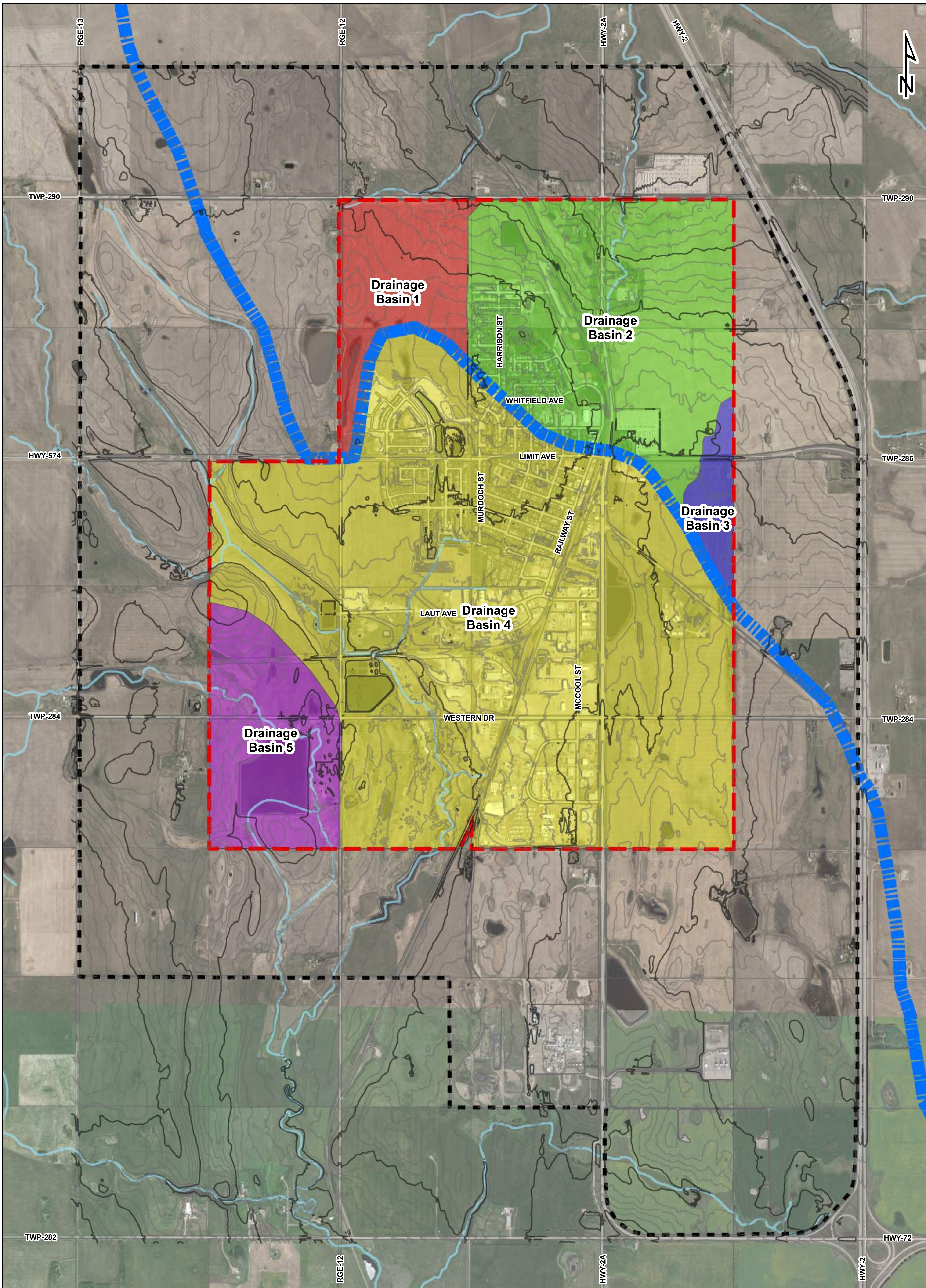

Credits:Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Metres
0 125 250 500 750 1,000
1:22,000 CANA83-3TM114

Legend

- Annexation Boundary
- Pre-Annexation Boundary
- Watercourse
- Watershed Boundary
- Drainage Basin 1
- Drainage Basin 2
- Drainage Basin 3
- Drainage Basin 4
- Drainage Basin 5

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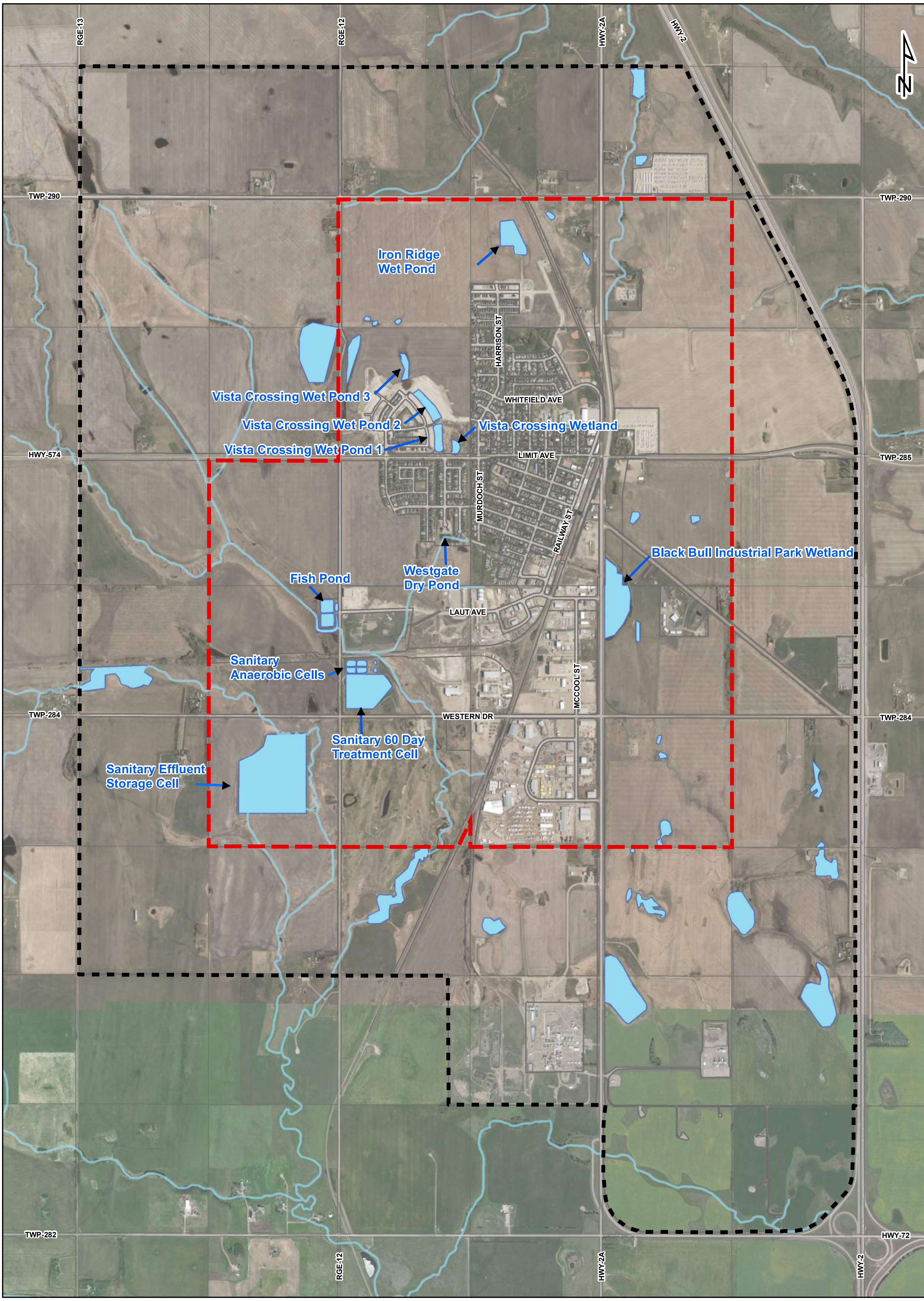
FIGURE 3.3
EXISTING OVERLAND DRAINAGE PATTERNS
CROSSFIELD STORMWATER MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.

Date: 4/13/2020 Document: H:\27309 - Supplemental\02_CADD\251_Figures\01_Report Figures\3.0 Existing Stormwater System\Figure3.2_Ex_Drainage_Patterns.mxd



Date: 4/13/2020 Document: H:\27309 - Supplemental\02_CADD\251_Figures\01_Report Figures\3.0 Existing Stormwater System\Figure3.3_Ex_Waterbodies.mxd

Credits:Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

0 125 250 500 750 1,000 Metres

1:22,000 CANA83-3TM114

Legend

- Watercourse
- Waterbody
- Annexation Boundary
- Pre-Annexation Boundary

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FIGURE 3.3
EXISTING WATERBODIES
CROSSFIELD STORMWATER
MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.

4.0 Hydraulic Model Development

4.1 Model Set-Up

The model used for assessing Crossfield's stormwater system was InfoWorks ICM developed by Innovyze, which was selected for its advanced capabilities associated with 2D modelling. Some of the advantages of InfoWorks ICM that were considered to be an asset for this project are summarized below:

- Effective in urban applications, InfoWorks ICM is the preferred modelling software utilized by numerous municipalities across the country.
- Ease with applying differential cell sizing.
- Rain on Mesh option is available, meaning that overland flow path assumptions are not necessarily required upfront.
- Triangular mesh elements mean that the surface can be modelled with extreme accuracy.
- Ability for terrain sensitive meshing, ensuring that changes in topography are reflected in the mesh.
- Mesh generation effectively accounts for building footprints.
- Model is very stable, therefore reducing the potential for corruptions. As well, the model saves automatically, so any fatal errors that may occur do not result in a loss of work.
- Many result formats are available, including 3D videos that can be used for presentations to stakeholders.
- There is complete integration with ArcGIS.

The InfoWorks ICM platform has been widely accepted by numerous municipalities across the country. A list of a number of municipalities with licenses to InfoWorks ICM is provided below:

- Regina
- Winnipeg
- Brandon
- Toronto
- Ottawa
- Vaughan
- Peel Region
- York Region
- Halton Region
- Kitchener
- London
- Windsor

The Town's model was constructed by utilizing available data combined with confirmations from survey, limited record drawings, and certain assumptions. Section 4.1.1 describes the process that was undertaken to develop the 1D portion of the model. In this section, the survey data that was collected is described, the source of record drawings is noted, and the assumptions that were applied are noted. Section 4.1.2 describes the process that was undertaken to develop the 2D portion of the model. This includes a discussion of the features and parameters that were required as input into the mesh development process, and a summary of the mesh generation itself.

4.1.1 Minor (1D) System Development

The minor system includes all underground piped infrastructure. InfoWorks ICM defines any point features as nodes and any line features as links. In the model, nodes can represent flow into the system, storage facilities such as wet wells, wet/dry ponds, or lakes, can be placed solely to represent a spot where links intersect, and can be used to store water under surcharge conditions. Links can convey water between nodes such as a conduit, channel or river reach, or can be a control such as an orifice, weir, or pump. In Crossfield, the following infrastructure was considered, and is classified either by a node or a link:

- Nodes
  - Manholes
  - Manhole Catchbasins
  - Catchbasins
  - Inlets
  - Dummy Nodes
  - Outfalls
- Links
  - Gravity Sewers
  - Catchbasin Leads
  - Culverts
  - Orifices
  - Weirs

To develop the 1D portion of the model, information pertaining to the Town's minor stormwater infrastructure was required. Limited information was available at the start of this project related to the Town's minor stormwater system, thus requiring a fair number of sources to fill in the data gaps. For newer areas, ISL was able to obtain record drawings in AutoCAD from various third parties. This data was available for:

- Iron Ridge (LMEA)
- Vista Crossing (EXP)
- Hawks Landing (Stantec)
  - Hawks Landing is a proposed development, thus was not included for existing conditions

The stormwater schematics from these sources were exported from AutoCAD into geographic information systems (GIS) so that data could be pre-processed in ArcGIS prior to importing into InfoWorks ICM. The pre-processing involved adding a number of fields for various pertinent parameters, including the following summarized in Table 4.1 below. Values for these parameters were obtained from the original AutoCAD sources.

Table 4.1: Summary of Data Input from Third Party Sources

Classification Type	Parameter	Unit	Value
Node	Type	N/A	Manhole, Catchbasin, Outfall, Plug
	Ground Elevation	m	Varies
	Invert Elevation	m	
	Grate Type	N/A	Twin C, Type K2, TF-50 Beehive Grate, ICD Type
Link	Type	N/A	Gravity Sewer, Culvert, Catchbasin Lead
	Size	mm	200, 250, 300, 375, 450, 600, 675, 750, 900, 1050
	Material	N/A	Concrete, Polyvinyl Chloride (PVC), Corrugated Steel Pipe (CSP)
	Length	m	Varies
	Upstream Invert	m	
	Downstream Invert	m	

For older areas of the Town that had no available record drawings, ISL conducted a virtual road inspection using Google's Street View. The intent of this exercise was to locate all areas within the Town that have catchbasins, thus indicating the presence of a stormwater system. The caveat here is the potential for cross-connections to the sanitary system, however the assumption was that no cross-connections exist. That said, if any cross-connections are identified in the future, the stormwater model should be updated accordingly. The areas that were flagged to have a minor stormwater system that did not overlap with the GIS data processed for the newer developments required survey to collect data pertaining to the system.

Existing survey information was obtained from the Joint ASP study completed in 2016 by ISL and from the survey work completed for the downtown area by Stantec. Supplemental surveying was undertaken by ISL in 2019 as part of this project to fill in the remaining gaps further. The 2019 survey consisted of determining the ground elevation of the flagged catchbasins and the apparent connected manholes, then measuring the depth to the bottom of either the catchbasin or manhole. Survey was also performed on a number of culverts, which included measuring the diameter of the culvert and obtaining a ground elevation. Geotagged photos were collected at each survey location. The source for each surveyed point is shown in Figure 4.1, noting that this figure omits infrastructure with alternate data sources, as shown in Figure 4.2.

The unknown diameters of pipes adjacent to the infrastructure surveyed in 2019 were assigned diameters through an approximation method from the geotagged photos. Remaining missing diameters were assigned values through assumptions from neighbouring infrastructure. Unknown pipe materials were assumed to have a Manning's roughness of 0.013, thus assumes a concrete pipe. Unknown culvert materials were assumed to have a Manning's roughness of 0.024, as is consistent with corrugated metal pipe (CMP) and CSP.

Information pertaining to catchbasin leads was not available in GIS for the majority of the Town, thus required to be manually added into the model. Catchbasin leads were assumed to tie into the nearest manhole. All added catchbasin leads were assumed to be 250 mm in size and have a roughness of 0.013. The downstream invert was assumed as the upstream invert of the downstream pipe while the upstream invert was found using the calculated length and assuming a 2% slope. These criteria are consistent with the Stormwater Management and Design Guidelines (City of Calgary, 2011). The guidelines stipulate that leads connected to single catchbasins shall have a minimum diameter of 250 mm and a minimum slope of 2%. Though twinned catchbasins are allowed a minimum diameter of 300 mm, this would present a less conservative modelling approach thus was not considered.

Rating curves were assigned to each catchbasin. If the catchbasin type was known, the associated rating curve and inlet control device (ICD), if applicable, was assigned. This was applied for areas where record drawings were available, as stipulated above. Otherwise, a standard Type C inlet with no ICD was assumed, with the capture rating data summarized in Table 4.2 below. The standard Type C grate type was selected as it is generally more conservative to the piped system versus the surface drainage, allowing piped capacity a more substantial role in system performance. As this is a generalized approach and may not fit all applications, it is recommended that if the model is used for a more localized design project, site reconnaissance is undertaken to determine each catchbasin grate type in the area and then a specific detailed model review be undertaken to optimize surface capture. Inlets associated with culverts were assigned their own unique head discharge curves based on diameter. These curves were derived using the Orifice Equation, given the area of the culvert.

Table 4.2: Type C Inlet Capture Rating Data under Ponding Conditions as per the Stormwater Management and Design Manual (City of Calgary, 2011)

Ponding Depth	Capture Rate
m	L/s
0	0.0
0.10	110.3
0.20	149.8
0.30	155.5
0.40	161.0
0.50	166.3

Following the identification and resolution of all data gaps, the node and link data that was pre-processed in ArcGIS was imported into InfoWorks ICM. An extensive QA/QC process was undertaken to ensure proper connectivity between all links and nodes in the model. Additional appurtenances, such as any weirs, orifices, and ICDs were then added to the model where necessary based on the provided record drawings noted above. All manhole catchbasins, catchbasins, and inlets were designated as 2D nodes, to facilitate the exchange between the 1D and 2D systems (referred to as coupling).

4.1.2 Major (2D) System Development

The major system consists of all overland drainage components listed in Section 3.0. In Crossfield, the following parameters have been considered to develop a mesh, which ultimately represents the overland drainage system:

- 2D Zone
- Mesh Zones
- Roughness Zones
- Infiltration Zones
- Building Footprints

The 2D Zone represents the boundary in which the 2D analysis will occur in. The 2D Zone was digitized to be a simplified version of the proposed annexation area. A mesh will be created within a 2D Zone. The mesh represents the surface through the use of triangulation. Each triangle is referred to as a mesh element, each with their own unique elevation, which is calculated using surface data, ultimately making each mesh element flat. Together with other mesh elements, a surface is formulated. The number of mesh elements has a direct impact on simulation run times. Various parameters can be considered when developing a mesh. For the model that has been developed as part of the SMP, these parameters include the Mesh, Roughness, and Infiltration Zones.

The Mesh Zone specifies different mesh element densities for various zones, to either increase or decrease the resolution of a zone depending on its importance. For example, in order to capture pertinent features such as the crowns of roads or curb and gutters, roadways are generally defined by denser, smaller elements. Alternatively, greenfields that do not impact existing developments could be considered for larger mesh elements.

The Roughness Zone allows various Manning's n roughness values for different parts of the mesh. A roughness value is assigned to each mesh element depending on which Roughness Zone that mesh element is a part of. The Roughness Zone allows for a more accurate representation of different surfaces within the model.

The Infiltration Zone allows for various infiltration parameters across the mesh, depending on the different surfaces that are apparent within the mesh. Each Infiltration Zone is designated an Infiltration Surface, where an Infiltration Type can be specified. Four Infiltration Types are available along with their related parameters, including:

- Fixed
  - Fixed Runoff Coefficient
- Horton
  - Horton Initial
  - Horton Limiting
  - Horton Decay
  - Horton Recovery
- Constant Infiltration
  - Fixed Runoff Coefficient
  - Infiltration Loss Coefficient
- Green-Ampt
  - Green-Ampt Suction
  - Green-Ampt Conductivity
  - Green-Ampt Deficit

In this model, impervious surfaces are represented through a fixed runoff coefficient, while pervious surfaces are represented by the Horton Infiltration Type.

Default mesh, roughness, and infiltration parameters were defined in the 2D Zone to represent impervious areas such as roadways and buildings. These default parameters are stipulated below in Tables 4.3, 4.4, and 4.5. Additionally, the options to 'Apply rainfall etc. directly to mesh' and 'Terrain-sensitive meshing' were selected. The 'Apply rainfall etc. directly to mesh' option ensures that rainfall is falling directly onto the surface, which provides a more accurate representation of overland flows. The 'Terrain-sensitive meshing' option better represents the surface topography among the mesh elements.

The Mesh, Roughness, and Infiltration Zones were generated through the geospatial development type information, in order to be able to specify different criteria depending on the development type. It is noted that the physical boundaries of each Mesh, Roughness, and Infiltration Zone polygon are identical, however the parameters vary depending on the type of polygon (i.e., whether it is a Mesh, Roughness, or Infiltration Zone). Maintaining the same extent for each polygon type ensured there would be no errors regarding overlaps between the different polygon layers. These polygons, differentiated based on land use type, are illustrated in Figure 2.5.

The parameters applied per development type are specified in Tables 4.3, 4.4, and 4.5 below for the Mesh, Roughness, and Infiltration Zones, respectively. The Mesh Zone parameters are based on ISL's past experience using InfoWorks ICM, optimizing both model simulation time and level of detail. The Roughness Zone parameters are based on engineering best practices, and are consistent with past projects completed by ISL. The Infiltration Zone parameters are based on a combination of the runoff coefficients stipulated in the Stormwater Management and Design Manual (City of Calgary, 2011), a review of pavement to grass ratios of various parcels throughout the Town and engineering best practices.

Table 4.3: Mesh Zone Parameters per Land Use Type

Land Use	Maximum Triangle Area	Minimum Element Area
	m^2	m^2
Business	50	25
Building (default value)	5	1
Commercial	50	25
Industrial	50	25
MHR[1]	50	25
Municipal	50	25
Residential	50	25
Roads (default value)	5	1
Urban Holdings	100	50

[1] *The acronym MHR defines a Residential – Manufactured Home District*

Table 4.4: Roughness Zone Parameters per Land Use Type

Land Use	Roughness Coefficient
Business	0.0181
Building (default value)	0.0160
Commercial	0.0181
Industrial	0.0167
MHR	0.0258
Municipal	0.0195
Residential	0.0258
Roads (default value)	0.0160
Urban Holdings	0.0300

Table 4.5: Infiltration Zone Parameters per Land Use Type

Land Use	Infiltration Type	Fixed Runoff Coefficient	Horton Initial	Horton Limiting	Horton Decay	Horton Recovery
			mm/hr	mm/hr	1/hour	1/hour
Business	Fixed	0.85	-	-	-	-
Building (default value)	Fixed	0.95	-	-	-	-
Commercial	Fixed	0.85	-	-	-	-
Industrial	Fixed	0.9	-	-	-	-
MHR	Fixed	0.3	-	-	-	-
Municipal	Fixed	0.6	-	-	-	-
Residential	Fixed	0.3	-	-	-	-
Roads (default value)	Fixed	0.95	-	-	-	-
Urban Holdings	Horton	-	75	7.5	4.14	0.001

Incorporating buildings into the 2D model was a major consideration. Ultimately, as the models utilize a rain on mesh ideology, the most conservative and effective approach was found to be raising the buildings on the LiDAR surface such that runoff could not penetrate the buildings, and allow rainfall to land on top of the building and fall off naturally. Building footprints were digitized based on the available aerial imagery, as shown in Figure 4.3. The building footprint polygons were clipped from the Mesh, Roughness, and Infiltration Zones such that there was a buffer between the edge of the building footprint polygon and the edge of each of the zones.

Mesh generation was an iterative process, in order to produce a smooth mesh with limited unnecessary mesh elements caused by small gaps between polygons or excessive vertices. With the mesh elements loaded to the network, these small clusters of mesh elements could be easily identified, as they appeared darker than other areas of the mesh. These issues were mitigated by closing the gaps between polygons, or by removing any unnecessary vertices. The result of this iterative process was a smooth mesh without excess mesh elements.

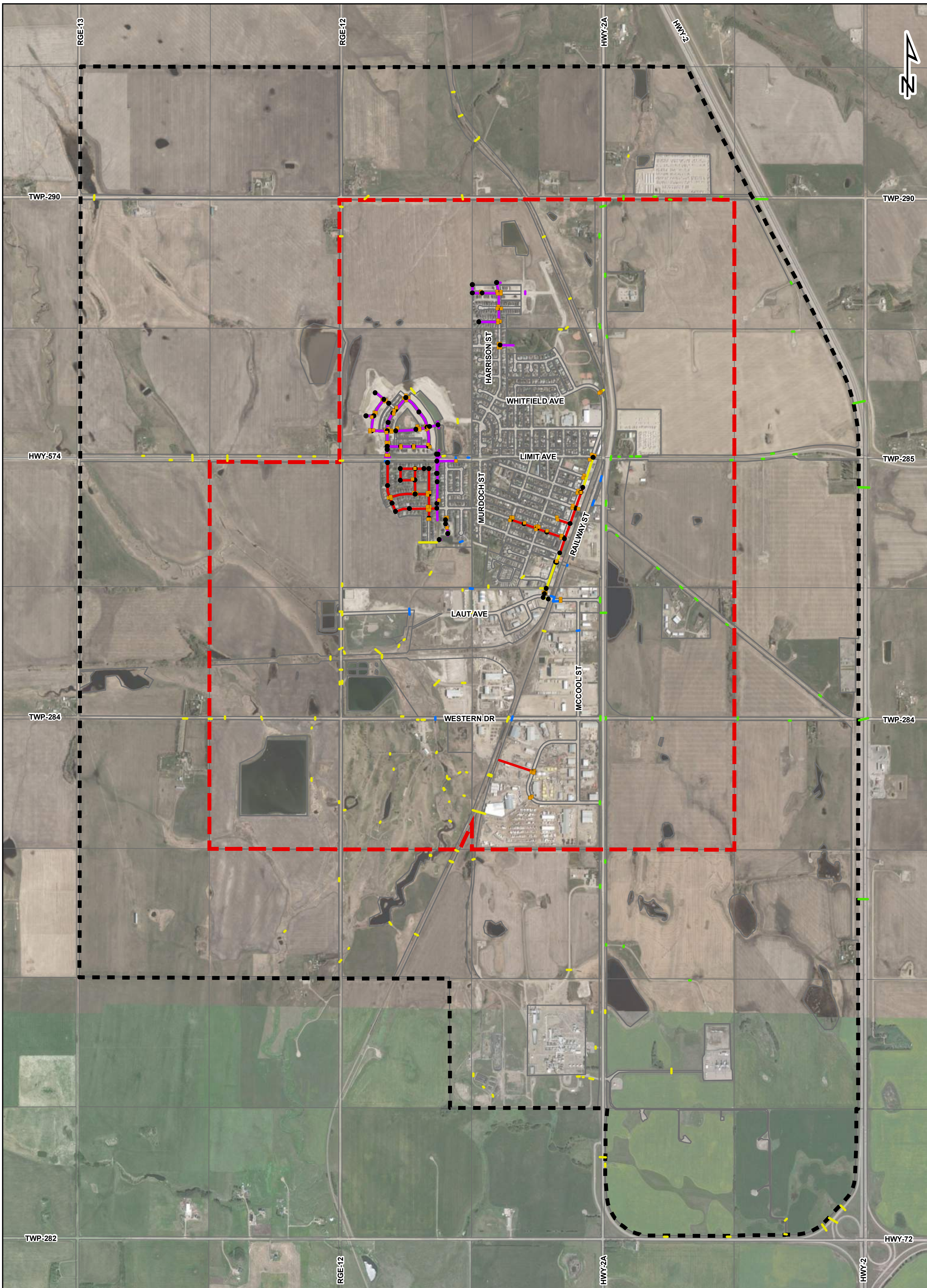
4.2 Subcatchment Delineation

4.2.1 Existing Subcatchments

Existing subcatchments were also delineated as part of this project. As the existing model is fully integrated between 1D-2D, the subcatchments were largely not necessary for the modelling process. Subcatchments were delineated nonetheless to be appended to the final version of the model for future use in 1D modelling applications. The subcatchments were delineated using a powerful ArcGIS tool, which found the highest elevations around an inflow node and digitized boundaries based on these elevations. The subcatchments were then checked for quality assurance/quality control (QA/QC), and refined adjusted, if required, for additional accuracy. Runoff parameters such as subcatchment area, average slope, and width were assigned to the shapefile polygons, in addition to unique IDs. The existing system subcatchments are shown in Figure 4.4. There are certain areas within the Town's boundary that do not have subcatchments delineated, specifically near the annexation boundary in the southwest. These are areas that drain out of the Town's boundary, that also have no minor system infrastructure within them.

4.2.2 Future Subcatchments

Generally speaking, future subcatchments were delineated based on a per quarter section basis with the assumption that current topography will be maintained. As such, these subcatchments should be revisited at the development stage to ensure that the proposed grading of each development site is accounted for. Some quarter sections were further divided, or grouped where necessary, based on significant changes in grade. One major consideration for the delineation of these subcatchments was the division between the Bow River and Red Deer Watersheds. Runoff parameters such as subcatchment area, average slope, width, and composite runoff coefficients were assigned to each subcatchment, in addition to unique IDs. Further discussion to these subcatchments is provided in Section 7.0 below.



Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Metres
0 125 250 500 750 1,000
1:22,000 CANA83-3TM114

Legend

- Manhole
- Catchbasin
- Annexation Boundary
- Pre-Annexation Boundary

Pipe Diameter Data Souce

- Obtained from 2016 Survey
- Obtained from 2019 Survey
- Obtained from As-Built Drawings or Storm Reports
- Approximated from Manhole Photos
- Assumed

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FIGURE 4.1
EXISTING SYSTEM
PIPE DIAMETER DATA SOURCE
CROSSFIELD STORMWATER
MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.

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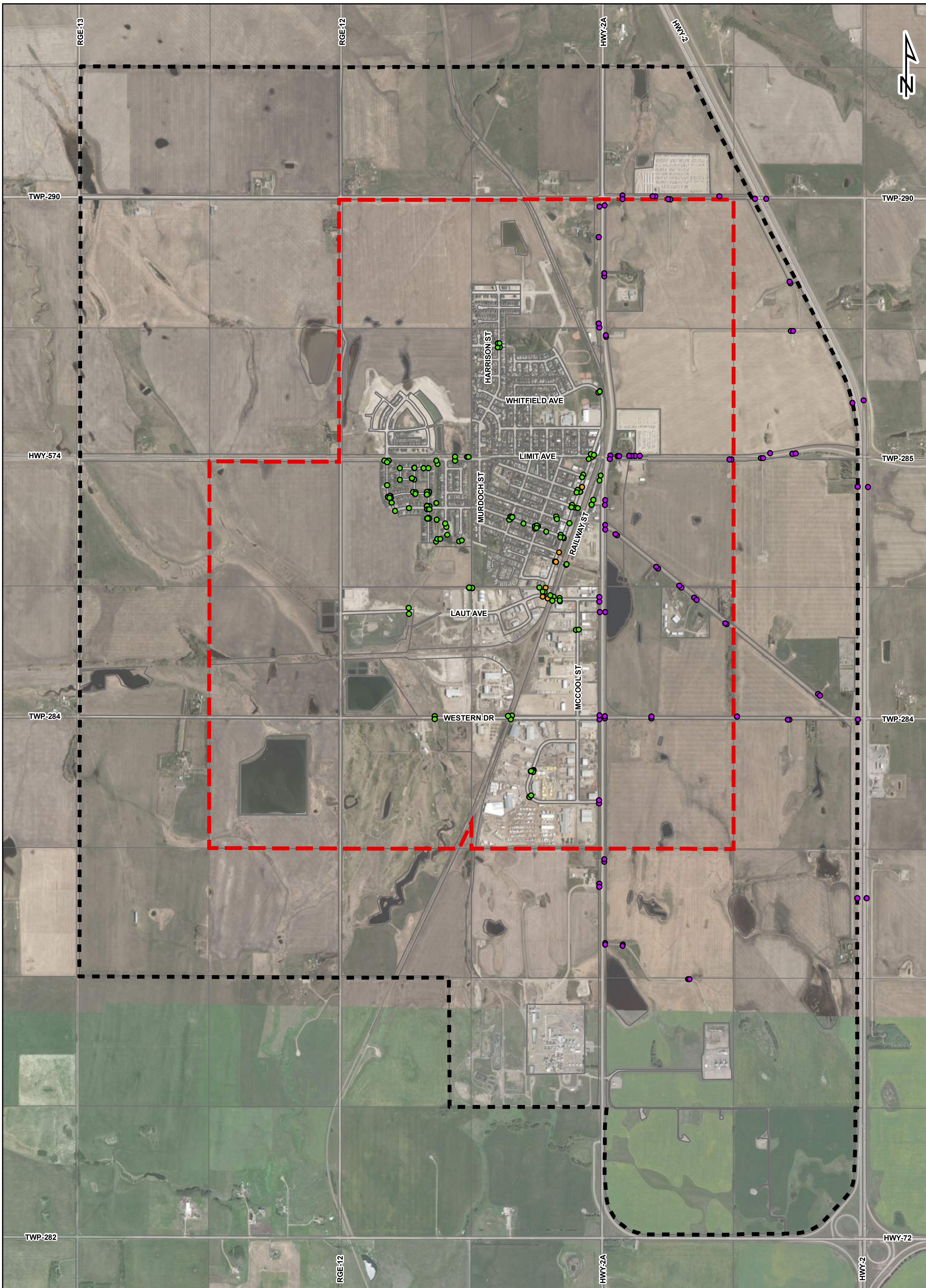

Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

0 125 250 500 750 1,000 Metres

1:22,000 CANA83-3TM114

Legend

- 2016 Survey Points
- 2019 Survey Points
- Downtown Survey Points
- Annexation Boundary
- Pre-Annexation Boundary

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FIGURE 4.2
EXISTING SYSTEM
SURVEYED POINTS
CROSSFIELD STORMWATER
MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.

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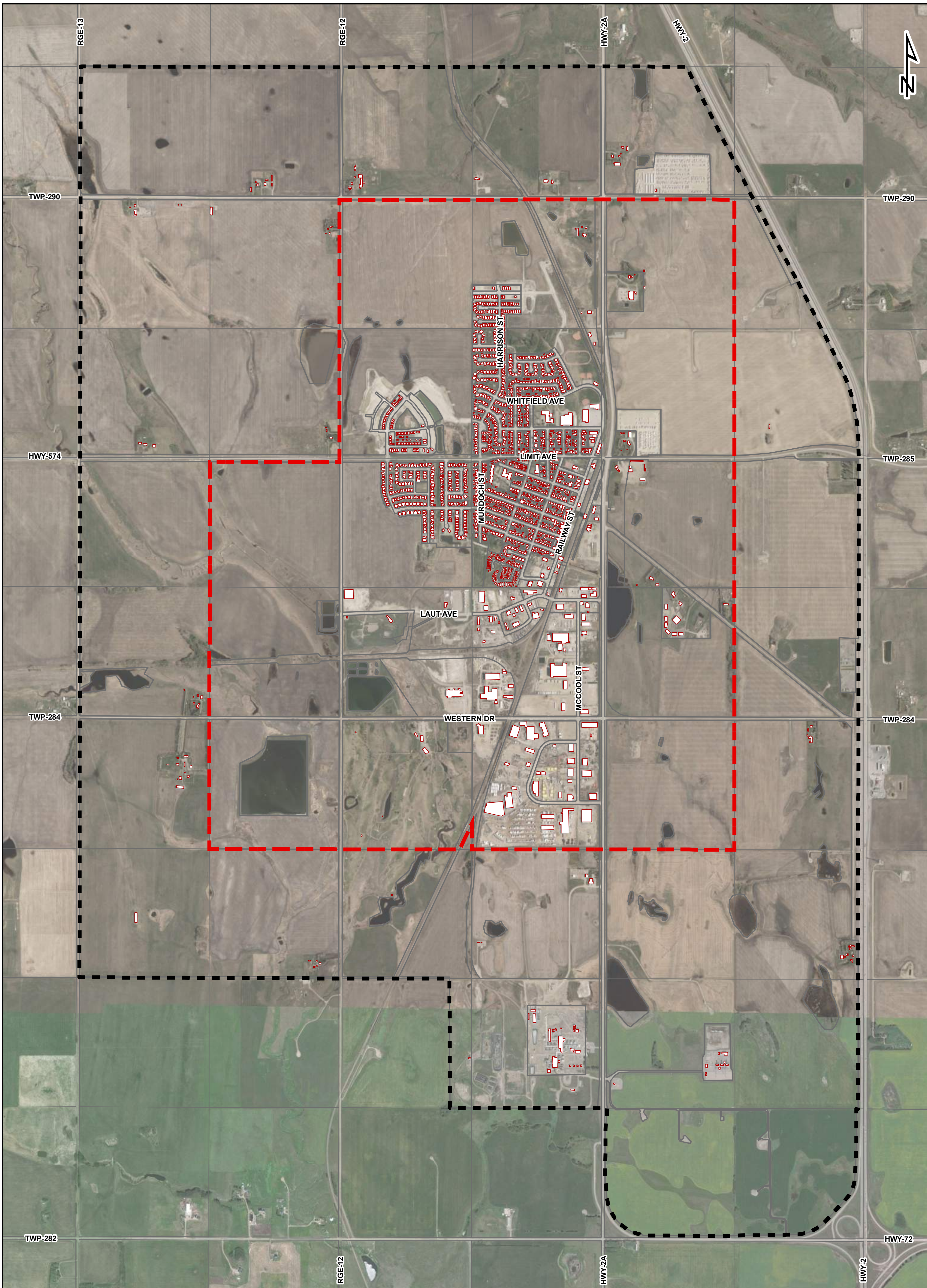

Date: 4/13/2020 Document: H:\27309 - Supplemental\02_CADD\251_Figures\01_Report Figures\4.0 Hydraulic Model Development\Figure4.3_Digitized Building Footprints.mxd

Credits:Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

0 125 250 500 750 1,000 Metres

1:22,000 CANA83-3TM114

Legend

- Digitized Building Footprints
- Annexation Boundary
- Pre-Annexation Boundary

FIGURE 4.3
DIGITIZED BUILDING FOOTPRINTS
CROSSFIELD STORMWATER MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.

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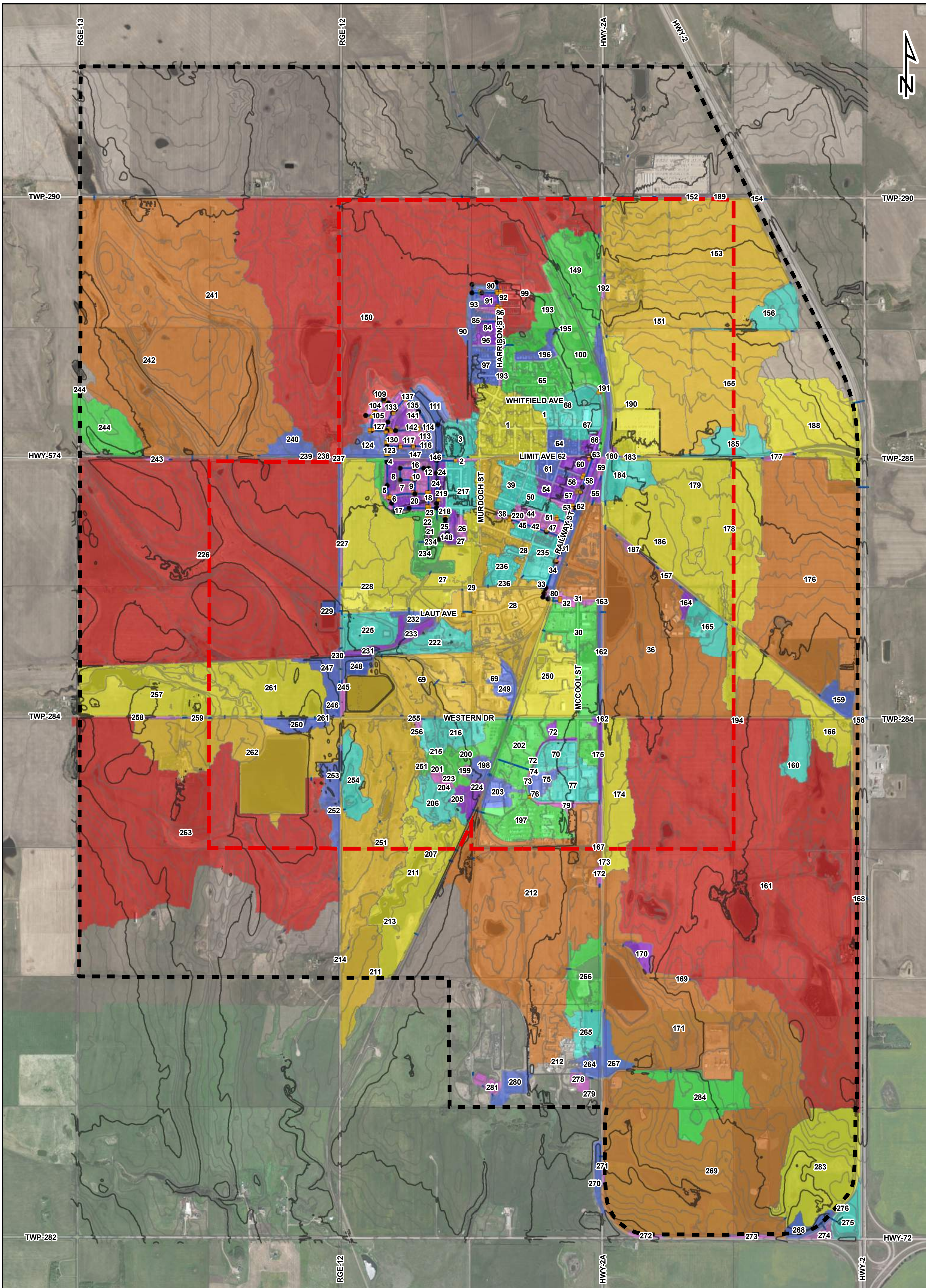

Credits:Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Metres
0 125 250 500 750 1,000
1:22,000 CANA83-3TM114

Legend

- Annexation Boundary
- Pre-Annexation Boundary
- Major Contour -10m Interval
- Minor Contour - 2m Interval
- Manhole
- Catchbasin
- Sewer

Subcatchment Area (sq.m)

- 0.0 - 1.0
- 1.1 - 2.0
- 2.1 - 4.0
- 4.1 - 8.0
- 8.1 - 16.0
- 16.1 - 32.0
- 32.1 - 64.0
- 64.1 - 128.0
- 128.1 - 256.0

FIGURE 4.4 EXISTING SUBCATCHMENTS CROSSFIELD STORMWATER MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.

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5.0 Design Criteria

The design criteria used to assess the stormwater system was based primarily on The City of Calgary's Stormwater Management and Design Manual, and engineering best practices utilized by ISL based on our experience with similar projects across Alberta, such as The City of Calgary, Town of High River, Town of Hinton, Rocky View County, and Mountain View County. The design criteria selected were then used for input into the InfoWorks ICM model to design and assess the stormwater drainage system.

5.1 Pre-Development Runoff Rate Analysis

The existing Town of Crossfield Master Drainage Plan (Stormwater Solutions Inc., 2008) proposes a peak stormwater discharge rate under 1:100 year conditions of 1.257 L/s/ha for Nose Creek and 1.4 L/s/ha for Crossfield Creek. The peak flow discharge rate for Nose Creek is keeping with that recommended in the Nose Creek Watershed Water Management Plan (Palliser, 2008). These rates have been applied when sizing the proposed SWMFs to be consistent with the past study and the recommendations stipulated by the Nose Creel Watershed Water Management Plan.

It should be noted that traditional stormwater management approaches in the Province of Alberta have focused on the control of peak discharge rates, but not total discharge volumes for all watersheds. Provincial guidelines as per the Stormwater Management Guidelines for the Province of Alberta (Alberta Environment, 1999) restrict post-development flow rates to pre-development flow rate levels, but do not deal with total discharge volumes.

For the Crossfield Creek Watershed, the focus of this report will be on peak discharge rates required in accordance with the Province of Alberta's guidelines, as volume targets are not currently imposed on this watershed. As part of the Nose Creek Watershed Water Management Plan, current volume targets are held at an allowable annual release of 16 mm and will be reduced to 11 mm in 2021. That said, there is potential for volume control targets to change again in the future. This has already been evident in The City of Calgary, as noted in the Industry Bulletin for Interim Runoff Volume Control (City of Calgary, 2019). This bulletin stipulates that the maximum degree possible of volume control should be achieve. For that reason, volume control targets have also been omitted for the Nose Creek Watershed in this SMP as it is unclear whether these targets will remain in effect moving forward. A comparison of relative pond sizing and costs between the 16 mm target and no target are provided in Section 7.0 below.

Volume control has been typically implemented in the Nose Creek Watershed to better match pre-development streamflow hydrology, reduce changes to the channel morphology, and enhance water quality. The risk of not implementing volume control targets includes widening of the stream, less suitable aquatic habitats, potentially unstable streambanks, and degraded riparian areas. That said, the restrictive targets currently in place have resulted in delayed or stalled developments because the volume controls cannot be achieved. A balance between ensuring development can progress within the Town while still adhering to the peak stormwater discharge rates was determined to be the ideal solution for the proposed SWMFs. That said, if the volume control targets are revised to allow for more leniency, the Town could choose to revisit SWMF sizing at that time. Note that sizing of the SWMFs has the potential to increase substantially as a result of implementing volume control.

5.2 Design Rainfall Event

The design storms applied in this study are based on The City of Calgary's adjusted Meteorological Service of Canada (MSC) intensity-duration-frequency (IDF) curves that are stipulated in the Stormwater Management and Design Manual document (City of Calgary, 2011). The adjusted MSC IDF curves are intended for computer modelling applications, as they are more closely fine-tuned to the best-fit curves. Tables 5.1 and 5.2 summarize the IDF intensities and parameters, respectfully.

Table 5.1: City of Calgary's Adjusted MSC IDF Curve – Intensity Summary (mm/hr)

Time	Return Frequency					
Minutes	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year
5	58.80	87.60	106.80	132.00	150.00	168.00
60	13.70	19.40	23.20	28.00	31.60	35.10
720	2.59	3.50	4.09	4.85	5.41	5.97
1440	1.55	2.13	2.52	3.00	3.37	3.73

Table 5.2: City of Calgary's Adjusted MSC IDF Parameters

Parameter	Return Frequency					
	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year
a	243.0	353.5	429.1	522.6	594.9	663.1
b	2.710	2.290	2.160	1.960	1.940	1.870
c	0.695	0.703	0.707	0.709	0.711	0.712

In assessing the storm drainage system in the area, a design rainfall event is required to generate runoff that will subsequently enter the network. The minor system is assessed to handle the runoff from storms up to the 1:5 year storm event while the major system must handle the excess flow during events that are greater than the 1:5 year storm event. Further to this, storm sewers shall be sized to convey the 1:5 year design peak flow and the major drainage system shall be designed to handle at least the 1:100 year storm event. These return periods are consistent with many other municipalities, therefore were used in assessing the stormwater system. The storms are set in 5-minute time steps, with the peak intensity set to a 5-minute duration for the selected storm return period.

The 1:5 year storm event is a 1-hour Chicago rainfall distribution. This storm tests the stormwater drainage system's capability of accommodating short duration, high intensity storm events – it is typically a critical event to review the minor (piped) drainage system. The 1:100 year storm is a 24-hour Chicago rainfall distribution. These rainfall distributions are based on The City of Calgary's IDF curves. Hydrographs of the 1:5 year 1-hour and 1:100 year 24-hour Chicago rainfall distributions based on Calgary's IDF parameters are illustrated below in Figure 5.1.

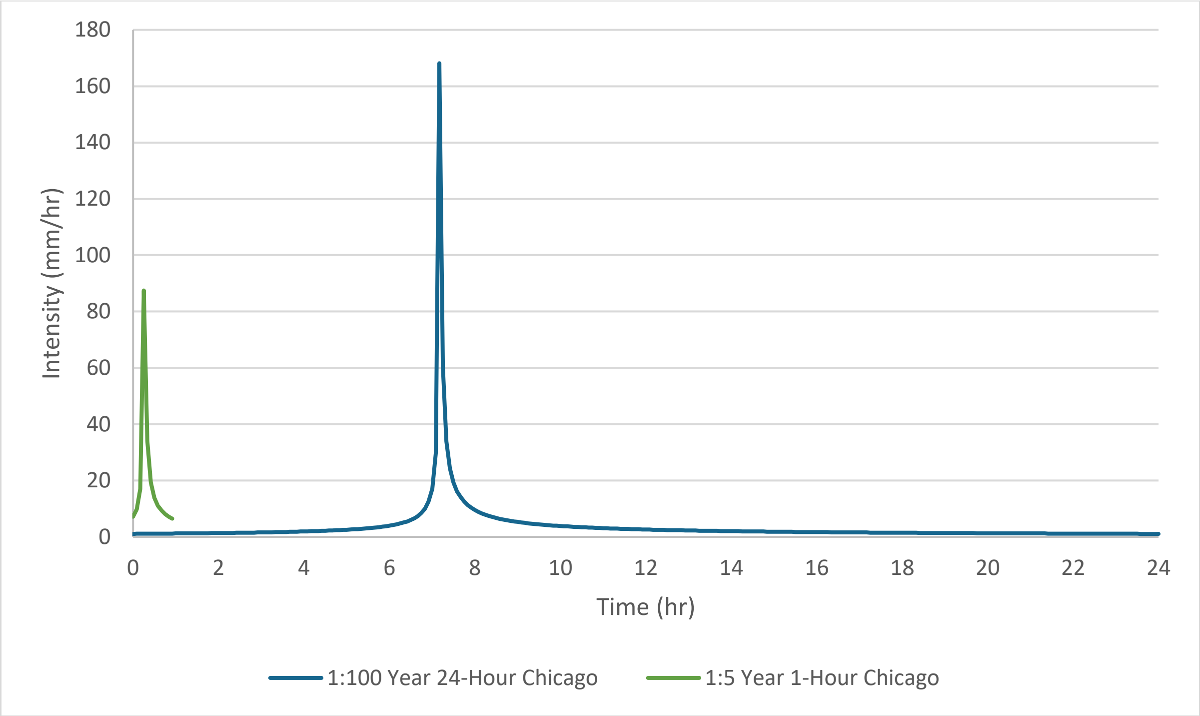


Figure 5.1: Utilized Design Rainfall Event Hydrographs

5.3 Assessment Criteria

The performance of the stormwater collection system under the existing conditions is ultimately determined based on the available freeboard between the ground elevation and high water level elevation (represented by the maximum hydraulic grade line (HGL)) at each manhole for each assessment design storm.

In assessing the storm drainage system in an area, typically a 1:5 year storm is used to assess the minor (piped) drainage system under short duration, high intensity rainfall events. This is followed by analysis with a large volume storm to test the system under large flow volumes once the system is saturated, this would typically be a 1:100 year, 24-hour event. The existing stormwater collection system was analyzed under the following two assessment scenarios to determine system conditions:

- 1:5 Year 1-Hour Chicago rainfall event
- 1:100 Year 24-Hour Chicago rainfall event

The performance of the existing 1D network was assessed in terms of two indicators as follows.

Maximum HGL Elevation Relative to the Ground

Maximum HGL Elevation Relative to the Ground is the amount of freeboard between the maximum water elevation and ground elevation at each manhole at the moment when maximum flow passes through.

The maximum allowable surcharge in the gravity portion of the stormwater systems must remain at least 1.2 m from the ground surface during a design storm scenario, as stipulated in The City of Calgary's Stormwater Management and Design Manual.

Hence, the Maximum HGL Elevation Relative to the Ground with a value of:

- Greater than 0.00 m is denoted as a red dot – indicating a surcharge/back-up to surface
- Between -1.2 m and 0.00 m is denoted as an orange dot – maximum HGL peaks within 1.2 m below the ground
- Between -1.2 m and -3.0 m is denoted as a yellow dot – maximum HGL peaks between 1.2 m and 3.0 m below the ground
- Less than -3.0 m is denoted as a green dot – maximum HGL peaks 3.0 m below the ground

Peak Discharge Relative to Sewer Capacity

Peak Discharge Relative to Sewer Capacity indicates the ratio of peak flow to sewer capacity; as a corollary to this, the data can be interpreted to indicate the amount of spare capacity during peak flows. This is calculated by employing a ratio of modelled flow in a sewer and its corresponding capacity. Sewers with ratios greater than one are considered to have no spare capacity thus indicating a section of sewer that might require upgrading, particularly where the length of the section is long enough to cause surcharge conditions immediately in the upstream reach.

Hence, the Peak Discharge Relative to Sewer Capacity (Q/Qman) with a ratio of:

- Greater than 1.00 is denoted as a red line – over capacity, or in another words the capacity is diminishing as the maximum flow theoretically occurs at roughly 93% of the sewer's diameter. This means that in principle, sewers with a Q/Qman ratio equal to or less than 1.05 have their flow still contained within the sewer
- Between 0.86 and 1.00 is denoted as an orange line – less than 14% of spare capacity available
- Less than 0.86 is denoted as a green line – spare capacity available

5.3.1 Additional Criteria

In addition to these two scenarios, the spare capacity of each sewer was determined. This indicates the amount of additional flow each sewer can handle before it becomes completely used. The amount of spare capacity ranges from less than 0 L/s to over 100 L/s, with the least capacity illustrated in red and the most capacity illustrated in green. In determining spare capacity, it becomes evident which sewers are available to handle any additional flows from future development, and which sewers should remain untouched.

To present and evaluate 2D assessment model results, model files were reviewed and results data was extracted for both depth and velocity at the maxima, for the 1:5 year and 1:100 year events, respectively. The complete model file contains velocity and depth properties at any time step within the simulation in the event they are required. Additionally, different storm events can be applied to the model to allow Crossfield to explore different scenarios if required.

To increase public safety, the Province of Alberta has stipulated permissible depths for submerged objects in relation to water velocity. This guideline, Stormwater Management Guidelines for the Province of Alberta, 1999, was implemented to ensure that a 20 kg child would be able to withstand the force of moving water, thus preventing possible tragedies. Figure 5.2 indicates these requirements.

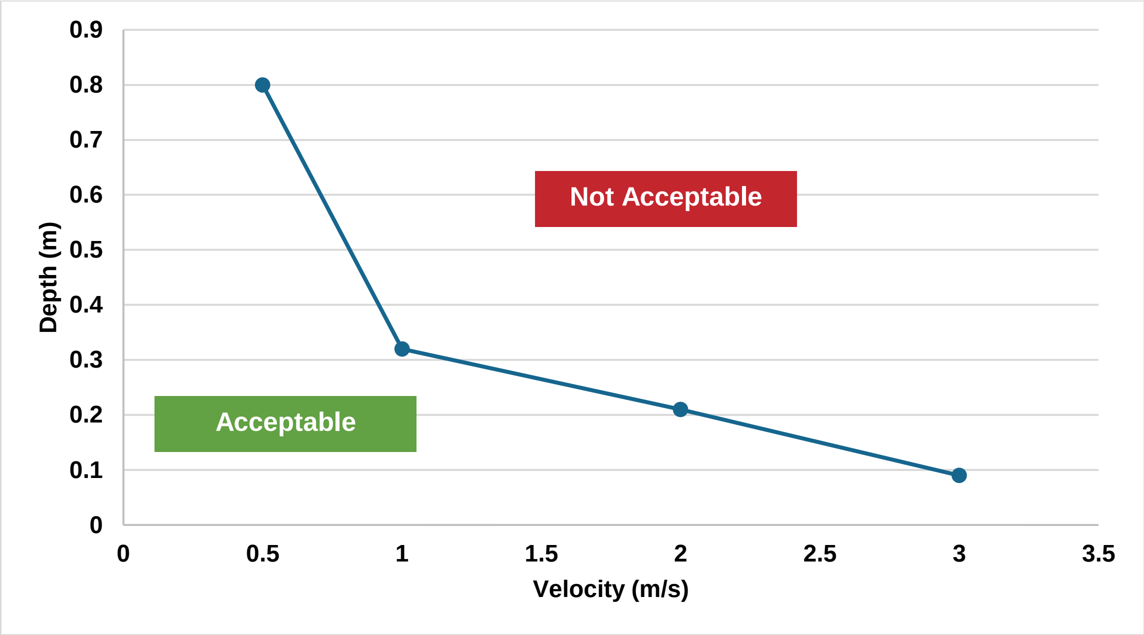


Figure 5.2: Permissible Depths for Submerged Objects

5.4 Design Guidelines for Future Stormwater Management Facilities (SWMF)

In determining future development requirements, the same criteria detailed in Table 4.5 was utilized to calculate runoff. In addition to this, there are several hydraulic design criteria necessary to conceptualize a future stormwater management system for the Study Area. The following criteria were utilized to develop the model under proposed conditions. Unless otherwise noted, these criteria are based on the Design Summary Guide for Wet Ponds in Table 6-2 of The City of Calgary's Stormwater Management and Design Manual.

- Maximum allowable area release rate of 1.257 L/s/ha in the Nose Creek Watershed, and a rate of 1.4 L/s/ha in the Crossfield Creek Watershed from all SWMFs, as discussed in Section 5.1.
- Minimum removal of 85% of particles 50 microns and larger on an annual basis as per Alberta Environment standards.
- New SWMFs were sized using a 1:100 year design storm with a maximum depth of 1.5 m from the normal water level (NWL) to the high water level (HWL).
- New pipes were sized for 1:5 year design storm based on The City of Calgary's IDF curve.
- Permanent pool depth of 2.0 m at a minimum.
- Maximum interior side slopes of 5:1 to 7:1 (H:V) within permanent pool, 5:1 between NWL and HWL, and 4:1 to 5:1 above HWL. It is noted that for the purposes of this SMP, a 5:1 side slope was maintained throughout.
- Minimum effective length to width ratio of 3:1 to 5:1.
- Minimum freeboard of 0.3 m.
- Quality control provided – typically by an oil/grit separator, normally upstream of the SWMF.

The runoff parameters that were utilized to construct the 1D model for the proposed stormwater concept for future development is described below in Table 5.3. These parameters are based on The City of Calgary's Stormwater Management and Design Manual.

Table 5.3: Runoff Parameters

Runoff Calculation Parameter		Value
Depression Storage	Impervious Areas	1.6 mm
	Pervious Areas	3.2 mm
Manning's 'n'	Impervious Areas	0.014
	Pervious Areas	0.25
Horton Infiltration	Maximum Infiltration Rate	75 mm/hr
	Minimum (Asymptotic) Infiltration Rate	7.5 mm/hr
	Infiltration Decay Rate ('k' value)	4.14/hr

6.0 Existing System Assessment and Upgrades

The existing system was assessed using the design criteria stipulated above in Section 5.3. The existing system was assessed under both the 1:5 year 1-hour Chicago design storm along with the 1:100 year 24-hour Chicago design storm. Simulation results under both rainfall distribution scenarios are described in Sections 6.1 and 6.2, respectively. Longitudinal profiles of a number of key locations in Crossfield's existing stormwater network are included in Appendix A.

6.1 1:5 Year Event Result Summary

6.1.1 1D Model Results

The results for the peak discharge relative to sewer capacity and the maximum HGL elevation relative to ground are shown in Figure 6.1. The spare capacity results are illustrated in Figure 6.2. Model results indicate that the surcharging remains isolated to the locations of the Town that are summarized in Table 6.1.

Table 6.1: 1D Model Result Areas of Concern

ID	Location	Diameter	Length	Maximum Q/Qman
		mm	m	
1	Along Railway Street	450 to 900	679.9	0.93 to 2.29
2	In the easement west of Stevens Place	450 to 675	123.4	1.52 to 1.92
3	The sewers along Stevens Place that discharge to Westgate Dry Pond	600	97.5	0.86 to 3.88
4	At the intersection of Mossip Avenue and Harrison Street, where the storm sewer discharges to the greenspace to the east	300	82	2.26
5	Various catchbasin leads throughout the Study Area	250 to 600	339.6	1.02 to 2.66

Many culverts and catchbasins within the Study Area show maximum HGLs relative to ground that are above the surface. As this is a 2D model, this is expected, as there is water on the surface where these nodes are located. Due to the applied inlet capacities, there may be constraints limiting the ability of these inlet nodes to intake flows, thus elevating the HGLs. This does not necessarily mean that these locations are undersized, but should be analyzed in conjunction with the 2D results to observe what exactly is occurring on the surface. Though the 1D modelling indicated extreme flooding depths at these nodes, there may be sufficient overland drainage in these areas to convey stormwater efficiently through overland flow paths ultimately to a waterbody. This is analyzed as part of the 2D modelling as discussed below.

It is evident from the spare capacity results that there are a number of sewers that possess some spare capacity. These results align well with the peak discharge relative to sewer capacity results. Though there are stretches of sewers with some spare capacity, there are also stretches of sewer either upstream or downstream of many of those sewers that are lacking capacity. Tying additional potential sewers into many of these sections would likely still require some existing sewers to be upsized. It is additionally noted that in areas with spare sewer capacity, if there are noted issues with ponding, catchbasin upgrades could be contemplated.

6.1.2 2D Model Results

To assess Crossfield's existing overland drainage system, model results were extracted at the maxima for both water depth relative to the LiDAR surface and surface flow velocity. It is noted that the maxima represents the peak depth/velocity value of each mesh element at a specific point in time. That said, the time stamps for each mesh element do not necessarily overlap, and each occurrence is independent of the next. The water depth and surface flow velocity results are illustrated in Figures 6.3 and 6.4, respectively.

The results shown on Figures 6.3 and 6.4 indicate that there are a number of locations throughout Crossfield that would experience surface flooding to some extent under the 1:5 year rainfall event. Areas with notable water depths largely focus around ditches, creeks and ponds, where the stormwater is intended to flow. These results are included for illustrative purposes. Crossfield's overland drainage system was ultimately assessed under the 1:100 year rainfall event as per the design criteria stipulated in Section 5.0.

6.2 1:100 Year Event Result Summary

6.2.1 1D Model Results

The results for the peak discharge relative to sewer capacity and the maximum HGL elevation relative to ground are shown in Figure 6.5. The spare capacity results are illustrated in Figure 6.6. Generally speaking, the minor system results under the 1:100 year 24-hour Chicago rainfall distribution are in line with those under the 1:5 year 1-hour Chicago rainfall distribution. This includes surcharging along Railway Street, upstream of the Westgate Dry Pond, and Mossip Avenue. The main variance is that surcharging extends further upstream of the Westgate Dry Pond.

Typically, in a 1D model, it would be anticipated that the 1:100 year 24-hour Chicago storm would completely overwhelm the minor system. That is not necessarily observed when reviewing these results, however. In a 2D model, low points on the surface are better represented on the mesh, thus providing storage points throughout the Study Area. As well, this model considered inlet capacities at each catchbasin and culvert, thus limiting the amount of flow that can enter the minor system. It is likely that the catchbasins are reaching their full capture potential under the 1:5 year scenario, meaning that the majority of additional runoff attributed to the 1:100 year scenario is remaining on the surface.

6.2.2 2D Model Results

To assess Crossfield's existing overland drainage system, model results were extracted at the maxima for both water depth relative to the LiDAR surface and surface flow velocity. It is noted that the maxima represents the peak depth/velocity value of each mesh element at a specific point in time. That said, the time stamps for each mesh element do not necessarily overlap, and each occurrence is independent of the next. The water depth and surface flow velocity results are illustrated in Figures 6.7 and 6.8, respectively.

The results shown on Figures 6.7 and 6.8 indicate that there are a number of locations throughout Crossfield that would experience surface flooding to some extent under the 1:100 year rainfall event. Table 6.2 summarizes critical locations in terms of surface depths and velocities; Figure 6.9 shows these locations compared to the Province's requirements and Figure 6.10 illustrates these locations geographically. The extent of these areas of concern vary, depending on how many mesh elements exceed or are close to exceeding the depth-velocity criteria. In Table 6.2 below, the maximum depth and maximum velocity among all exceeded mesh elements are recorded.

Table 6.2: 1:100 Year Event 2D Modelling Critical Location Surface Depths and Velocities

ID	Location	Maximum Depth	Maximum Velocity
		m	m/s
1	Limit Avenue, west of Harrison Street	0.356	1.002
2	Ross Street (southwest bend)	0.476	0.661
3	Between Railway Street and Highway 2A, north of Crossfield Surplus	1.033	1.053
4	Alberta Highway Services Ltd.	0.733	0.724
5	Nanton Avenue between Ross Street and Railway Street	1.249	0.841
6	Stevens Place south of Smith Avenue	0.406	1.166
7	Intersection of Smith Avenue and Sunset Heights	0.332	0.529
8	Modus Structures Inc.	1.191	0.092
9	Intersection of Mossip Avenue and Harrison Street	0.384	1.03

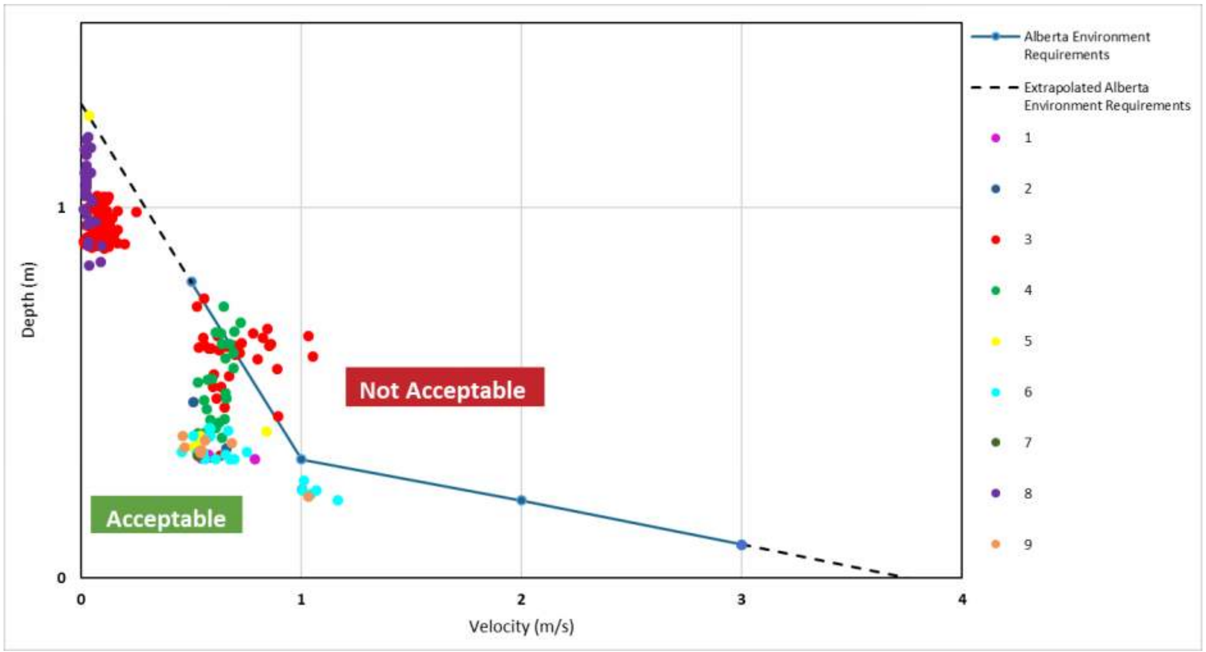


Figure 6.9: Velocity and Depth Guidelines

Another location to note, though it does not exceed the depth-velocity criteria, is at the sanitary lagoon in the southwest. All of the cells, including the anaerobic, 60 day treatment, and effluent storage cells, have a degree of stormwater ponding under both the 1:5 year and 1:100 year events. This is attributed to direct rainfall onto the surface with no discharge point. Typically evaporation is considered when sizing the effluent storage cells. In the Calgary region, the total annual shallow lake evaporation is approximately 750 mm, thus would result in a net decrease in depth, given an annual average precipitation of approximately 325 mm. As the anaerobic, 60 day treatment, and effluent storage cells are all hydraulically connected, the cells equalize depths accordingly. Additionally, as the freeboard provided for lagoons is generally very high (in the 1 – 2 m range), spills from larger rainfall events is not likely.

At the effluent storage cell, in addition to the direct rainfall there are four locations where stormwater runoff is conveyed into the cell from low points in the berm. Three of these low points are located in the northwest corner, while the fourth is located approximately at the halfway point of the south boundary. It is recommended that detailed survey is compiled for the berm surrounding the lagoon to determine if these low points are evident, noting that the LiDAR data is only accurate to 0.5 m. If the collected survey suggests these low points exist, regrading of the berm will be needed in order to prevent stormwater runoff from entering the facility.

6.3 Recommendations for Observed Areas of Concern

Based on the findings of the 1:5 year 1-hour and 1:100 year 24-hour Chicago storm event scenarios, the following recommendations described below in Table 6.3 are suggested. Priorities are ranked as follows:

- Priority 0: the upgrades recommended at these locations are ongoing as of the Final Report submission of the SMP.
- Priority 1: these locations exceed the depth-velocity guidelines prescribed by Alberta Environment.
- Priority 2: these locations exhibit higher depth-velocity relationships, however do not exceed the criteria stipulated by Alberta Environment.
- Priority 3: this location exhibits a higher depth-velocity relationship, however, does not exceed the criteria stipulated by Alberta Environment and is also located on private property.
- Priority N/A: this location exceeds the depth-velocity criteria, however as the criteria is exceeded within an existing wetland, it is not flagged for upgrades. It is recommended that this location is only monitored, and upgrades proceed only if conditions within this wetland change or become an issue.

It is noted that many of the descriptions include confirming the current pipe size prior to performing any upgrades. This condition is stipulated due to the number of assumptions that were needed in terms of pipe sizing when constructing the existing system model. Thus, in some events where assumptions were needed, the more conservative, smaller, pipe size was taken. This means that there is the potential that some of these pipes are already at the recommended pipe size, however, were modelled as the smaller size. Confirming the size of these locations is therefore critical, to avoid completing unnecessary upgrades. This is recommended at the pre-design stage of an upgrade project.

Table 6.3: 1:100 Year Event 2D Modelling Notable Concerns

Upgrade ID	Location	Depth-Velocity Criteria	Description	Current Parameter to Confirm		Priority
				Diameter	Slope	
		m; m/s		mm	m/m	
1	Limit Avenue, west of Harrison Street	0.8>D>0.32 and 1>V>0.5 0.32>D>0.21 and 2>V>1	Ponding on roadway; implement catchbasin and tie to existing culvert to the west.	N/A		2
2	Ross Street (southwest bend)	0.8>D>0.32 and 1>V>0.5	Capacity constraints in culvert; confirm size, and upgrade to 600 mm if required.	450	0.00455	2
3	Between Railway Street and Highway 2A, north of Crossfield Surplus	D>0.8 and V<0.5 0.8>D>0.32 and 1>V>0.5	Continuation of wetland east of Highway 2A; leave as is.	N/A		N/A
4[1]	Alberta Highway Services Ltd.	0.8>D>0.32 and 1>V>0.5	Flooding from ditch to north end of property; regrade ditch to provide constant 0.1% slope and remove sedimentation within the ditch.	N/A		0
5	Nanton Avenue between Ross Street and Railway Street	D>0.8 and V<0.5 0.8>D>0.32 and 1>V>0.5	Pipes surcharged to surface; confirm size, and increase pipe size to 525 mm if required.	300	0.00440	1
6	Stevens Place south of Smith Avenue	0.8>D>0.32 and 1>V>0.5 0.32>D>0.21 and 2>V>1	Catchbasin leads surcharged to surface due to capacity constraints; confirm size, and increase catchbasin lead size to 450 mm if required.	250	0.02000	2
7	Intersection of Smith Avenue and Sunset Heights	0.8>D>0.32 and 1>V>0.5	Pipes surcharged to surface; confirm size, and increase downstream pipe size to 675 mm if required.	450	0.00844	2
8	Modus Structures Inc.	D>0.8 and V<0.5	Increased ponding at low point of private property; suggest regrading to owner.	N/A		3
9	Intersection of Mossip Avenue and Harrison Street	0.8>D>0.32 and 1>V>0.5 0.32>D>0.21 and 2>V>1	Pipes surcharged to surface; confirm size, and increase pipe size to 600 mm if required.	300	0.00319	2
10	Railway Street	N/A	Pipe surcharging noted; upgrades currently in progress.	N/A		0

[1] *It is noted that the Town is currently regrading this ditch. A modelling exercise will be undertaken once survey data for the revised ditch is available, to determine if this satisfies the flooding concerns in the area.*

The pipe surcharging along Railway Street, was flagged as a concern as part of the existing system assessment. During this time, the Town had noted that the planning and execution of infrastructure improvements along Railway Street were in progress. Confirmatory modelling was undertaken by ISL to ensure the proposed infrastructure could accommodate flows from the 1:5 year 1-hour Chicago storm event. Figures illustrating the longitudinal profile along Railway Street under both existing and upsized conditions have been included in Figures 6.11 and 6.12.

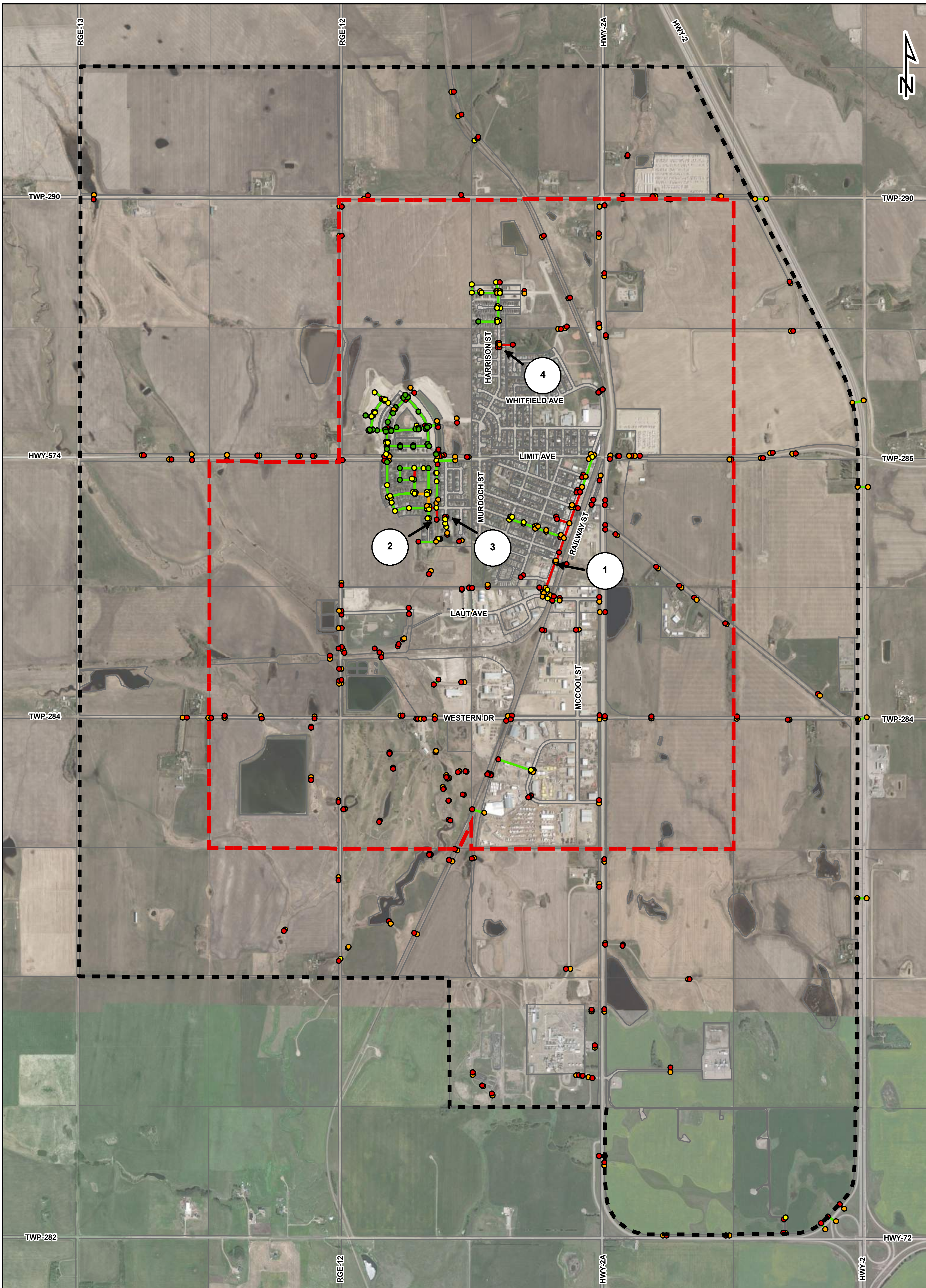
Surcharged catchbasin leads throughout the Study Area are not considered critical, as assumptions were made at the start of the model construction process for sizing and slopes. It is likely that these assumptions were too conservative for these catchbasin leads. The recommendation here would be to monitor the flagged catchbasin leads, and if capacity constraints are evident, upgrading options are proposed at that time.

6.4 Cost Estimates

A summary of the costs associated with the remaining recommended existing system upgrades are detailed below in Table 6.4. A full breakdown of the costs has been provided in Appendix B. Figure 6.13 illustrates the proposed upgrades and associated costs.

Table 6.4: Class D Cost Estimates for Recommended Upgrades to the Existing System

ID	Description	Total Cost
1	Implement catchbasin on Limit Avenue, west of Harrison Street, and tie to existing culvert to the west.	$90,000
2	Upgrade the existing culvert on Ross Street to 600 mm.	$26,000
3	No upgrades recommended for this area of concern as it is within a wetland.	
4	Costing not provided as these upgrades are currently in progress.	
5	Upgrade the existing pipes on Nanton Avenue between Ross Street and Railway Street to 525 mm.	$258,000
6	Upgrade the existing pipe on Stevens Place South of Smith Avenue to 450 mm.	$81,000
7	Upgrade the pipe in the easement west of Stevens Place to 675 mm.	$115,000
8	No upgrades recommended for this area of concern as it is on private property.	
9	Upgrade the pipes at the intersection of Mossip Avenue and Harrison Street to 600 mm.	$155,000
10	Costing not provided as these upgrades are currently in progress.	
	Total	**$725,000**



Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

0 125 250 500 750 1,000 Metres

1:22,000 CANA83-3TM114

Legend

Maximum HGL Relative to Ground	Peak Flow Relative to Capacity
Less than -3.0m	Less than 86%
-3.0m to -1.2m	86% to 100%
-1.2m to 0.0m	Greater than 100%
Greater than 0.0m	

Annexation Boundary

Pre-Annexation Boundary

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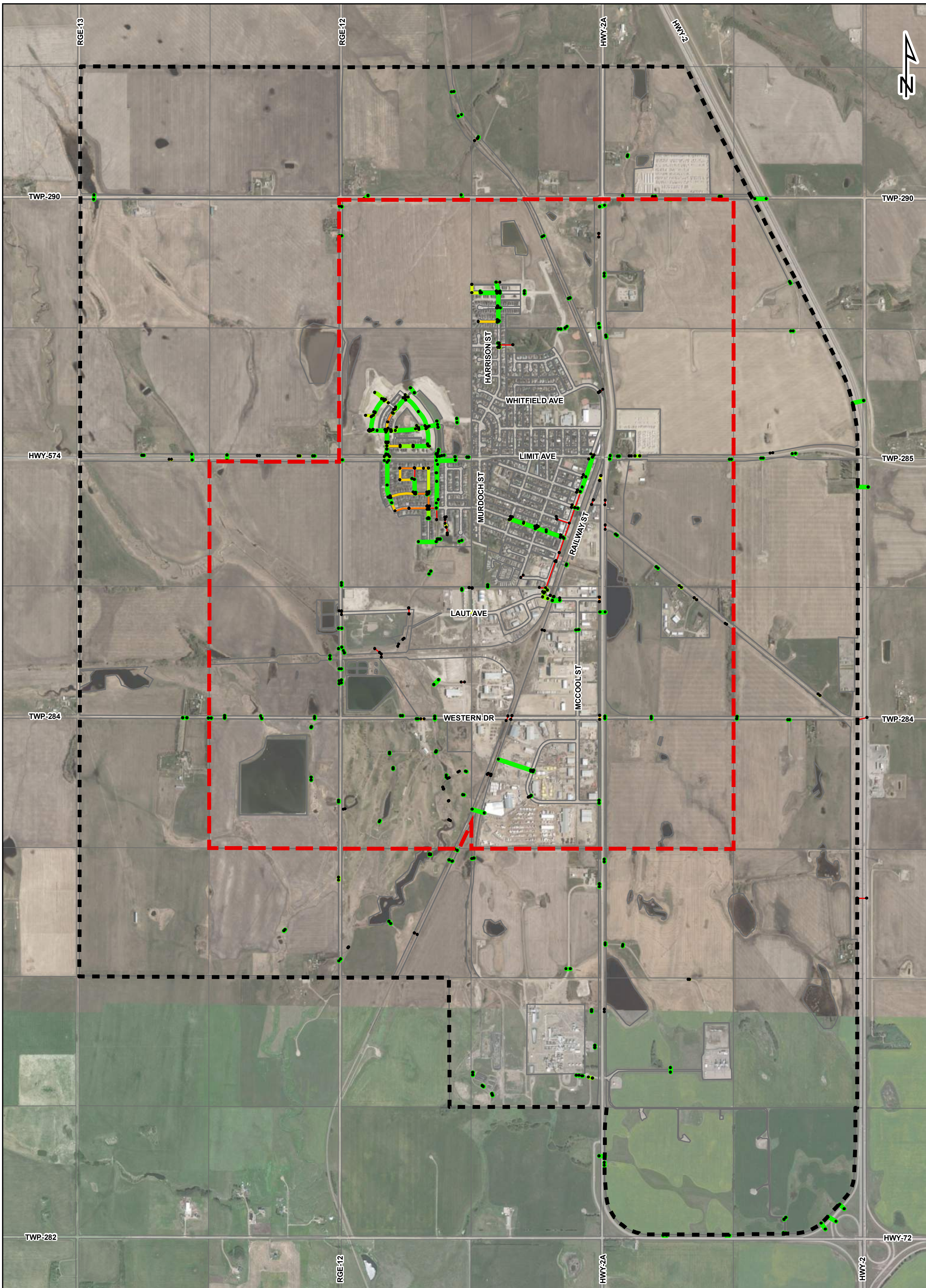
FIGURE 6.1
ASSESSMENT RESULTS - 1D 5 YR 1 HR DESIGN STORM
CROSSFIELD STORMWATER MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.



Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Metres
0 125 250 500 750 1,000
1:22,000
CANA83-3TM114

Legend

- Node

Spare Capacity

- Less than 0L/s
- 0 - 25L/s
- 25 - 50L/s
- 50 - 75L/s
- 75 - 100L/s
- Greater than 100L/s
- Annexation Boundary
- Pre-Annexation Boundary

FIGURE 6.2
SPARE CAPACITY - 1D
5 YR 1 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.

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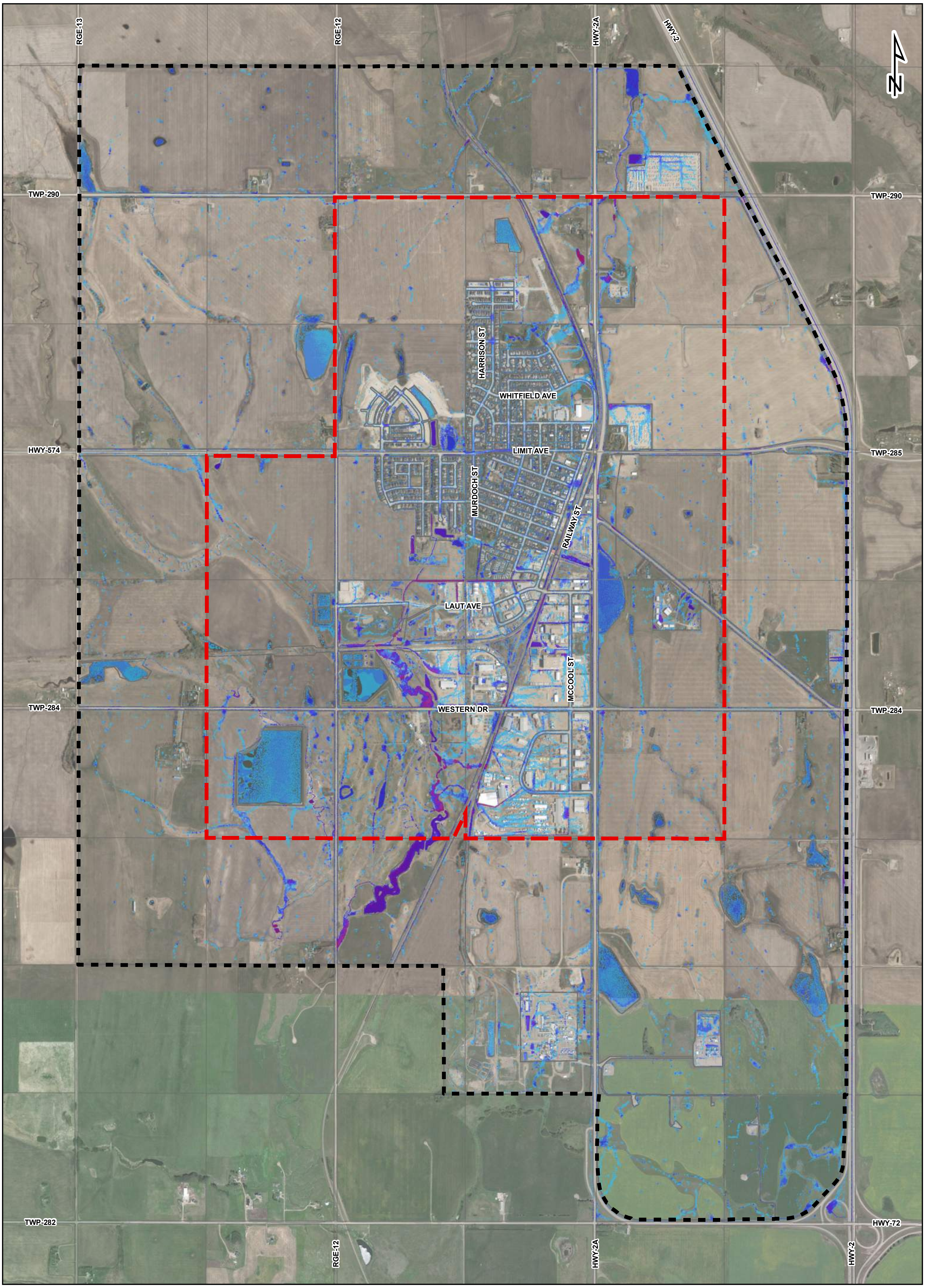
Date: 4/1/2020 Document: H:\27309 - Supplemental\02_CADD\251_Figures\01_Report Figures\6.0 Existing System Assessment and Upgrades\Figure6.2_Ex_Results_1D_5yr_Spare Capacity.mxd



Credits:Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Metres
0 125 250 500 750 1,000
1:22,000 CANA83-3TM114

Legend

Annexation Boundary
Pre-Annexation Boundary

Maximum Depth (m)

Less than 0.01
0.011 - 0.025
0.026 - 0.050
0.051 - 0.100
0.101 - 0.200
0.201 - 0.400
0.401 - 0.800
0.801 - 1.250
1.251 - 1.500
Greater than 1.500

FIGURE 6.3
ASSESSMENT RESULTS - 2D
MAXIMUM WATER DEPTH
5 YR 1 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.

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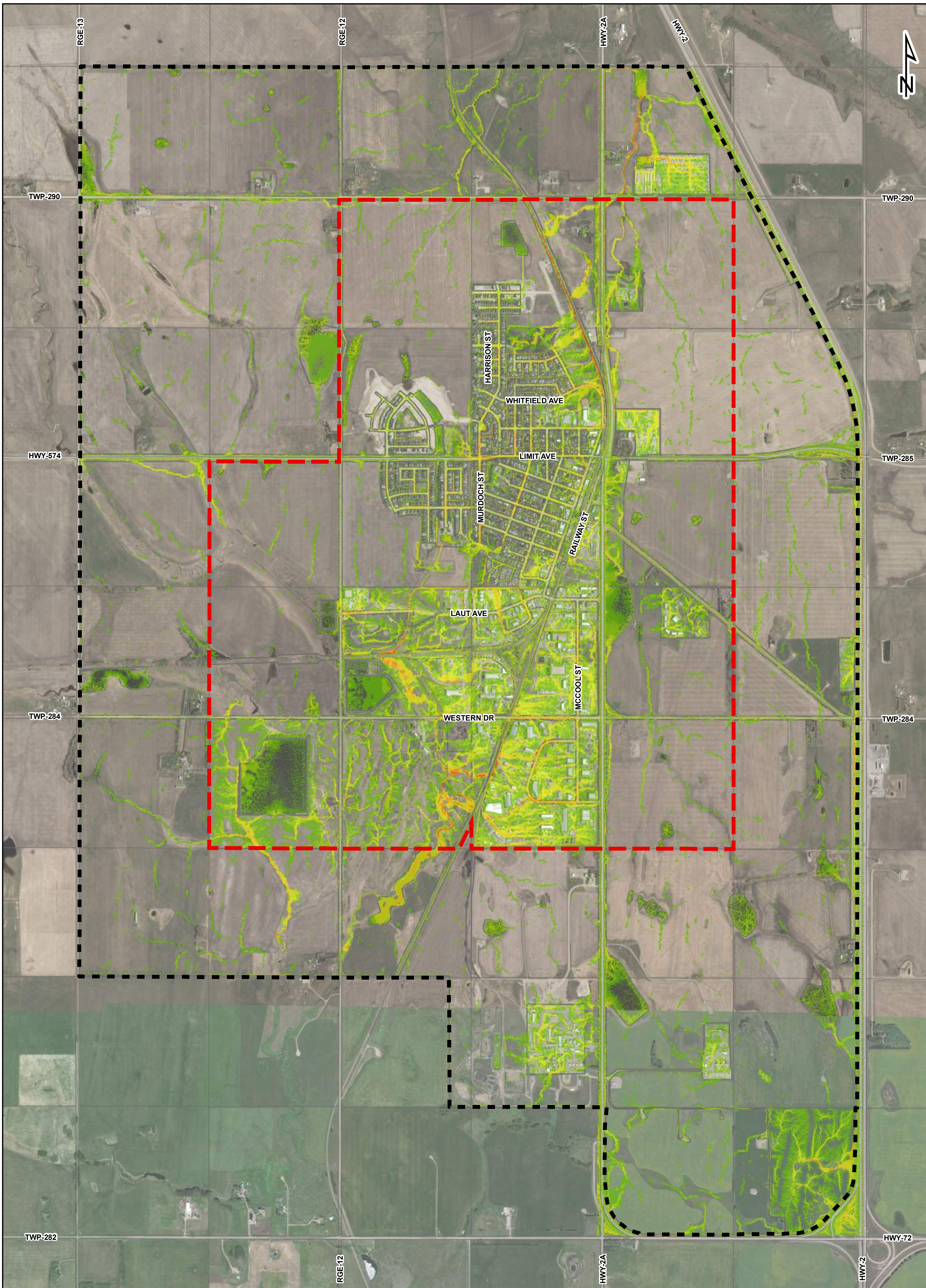

Credits:Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEROGRID, IGN, and the GIS User Community

0 125 250 500 750 1,000 Metres

1:22,000 CANA83-3TM114

Legend

- Annexation Boundary
- Pre-Annexation Boundary

Flow Velocity (m/s)

- Less than 0.025
- 0.026 - 0.050
- 0.051 - 0.100
- 0.101 - 0.250
- 0.251 - 0.500
- 0.501 - 1.000
- 1.001 - 5.000
- Greater than 5.000

FIGURE 6.4
ASSESSMENT RESULTS - 2D
PEAK SURFACE FLOW VELOCITY
5 YR 1 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.

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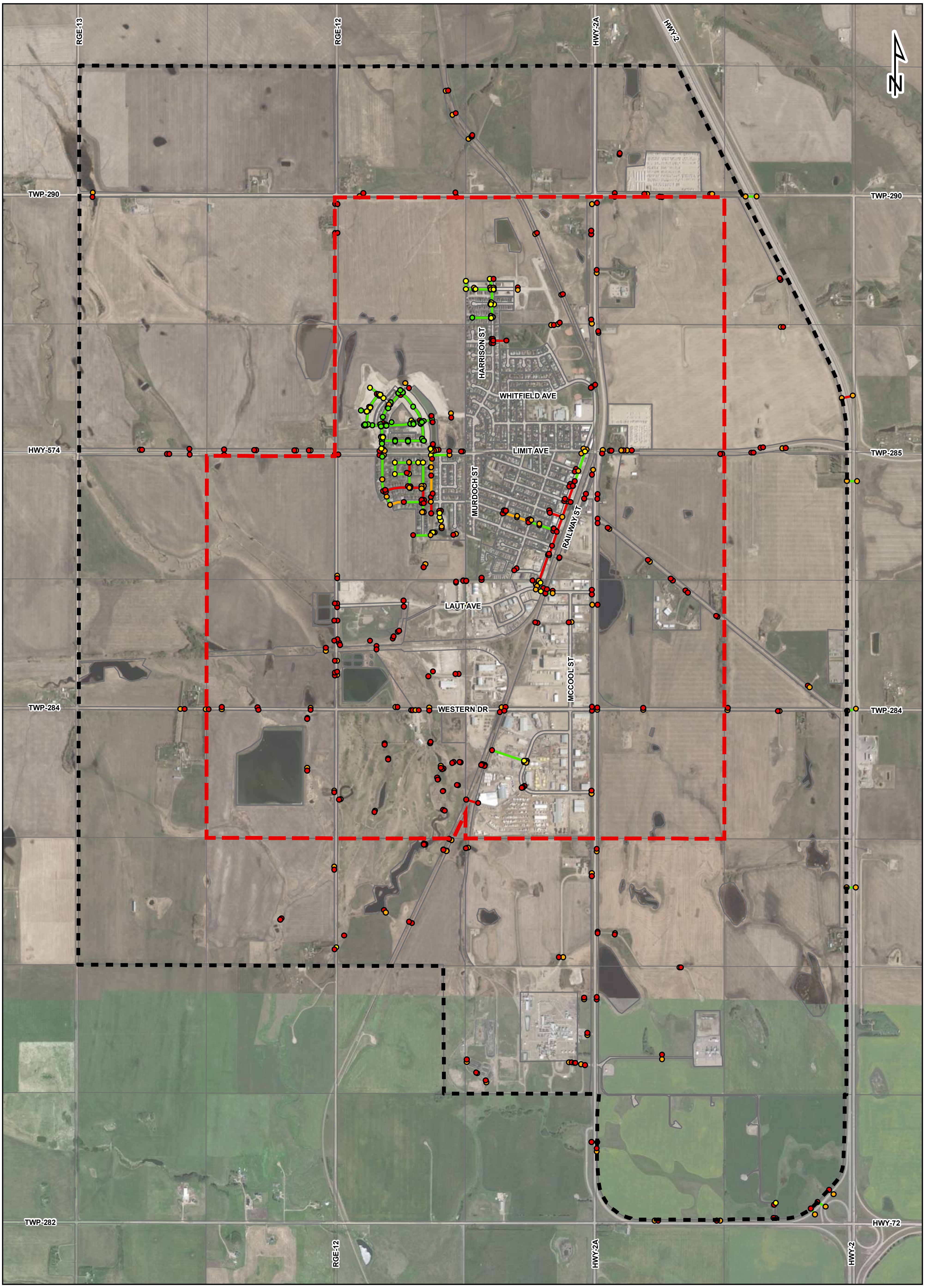
Date: 4/1/2020



Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Legend

Maximum HGL Relative to Ground	Peak Flow Relative to Capacity
Less than -3.0m	Less than 86%
-3.0m to -1.2m	86% to 100%
-1.2m to 0.0m	Greater than 100%
Greater than 0.0m	

Annexation Boundary

Pre-Annexation Boundary

FIGURE 6.5
ASSESSMENT RESULTS - 1D
100 YR 24 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.

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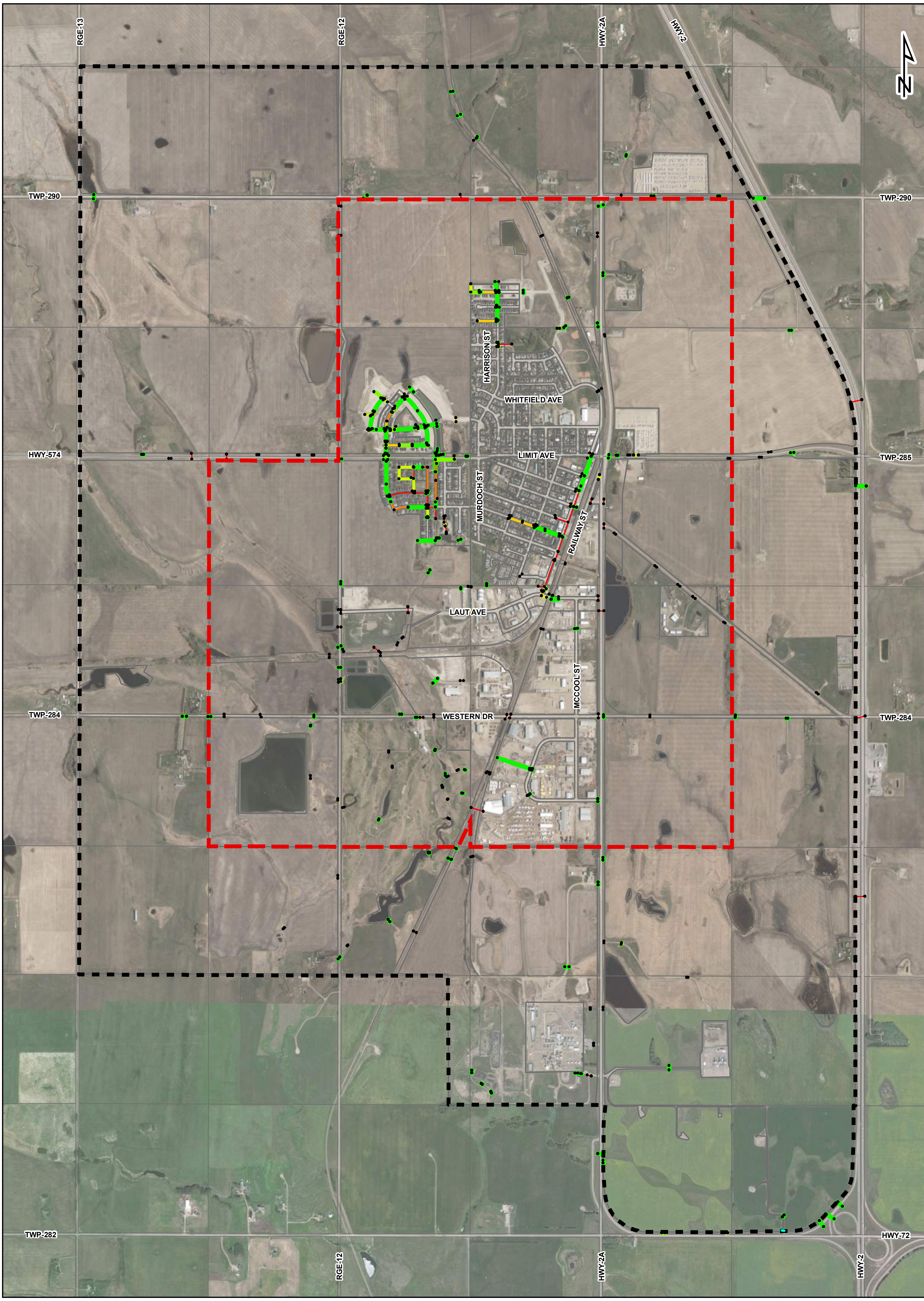
Date: 4/1/2020 Document: H:\27309 - Supplemental\02_CADD\251_Figures\01_Report Figures\6.0 Existing System Assessment and Upgrades\Figure6.5_Ex_Results_1D_100yr.mxd



Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

0 125 250 500 750 1,000 Metres

1:22,000 CANA83-3TM114

Legend

Spare Capacity

- Less than 0L/s
- 0 - 25L/s
- 25 - 50L/s
- 50 - 75L/s
- 75 - 100L/s
- Greater than 100L/s
- Annexation Boundary
- Pre-Annexation Boundary

FIGURE 6.6
SPARE CAPACITY - 1D
100 YR 24 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

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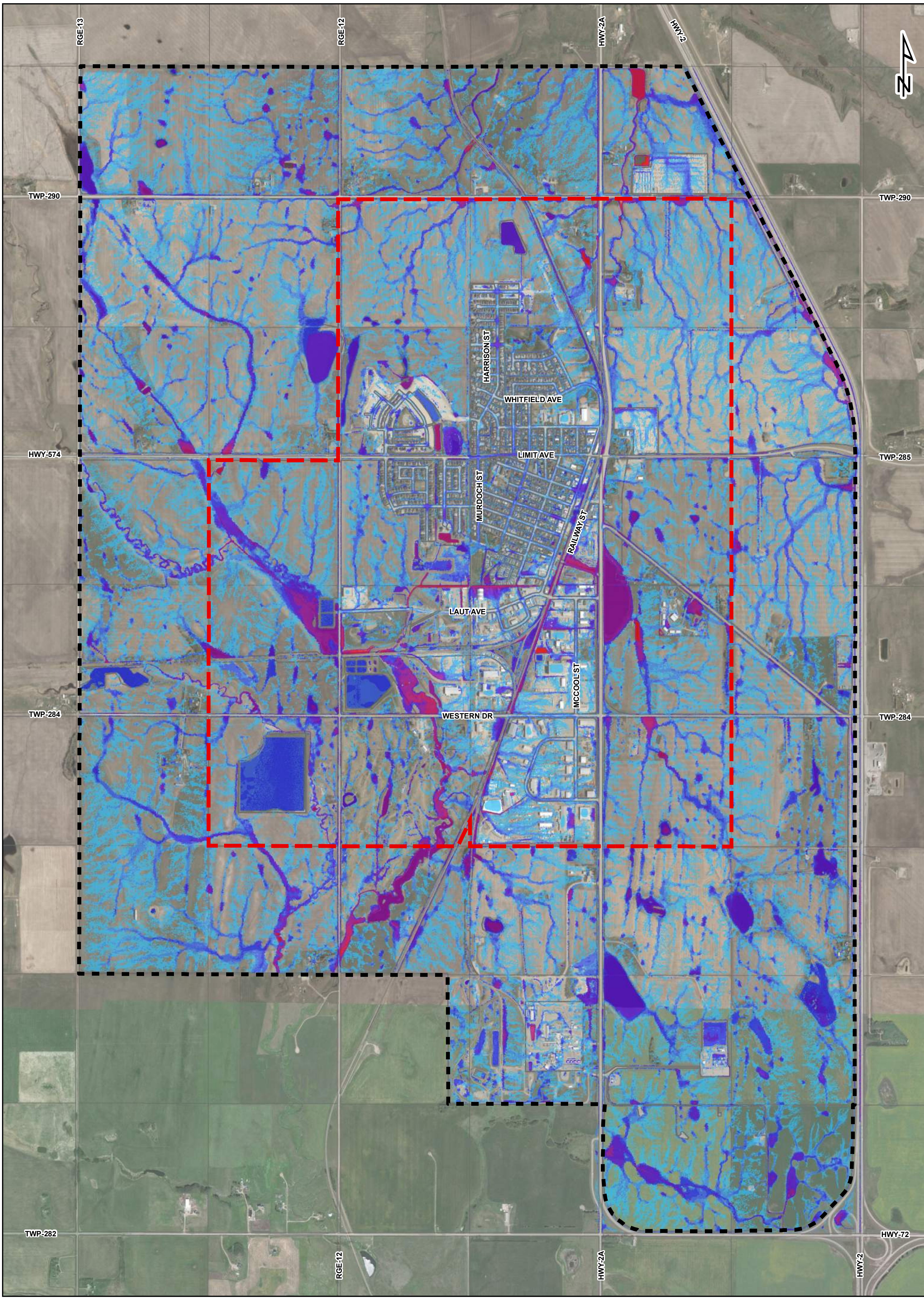

Credits:Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Date: 4/1/2020 Document: H:\27309 - Supplemental\02_CADD\251_Figures\01_Report Figures\6.0 Existing System Assessment and Upgrades\Figure6.7_Ex_Results_2D_100yr_Depth.mxd

0 125 250 500 750 1,000 Metres

1:22,000 CANA83-3TM114

Legend

- Annexation Boundary
- Pre-Annexation Boundary

Maximum Depth (m)

- Less than 0.01
- 0.011 - 0.025
- 0.026 - 0.050
- 0.051 - 0.100
- 0.101 - 0.200
- 0.201 - 0.400
- 0.401 - 0.800
- 0.801 - 1.250
- 1.251 - 1.500
- Greater than 1.500

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FIGURE 6.7
ASSESSMENT RESULTS - 2D
MAXIMUM WATER DEPTH
100 YR 24 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

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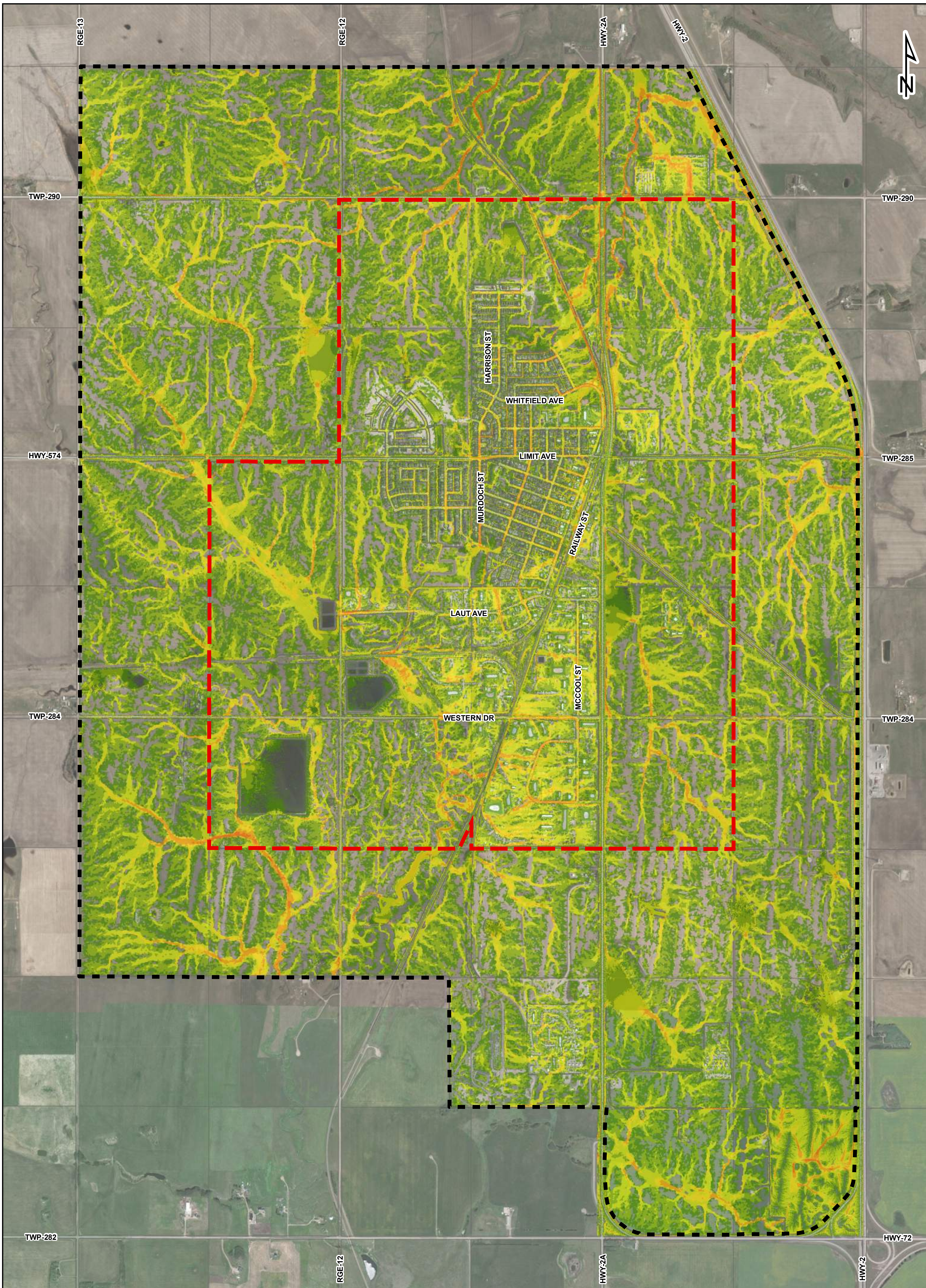

Credits:Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Metres
0 125 250 500 750 1,000
1:22,000 CANA83-3TM114

Legend

- Annexation Boundary
- Pre-Annexation Boundary

Flow Velocity (m/s)

- Less than 0.025
- 0.026 - 0.050
- 0.051 - 0.100
- 0.101 - 0.250
- 0.251 - 0.500
- 0.501 - 1.000
- 1.001 - 5.000
- Greater than 5.000

FIGURE 6.8
ASSESSMENT RESULTS - 2D
PEAK SURFACE FLOW VELOCITY
100 YR 24 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.

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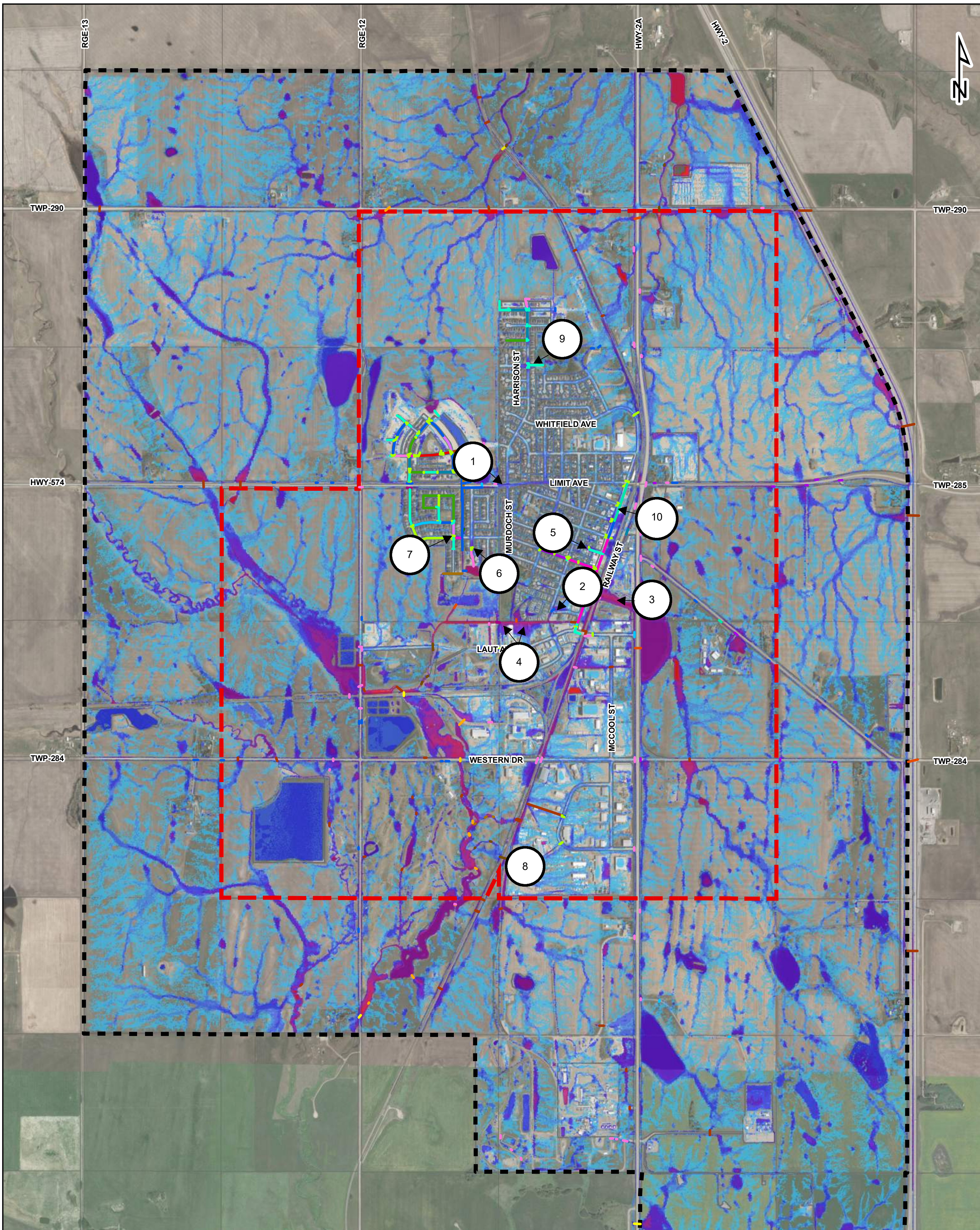

Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

0 125 250 500 750 1,000 Metres

1:22,000 CANA83-3TM114

Legend

Annexation Boundary

Pre-Annexation Boundary

Pipe Diameter (mm)

150	350	700
200	375	750
250	400	800
300	450	900
	500	1000
	525	1050
	600	1200
	675	1700
	1800	
	2400	

Maximum Depth (m)

- Less than 0.01
- 0.011 - 0.025
- 0.026 - 0.050
- 0.051 - 0.100
- 0.101 - 0.200
- 0.201 - 0.400
- 0.401 - 0.800
- 0.801 - 1.250
- 1.251 - 1.500
- Greater than 1.500

FIGURE 6.10
ASSESSMENT RESULTS - 2D
PROPOSED UPGRADES
CROSSFIELD STORMWATER
MASTER PLAN

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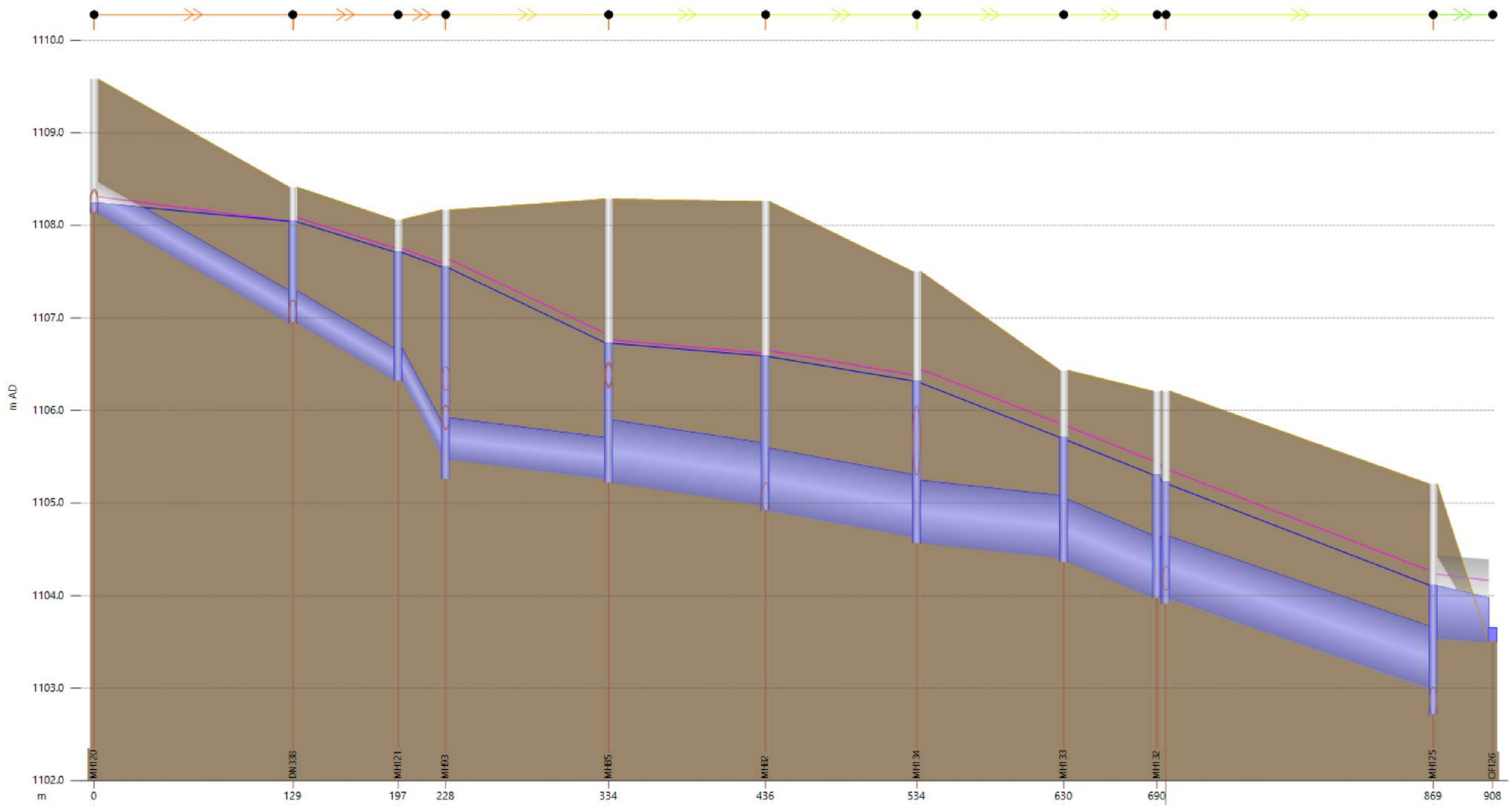
Date: 2020-04-03 Document: H:\27309 - Supplemental\02_CADD\251_Figures\01_Report Figures\6.0 Existing System Assessment and Upgrades\Figure6.10_Proposed Upgrades.mxd



Link	MH120.1	DN338.1	-	MH93.1	MH85.1	MH82.1	MH134.1	MH133.1	MH131.1	MH125.1
length (m)	129.3	68.1	30.8	105.9	101.8	98.4	95.3	60.4	173.7	38.6
width (mm)	350	350	350	450	675	675	675	675	675	900
r.pfc (m3/s)	0.139	0.139	0.235	0.128	0.412	0.454	0.350	0.676	0.628	0.576
DS flow (m3/s)	0.02718	0.13660	0.13594	0.29174	0.39174	0.44769	0.65560	0.65560	0.66152	0.66431

Node	MH120	DN338	MH121	MH93	MH85	MH82	MH134	MH133	MH132	MH131	MH125	-
ground (m AD)	1109.578	1108.410	1108.060	1108.165	1108.282	1108.257	1107.498	1106.433	-	1106.208	1105.204	-
Ch floor lev (m AD)	1108.123	1106.942	1106.320	1105.255	1105.220	1104.915	1104.568	1104.363	-	1103.912	1102.704	-

Legend

- Existing - Total Head
- Existing - Water Level
- Ground Elevation

FIGURE 6.11
RAILWAY STREET LP - EXISTING
5 YR 1 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

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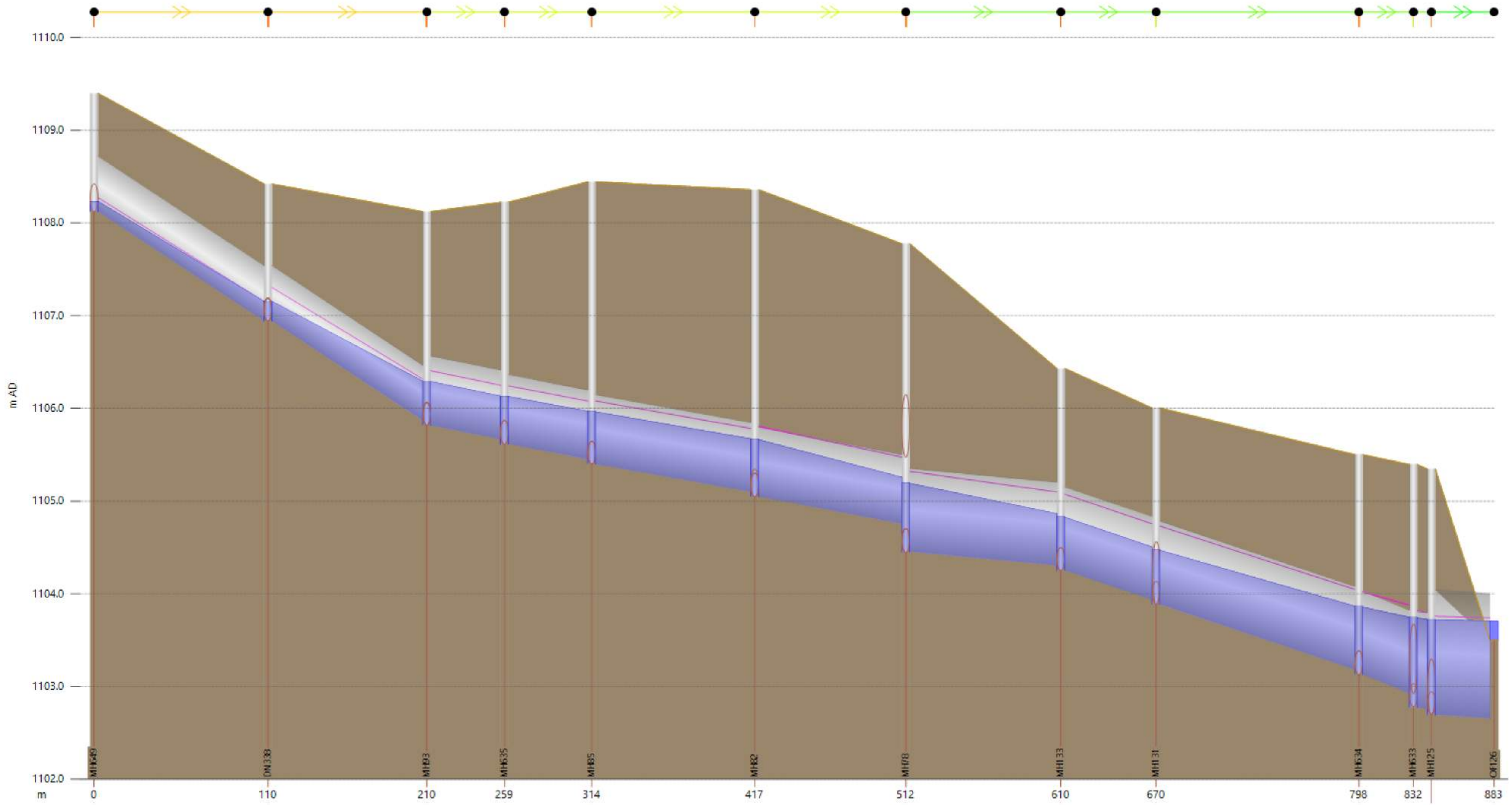
ISL



Link	MH649.1	DN338.1	MH93.1	MH635.1	MH85.1	MH82.1	MH78.2	MH133.1	MH131.1	MH634.1	-	MH125.1
length (m)	109.8	100.0	49.1	54.9	102.8	95.4	97.6	60.1	128.1	34.3	-	39.5
width (mm)	600	600	750	750	750	750	900	900	900	900	-	1350
r.pfc (m3/s)	0.637	0.637	0.615	0.614	0.601	0.620	0.708	1.319	1.343	1.404	-	1.699
DS flow (m3/s)	0.03006	0.14966	0.44141	0.48273	0.53866	0.65090	0.89018	0.93931	0.98258	0.98524	-	1.02394

Node	MH649	DN338	MH93	MH635	MH85	MH82	MH78	MH133	MH131	MH634	-	-	-
ground (m AD)	1109.400	1108.421	1108.123	1108.225	1108.445	1108.360	1107.776	1106.433	1106.005	1105.502	-	-	-
Ch floor lev (m AD)	1108.123	1106.942	1105.817	1105.610	1105.400	1105.050	1104.450	1104.250	1103.886	1103.130	-	-	-

Legend

- Upsized Proposed - Total Head
- Upsized Proposed - Water Level
- Ground Elevation

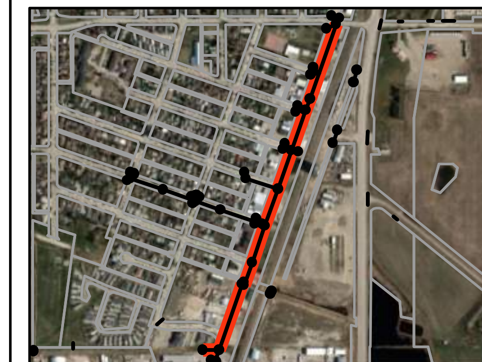


FIGURE 6.12
RAILWAY STREET LP - UPSIZED PROPOSED
5 YR 1 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

Document: H:\27309 - Supplemental\02_CADD\251_Figures\01_Report Figures\6.0 Existing System Assessment and Upgrades\Figure6.12_ProposedandUpsizedRailwayStreet_LP.mxd

Date: 4/1/2020

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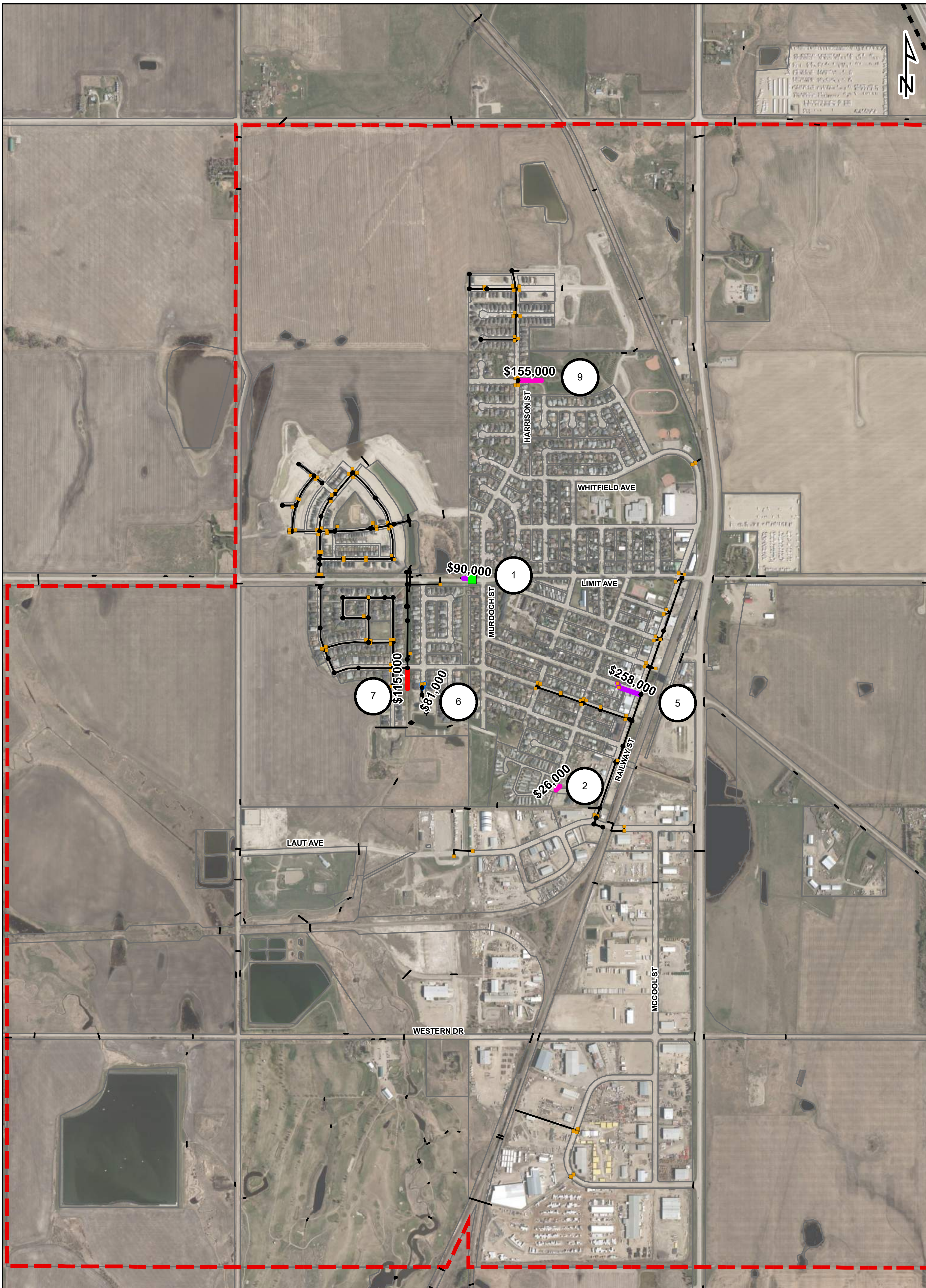

Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

0 70 140 280 420 560 Metres

1:12,500 CANA83-3TM114

Legend

- Manhole
- Catchbasin
- Proposed Catchbasin
- Existing Conduits
- Annexation Boundary
- Pre-Annexation Boundary

Recommended Upgrade

- 450mm Upgrade
- 525mm Upgrade
- 600mm Upgrade
- 675mm Upgrade

FIGURE 6.13
PROPOSED UPGRADES
WITH ASSOCIATED COSTS
CROSSFIELD STORMWATER
MASTER PLAN

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7.0 Future System Assessment and Upgrades

Including the future annexation area, Crossfield has a number of undeveloped parcels. Of these parcels, roughly half have been flagged for future development, either in the MDP or an ASP. The following ASPs were considered when developing the areas that are planned for future development:

- Black Bull Industrial Park
- Crossfield East ASP
- Highway 2A – Crossfield ASP
- Rocky View County / Crossfield Joint ASP
- Hawks Landing ASP

Note that the following ASPs for portions of Town were excluded from the analysis, as they are either predominantly built or at a minimum have their SWMF already constructed. These include:

- Vista Crossing ASP
- Iron Landing ASP
- Sunset Ridge ASP

The land uses and areas that are entailed in this proposed development are stipulated in Figure 7.1. In terms of planning for the Town's future stormwater system, only quarter sections where growth is currently planned for are included. As the remaining quarter sections without ASPs or reference in the SMP do not have stipulated land uses, sizing SWMF at this time is not feasible. These areas are shown on Figure 7.1 as being classified as urban holdings, mostly located within the proposed annexation areas. For these areas, conceptual SWMF locations and network routing have been provided without system sizing to provide input in the event that any of these areas are flagged for development. Further discussion pertaining to the quarter sections that are planned for future development is provided below.

7.1 Future Drainage Patterns

To develop this land, major and minor stormwater drainage systems are required to collect and control runoff in these areas. Runoff due to development in these areas must be controlled to ensure public safety and minimize property damage and environmental impacts. This is best accomplished by collecting storm runoff by major storm sewers and conveying it to a SWMF where the release rate can be controlled. Based on Alberta Environment and Parks' (AEP) regulations, it is specified that post-development flows released should not exceed pre-development flows.

Future drainage basins were established, shown in Figure 7.2, while Figure 7.3 illustrates only the drainage basins that were considered for future development (i.e., sizing providing below, noting a conceptual design is provided for all drainage basins). Generally, future development area drainage patterns are summarized in Table 7.1. These catchments were delineated based on the current topography. As mentioned, these catchments should be revisited at the development stage to ensure that the proposed grading of each development site is accounted for. Noted above, drainage patterns are generally divided on a per quarter section basis and further split or grouped based on major changes in topography.

Table 7.1: Summary of Future Development Area Drainage

ID	Watershed	Location	Drainage Direction	Area
				ha
Bow_Catchment-1	Bow River / Nose Creek	Crossfield East	Southwest	39.2
Bow_Catchment-2	Bow River / Nose Creek	Crossfield East / Black Bull Industrial Park	Northwest	89.6
Bow_Catchment-3	Bow River / Nose Creek	Crossfield East / Black Bull Industrial Park	North	61.3
Bow_Catchment-4	Bow River / Nose Creek	North Central Industrial	West	60.0
Bow_Catchment-5	Bow River / Nose Creek	Range Road 12 / Collicutt Siding Golf Club	South	50.1
Bow_Catchment-6	Bow River / Nose Creek	East / West of CPR, South of Existing Town Boundary	West	44.9
Bow_Catchment-7	Bow River / Nose Creek	West of Highway 2A, South of Existing Town Boundary	Northwest	66.4
Bow_Catchment-8	Bow River / Nose Creek	North Central Industrial	Northwest	47.4
Bow_Catchment-9	Bow River / Nose Creek	North Central Industrial	Northwest	105.0
Bow_Catchment-10	Bow River / Nose Creek	West of Highway 2A, South of Bow_Catchment-7	Northwest	60.6
Bow_Catchment-11	Bow River / Nose Creek	East of Highway 2A, South of Bow_Catchment-8	Southwest	64.9
RedDeer_Catchment-1	Red Deer River / Crossfield Creek	Hawks Landing	Northeast	64.7
RedDeer_Catchment-2	Red Deer River / Crossfield Creek	Adjacent to Iron Landing	Northeast	26.2
RedDeer_Catchment-3	Red Deer River / Crossfield Creek	Crossfield East	Northwest	64.7
RedDeer_Catchment-4	Red Deer River / Crossfield Creek	North Central Industrial	North	26.5
RedDeer_Catchment-5	Red Deer River / Crossfield Creek	Crossfield East	Northeast	64.5
RedDeer_Catchment-6	Red Deer River / Crossfield Creek	North Central Industrial	Northeast	56.3
RedDeer_Catchment-7	Red Deer River / Crossfield Creek	Crossfield East / North Central Industrial	Northeast	130.9

7.2 Future System Concept

The specified sewer sizes are the smallest possible determined based on the required minimum design slope to provide a self-cleansing full sewer velocity, under the derived peak flows, based on the parameters summarized in Table 7.2. All proposed stormwater sewers were assumed to have relatively straight alignments.

Table 7.2: Minimum Design Slopes for Sewers

Nominal Sewer Size	Minimum Design Slope		Full Sewer Velocity	Full Sewer Capacity[1]
mm	%	m/m	m/s	L/s
375	0.15%	0.0015	0.61	68
450	0.12%	0.0012	0.62	99
525	0.10%	0.001	0.63	136
600	0.10%	0.001	0.69	194
675	0.10%	0.001	0.74	266
750	0.10%	0.001	0.80	352

[1] Assumes a Manning's 'n' of 0.013.

If flatter slopes are preferred or required at the detailed design stages, this can be reviewed, though it could have negative repercussions. If this was acceptable, the determined sewer sizes would potentially need to be increased to meet the specified design flows.

Based on this design criteria, and that described in Section 5.4, trunk storm sewers and SWMFs were sized for new development areas within Crossfield. The conceptual design of the future SWMFs and conveyance can be seen in Figure 7 4. Local storm sewers feeding each SWMFs would be built by the respective developers in each area at the time of development, thus were excluded for this purpose.

Crossfield could consider implementing low impact development (LID) techniques in the new development areas to assist with reducing stormwater runoff and increasing the quality of stormwater being distributed into the downstream receiving bodies of water. Some of these techniques include rain gardens, green roofs and pervious pavement. A summary of many of the best management practices (BMP) options available is provided in Section 7.5.

Design parameters used to size the proposed SWMFs are shown in Table 7.3. It is noted that the SWMFs for Bow_Catchment-1 and Bow_Catchment-2 and for RedDeer_Catchment-2 and RedDeer_Catchment-3 were combined into a single facility, as the low points for the catchments converge to the same location. Of note is the fact that Bow_Catchment-10 has been sized to exclude the TAQA Gas Plant, as it is currently already developed.

Table 7.3: Future Storm SWMF Design Parameters

SWMF ID	Catchment Area	Runoff Coefficient	Catchment Width	Average Slope	Release Rate	Max. Release Flow
	ha		m	%	L/s/ha	L/s
Bow_SWMF-1-2	128.79	0.950	985	1.38%	1.257	161.9
Bow_SWMF-3	61.35	0.950	960	1.00%		77.1
Bow_SWMF-4	60.01	0.950	805	0.96%		75.4
Bow_SWMF-5	50.06	0.197	960	1.82%		62.9
Bow_SWMF-6	44.93	0.686	890	1.64%		56.5
Bow_SWMF-7	66.38	0.950	830	2.12%		83.4
Bow_SWMF-8	47.44	0.950	535	2.52%		59.6
Bow_SWMF-9	105.05	0.832	1050	1.16%		132.0
Bow_SWMF-10	60.56	0.950	815	1.88%		76.1
Bow_SWMF-11	64.85	0.950	805	3.50%		81.5
RedDeer_SWMF-1	64.70	0.605	1080	1.60%	1.4	90.6
RedDeer_SWMF-2-3	90.86	0.582	600	2.81%		127.2
RedDeer_SWMF-4	26.51	0.950	420	1.78%		37.1
RedDeer_SWMF-5	64.49	0.532	805	1.23%		90.3
RedDeer_SWMF-6	56.31	0.950	970	2.43%		78.8
RedDeer_SWMF-7	130.92	0.950	750	1.36%		183.3

When sizing the SWMFs, the allowable discharge flow rates were applied to the orifice equation to determine the required orifice size. The orifices were then rounded down to the nearest nominal diameter (50 mm increments) to ensure the SWMFs would be able to accommodate the total volume without allowing additional discharge over the stipulated flow rates. Orifice and pipe sizing are detailed in Table 7.4.

Table 7.4: Pipe and Orifice Sizing Parameters

SWMF ID	Release Flow Rate	Additional Flow	Total Flow	Orifice Diameter	Nominal Orifice Diameter	Nominal Flows	Pipe Diameter	Nominal Pipe Diameter	Pipe Capacity	Spare Capacity
	L/s			mm		L/s	mm		L/s	
Bow_SWMF-1-2	161.9	0.0	161.9	252	250	153.0	545	600	229	76
Bow_SWMF-3	77.1	207.5	284.6	334	300	218.3	663	750	352	134
Bow_SWMF-4	75.4	0.0	75.4	172	150	56.1	374	375	80	24
Bow_SWMF-5	62.9	0.0	62.9	157	150	56.1	374	375	80	24
Bow_SWMF-6	56.5	0.0	56.5	149	100	25.1	277	300	54	28
Bow_SWMF-7	83.4	0.0	83.4	181	150	56.1	374	375	80	24
Bow_SWMF-8	59.6	0.0	59.6	153	150	56.1	374	375	80	24
Bow_SWMF-9	132.0	0.0	132.0	227	200	98.8	463	525	161	62
Bow_SWMF-10	76.1	59.6	135.7	230	200	98.8	463	525	161	62
Bow_SWMF-11	81.5	0.0	81.5	179	150	56.1	374	375	80	24
RedDeer_SWMF-1	90.6	0.0	90.6	188	150	56.1	374	375	80	24
RedDeer_SWMF-2-3	127.2	0.0	127.2	223	200	98.8	463	525	161	62
RedDeer_SWMF-4	37.1	0.0	37.1	120	100	25.1	277	300	54	28
RedDeer_SWMF-5	90.3	0.0	90.3	188	150	56.1	374	375	80	24
RedDeer_SWMF-6	78.8	90.3	169.1	257	250	153.0	545	600	229	76
RedDeer_SWMF-7	183.3	0.0	183.3	268	250	153.0	545	600	229	76

The future stormwater system is generally designed in concept as follows:

- **Bow_Catchment-1 / Bow_Catchment-2** – the SWMF of these catchments is located at the midpoint between their shared boundary. Stormwater runoff is captured by the SWMF and discharged at 153.0 L/s through a 600 mm gravity sewer. The gravity sewer conveys flows from east to west towards the existing wetland.
- **Bow_Catchment-3** – this SWMF, located at the north end of the catchment, is at the downstream end of a series of SWMFs. Discharge from Bow_SWMF-4 and Bow_SWMF-9 is routed through this facility, noting that orifice sizing at Bow_SWMF-3 is designed to allow the discharge from these upstream facilities to pass through. As a result, the discharge pipe from this facility is a 750 mm gravity sewer.
- **Bow_Catchment-4** – the SWMF within Bow_Catchment-4 is located to the southwest. Stormwater is discharged from the SWMF at 56.1 L/s through a 375 mm gravity sewer. The 375 mm gravity sewer converges with the sewer from Bow_SWMF-9, where it is upsized to a 600 mm gravity sewer. As mentioned, this is then routed through Bow_SWMF-3 and discharged through a 750 mm gravity sewer to the outlet.
- **Bow_Catchment-5** – this SWMF is located in the southwest corner of the catchment, and discharges stormwater at a flow rate of 56.1 L/s to the west. The 375 mm gravity sewer conveys the flows from east to west for a short length, where it outlets to Nose Creek.
- **Bow_Catchment-6** – the SWMF for Bow_Catchment-6 is located on the west end of the catchment. Stormwater runoff is collected in the facility and discharged at 25.1 L/s through a 300 mm gravity sewer to a tributary of Nose Creek.
- **Bow_Catchment-7** – the facility for this catchment is located at the northwest corner. The orifice is sized to discharge stormwater runoff at a flow rate of 56.1 L/s. Flows are discharged through a 375 mm gravity sewer, which generally follows the alignment of the CPR through Bow_Catchment-6. Downstream, the sewer converges with the sewer from Bow_Catchment-8 and Bow_Catchment-10, where the sewer is upsized to 600 mm. The outfall for this 600 mm gravity sewer is an existing wetland that ultimately ties to Nose Creek.
- **Bow_Catchment-8** – the SWMF for Bow_Catchment-8 is located on the west end of the catchment, and is set to discharge at 56.1 L/s. The 375 mm gravity sewer from this facility is routed through Bow_Catchment-10, where it is subsequently upsized to a 525 mm gravity sewer. As mentioned above, this sewer ties to the network along the CPR alignment, upsizes to a 600 mm sewer, and outlets to a wetland.
- **Bow_Catchment-9** – Bow_SWMF-9 is situated in the northwest corner of the catchment. Stormwater runoff is collected in this facility and discharged at a rate of 98.8 L/s through a 525 mm gravity sewer. As noted, this gravity sewer converges with the gravity sewer from Bow_Catchment-4, and as a result is upsized to a 600 mm sewer. These flows are routed through Bow_SWMF-3, following which a 750 mm gravity sewer conveys flows to the outfall at the existing wetland.
- **Bow_Catchment-10** – the SWMF in this catchment is located in the northwest. Discharge from Bow_SWMF-8 is routed through this facility, noting that orifice sizing at Bow_SWMF-10 is designed to allow the discharge from this upstream facility to pass through. As a result, the discharge from this facility is a 525 mm gravity sewer, ultimately upsizing to 600 mm where it converges with the proposed gravity sewer along the CPR alignment.
- **Bow_Catchment-11** – this SWMF is located in the south of the catchment. Stormwater runoff is captured at the facility and discharged at a rate of 56.1 L/s through a 375 mm gravity sewer. This sewer conveys flows to the south to an existing wetland, which is at the upstream end of a creek that is a tributary to Nose Creek.

- **RedDeer_Catchment-1** – RedDeer_SWMF-1 is situated in the northeast corner of the catchment. It is noted that this catchment covers the Hawks Landing ASP area, which has also stipulated that the SWMF is to be in the northeast corner of the catchment. Runoff is collected at this location and discharged via a 375 mm gravity sewer to a tributary of Crossfield Creek. This is in line with the Hawks Landing ASP. Flows are controlled to a rate of 56.1 L/s to meet the peak flow discharge rate of 1.4 L/s/ha that has been enforced for the Crossfield Creek Watershed.
- **RedDeer_Catchment-2** / **RedDeer_Catchment-3** – the SWMF for this catchment is located along the boundary of RedDeer_Catchment-2 and RedDeer_Catchment-3 on the north edge. Stormwater runoff is collected at this facility, and controlled to a flow of 98.8 L/s. The flows are discharged through a 525 mm gravity sewer from west to east, to a tributary of Crossfield Creek.
- **RedDeer_Catchment-4** – RedDeer_SWMF-4 sits at the northeast corner of the catchment. Stormwater runoff is collected here, and controlled to a flow of 25.1 L/s. The flows are discharged via a 300 mm gravity sewer from east to west, to a creek which is a tributary of Crossfield Creek.
- **RedDeer_Catchment-5** – this SWMF, RedDeer_SWMF-5, is located in the northeast corner of the catchment, and discharges to the east ultimately to RedDeer_SWMF-6 at a rate of 56.1 L/s. From RedDeer_SWMF_5 to RedDeer_SWMF-6, the gravity sewer is 375 mm, while from RedDeer_SWMF-6 to the outfall the gravity sewer is 600 mm.
- **RedDeer_Catchment-6** – RedDeer_SWMF-6 is situated in the northwest corner of the catchment. Discharge from RedDeer_SWMF-5 is routed through this facility, noting that orifice sizing at RedDeer_SWMF-6 is designed to allow the discharge from this upstream facility to pass through. As a result, the discharge from this facility is a 600 mm gravity sewer.
- **RedDeer_Catchment-7** – the SWMF for this catchment is located in the north, directly south of the cemetery. Runoff from this catchment is collected at the SWMF, and discharged at a rate of 153 L/s through a 600 mm gravity sewer. The outfall for this network is a creek which is a tributary of Crossfield Creek.

SWMFs were sized with the criteria stipulated in Section 5.4. Sizing is summarized in Table 7.5.

Table 7.5: SWMF Sizing Parameters

SWMF ID	Catchment ID(s)	Total Catchment Area	Runoff Coefficient	SWMF Elevation Bottom	SWMF Elevation Top	Area at Bottom of SWMF	Area at Normal Water Level	Area at High Water Level	Area at Top of Freeboard	Permanent Volume	Active Volume	Freeboard Volume	Total Volume	Catchment Area	Percent of Catchment Area
		ha		m		m²				m³					%
Bow_SWMF-1-2	Bow_Catchment-1 & Bow_Catchment-2	128.79	0.950	1104.060	1107.860	53,500	62,000	68,800	70,200	116,000	101,000	21,000	238,000	1,287,899	5.45
Bow_SWMF-3	Bow_Catchment-3	61.35	0.950	1105.010	1108.810	23,300	29,000	33,700	34,700	53,000	49,000	11,000	113,000	613,472	5.64
Bow_SWMF-4	Bow_Catchment-4	60.01	0.950	1113.683	1117.483	22,500	28,100	32,700	33,700	51,000	48,000	10,000	109,000	600,139	5.61
Bow_SWMF-5	Bow_Catchment-5	50.06	0.197	1091.070	1094.870	2,300	4,200	5,700	6,600	7,000	7,000	2,000	16,000	500,554	1.30
Bow_SWMF-6	Bow_Catchment-6	44.93	0.686	1091.087	1094.887	10,700	14,600	18,000	18,700	26,000	27,000	6,000	59,000	449,318	4.15
Bow_SWMF-7	Bow_Catchment-7	66.38	0.950	1098.120	1101.920	26,700	32,800	37,800	38,800	60,000	54,000	12,000	126,000	663,837	5.84
Bow_SWMF-8	Bow_Catchment-8	47.44	0.950	1111.775	1115.575	17,700	22,700	26,900	27,800	41,000	38,000	9,000	88,000	474,372	5.85
Bow_SWMF-9	Bow_Catchment-9	105.05	0.832	1113.760	1117.560	36,200	43,200	49,000	50,100	80,000	73,000	15,000	168,000	1,050,471	4.77
Bow_SWMF-10	Bow_Catchment-10	60.56	0.950	1097.285	1101.085	23,200	28,900	33,600	34,600	53,000	49,000	11,000	113,000	605,580	5.71
Bow_SWMF-11	Bow_Catchment-11	64.85	0.950	1107.707	1111.507	25,700	31,600	36,500	37,500	58,000	52,000	12,000	122,000	648,510	5.78
RedDeer_SWMF-1	RedDeer_Catchment-1	64.70	0.605	1095.550	1099.350	14,700	19,200	23,100	23,900	34,000	32,000	8,000	74,000	647,026	3.69
RedDeer_SWMF-2-3	RedDeer_Catchment-2 & RedDeer_Catchment-3	90.86	0.582	1077.792	1081.592	18,800	23,900	28,100	29,000	43,000	42,000	9,000	94,000	908,634	3.19
RedDeer_SWMF-4	RedDeer_Catchment-4	26.51	0.950	1082.350	1086.150	8,900	12,500	15,700	16,300	22,000	22,000	5,000	49,000	265,105	6.15
RedDeer_SWMF-5	RedDeer_Catchment-5	64.49	0.532	1096.715	1100.515	11,500	15,500	19,000	19,700	28,000	28,000	6,000	62,000	644,880	3.05
RedDeer_SWMF-6	RedDeer_Catchment-6	56.31	0.950	1090.407	1094.207	20,600	26,000	30,500	31,400	47,000	45,000	10,000	102,000	563,083	5.58
RedDeer_SWMF-7	RedDeer_Catchment-7	130.92	0.950	1099.070	1102.870	53,600	62,100	68,800	70,200	116,000	103,000	21,000	240,000	1,309,214	5.36

As noted in Section 5.0, volume targets have not been factored into the design of the ponds due to the potential effect that imposing these targets has on delaying and stalling new developments. It is also noted that by in large, volume targets are not currently being employed in any set fashion except where deemed feasible (which would include considerations for development fiscal viability). This is as noted in The City of Calgary Industry Bulletin for Interim Runoff Volume Control (City of Calgary, 2019). To illustrate the difference between sizing the SWMFs with and without volume control targets, a test case was developed. The test case represents an area that is 64 ha, or roughly equal to one quarter section, with an imperviousness of 75% (the average overall imperviousness across the developable areas). The City of Calgary's Water Balance Spreadsheet was used to determine the required pond sizing to meet the annual average volume control target of 16 mm. Results are summarized in Table 7.6, noting that these scenarios assume no LID measures, which would result in a reduction in pond size, have been implemented.

Table 7.6: Pond Sizing Comparison through Volume Control

Scenario	Annual Volume	Area at NWL	Area at HWL	Area at Freeboard	Total Volume	Cost
	mm	m^2	m^2	m^2	m^3	
Without Volume Control	218	15,500	18,300	19,000	56,000	$1,555,000
With Volume Control	16	238,500	239,400	242,000	580,000	$13,440,000

7.3 Future System Assessment

The proposed SWMF and conveyance system were set up in the model to address the adequacy of the proposed stormwater management system to handle expansion of Crossfield. As the proposed network is independent of the existing stormwater system, the modelling exercise primarily served as a check to ensure appropriate SWMF and sewer sizes were implemented.

To assess the capacity of Crossfield's proposed drainage system, the hydraulic model was run using the 1:5 year 1-hour Chicago distribution rainfall event and the 1:100 year 24-hour Chicago distribution event. The results of these analyses are illustrated in the following:

- Figure 7.5 – the 1D 1:5 year Peak Discharge Relative to Sewer Capacity and Maximum HGL Elevation Relative to Ground
- Figure 7.6 – the 1D 1:5 year Spare Capacity
- Figure 7.7 – the 1D 1:100 year Peak Discharge Relative to Sewer Capacity and Maximum HGL Elevation Relative to Ground
- Figure 7.8 – the 1D 1:100 year Spare Capacity

2D modelling was not performed for the future system. As the exact grading and configuration of the future areas cannot be known until development begins to occur, determining ultimate grading and detailed land use types (to provide input into Mesh, Roughness, and Infiltration Zone parameters) would be a complete estimation. Therefore, 2D modelling at this point is premature as it could not accurately depict or foresee areas with enhanced surface flows. Additionally, it is assumed that developers are required to maintain pre-development flow rates, thus there would be no net impact caused by the added developments. It is recommended that the 2D model be updated and assessed on a regular basis to include developments that have just come online.

The SWMFs are completely independent of the existing stormwater system, therefore SWMF and sewer capacities were designed appropriately to accommodate the flows from major stormwater events. This is seen in the results shown on the figures mentioned above, as no surface flooding is observed, and sewer utilization remains under 100%.

7.4 Recommendations

Upgrades to the stormwater network for future development is generally limited to construction of new SWMFs, outlet control structures, gravity mains, and outfalls. As per The City of Calgary's Stormwater Management and Design Manual (City of Calgary, 2011), it is recommended that backflow prevention valves are installed at any outfall servicing catchment areas with ground or basement elevations below the local 1:100 year creek flood level.

7.5 Low Impact Developments (LIDs)

In order to reduce the overall runoff produced by the developed site, several LID options may be integrated into the stormwater design. LID generally functions to improve stormwater conditions by providing a combination of peak flow attenuation, water quality improvement, and volume reduction through the promotion of infiltration and evapotranspiration.

Integrating LID into the stormwater design of individual sites within the overall development will improve the volumes and quality of water flowing to the proposed SWMFs, resulting in a reduced required SWMF size as discussed above. In addition to this, LID implementation can provide reductions in the total loadings to the receiving waters. As such, LID would support the development in adhering to the recommendation to reduce total suspended solids (TSS), carbonaceous biochemical oxygen demand (CBOD), nitrogen, and phosphorus in accordance with The City of Calgary Total Loading Management Plan (TLMP), and thus promote the overall health of the Nose Creek and Crossfield Creek Watersheds. It is noted that the implementation of LID measures aligns closer to scenarios where there are mandated volume targets. The following information should be leveraged in the event that volume targets are introduced in Crossfield.

7.5.1 Available Source Control Measures

Source control measures are physical measures that are located at the beginning of a drainage system, generally on private properties which may include:

- Residential properties
- Community centers
- Municipal buildings
- Place of worship
- Schools and
- Parks

It is recommended that the Town employ a selection of the technologies in conjunction with the SWMFs in order to achieve an optimal stormwater runoff water quality and volume reduction. Source control options to be considered are summarized in Table 7.7.

Table 7.7: Source Control Practice Table

Source Control Practice	Description	Driving Forces
Stormwater Re-use/ Rainwater Harvesting	Stormwater could be captured in SWMFs or underground storage tanks and used for non-potable uses such as irrigation. This would need to be assessed at the time of development as to whether suitable guidelines for stormwater re-use exist at that stage.	• Potentially significant use of stormwater runoff • Stormwater pollutants retained by storage ponds • Highly applicable to both residential and commercial areas
Bioswales /Vegetated Swales	Stormwater is diverted into surface drainage swales that are vegetated. The net effect is similar to a combination of a grassed swale and an infiltration trench. Significant vegetation is planted to provide additional quality treatment. Subdrains are often installed in soils with infiltration rates below 12.5 mm/hr.	• Provides high amount of volume/rate control • Provides high amount of stormwater pollutant control by retaining pollutants in the swales • Highly applicable to both residential, light commercial, and industrial areas
Absorbent Landscapes	Stormwater runoff is reduced by promoting infiltration into the soil as runoff flows overland. This is often accomplished by designing for significant greenspace. Increased depth of topsoil and reduced soil compaction are also provided for the landscaped areas. This promoted infiltration can allow the soil to work like a sponge to absorb stormwater. Given this technology operates through the promotion of infiltration, soil with a high infiltration rate (low fines content) is recommended. Local geology may limit the effectiveness of this option if a low-permeable soil underlays the added topsoil. A geotechnical report is recommended if this source control is to be implemented.	• Provides high amount of volume/rate control • Highly applicable for low-intensity commercial areas • Somewhat applicable for residential areas • Minimal maintenance required
Green Roofs	Stormwater runoff is reduced by using vegetated roofs. Stormwater is absorbed into soil and is then either evaporated naturally or collected by a subdrain system.	• Works well for roofs of larger buildings (normally commercial and industrial) • Provides high amount of volume/rate control, particularly for small events • Can be used as on-lot stormwater control for commercial/industrial areas
Bioretention Areas	Bioretention areas consist of of depressed, landscaped areas utilized to improve water quality, attenuate peak flows to the stormwater minor system, and to reduce overall stormwater volume through promotion of evapotranspiration. Stormwater is absorbed into soil and is then either evaporated naturally or collected by a subdrain system. Plantings are chosen specifically to optimize the uptake of stormwater nutrient loadings (nitrogen, phosphorus) in the geographic location of interest. Municipalities should be mindful that some maintenance of these systems is required when sediment buildup occurs and following the winter frost.	• Works well for most land uses (can be incorporated into parks, roadway medians, parking lots, sidewalk planting strips, etc.) • Can be used as on-lot stormwater control for commercial, residential, and industrial areas. • Provides high amount of volume/rate control, particularly for small events • Provides high amount of stormwater pollutant control by retaining pollutants

7.5.2 Feasibility of LID

The dominant soils within the Town of Crossfield have been characterized as having an ultimate infiltration rate 7.5 mm/hr which would suggest a loam to silt loam (SCS Class C) soil type. This is not ideal from a soil infiltration aspect and will require the provision of a subdrain for all LIDs. This suggests a physical constraint which could limit the use of LID source and conveyance controls but does not in any way indicate that area soils with lower relative infiltration rates be excluded from infiltration practices. The infiltration rate of soils will have an obvious effect on the drawdown-time of the facility between events and therefore should be sized accordingly based on design guidance from sources such as the City of Calgary Source Control Practices Handbook (2007) and TRCA/CVC LID Planning and Design Guide (2010). The ultimate infiltration rate of the local soils should not be interpreted as a prohibition but as a caution that controls relying primarily on infiltration may not be as effective as they could be on soils with higher relative rate of infiltration.

LID stormwater management practices in soils with lower infiltration rates such as Class C soils are designed through the provision of an subdrain such that they utilize multiple mechanisms (beyond simply infiltration) such as, but not limited to filtration, retention, evaporation and/or transpiration.

The primary function of LID practices in Class C soils in not infiltration. Through in-situ testing of the site specific native soils, the application of appropriate safety factors, the LID designs will function in a manner such that the facility only infiltrates what the local soils can reasonably accommodate within the recommended emptying times. The mechanisms of filtration, retention, and evaporation and/or transpiration can be used to improve water quality and reducing runoff volumes. Provided that the proposed LID techniques incorporate the appropriate runoff storage volumes, empty within inter-event periods and are otherwise appropriately sited, designed, monitored and maintained (similar to all other SWMFs), there should be no impediment to the application of LID technologies for the realization of water quality in the Town. This is supported by The City of Calgary Source Control Practices Handbook (2007) which presents a summary overview of the potential applicability of LID controls measures within an urban context and in relation to Calgary soils and climate (Table 7.8).

Table 7.8: Applicability Matrix

LID Practice	Suitability for Calgary Climate & Soils[1]	Land Use Type			
		Industrial	Commercial & Multi family	Residential	Parks and Open Space
Stormwater Re-use/ rainwater harvesting	High	✓✓	✓✓	✓✓	✓✓
Grass swale/ bioswales	High	✓✓	✓	✓✓	✓✓
Bioretention	High	✓	✓✓	✓✓	✓✓
Green Roofs	High	✓✓	✓✓	*X*	*X*
Absorptive Landscapes	High	✓✓	✓✓	✓	✓✓

✓ = somewhat applicable, ✓✓ = highly applicable, *X = not applicable*

[1] Subdrain system may be required

Adapted from Table I-2 & I-3, City of Calgary Source Control Practices Handbook (2007)

7.5.3 LID Performance

In general, water quality improvements begin with filtration of particulates as runoff flows over the surface of the LID and through vegetation, mulch, soil layers and or aggregate layers (City of Edmonton, 2011). For vegetated practices, soil microbes provide decomposition for pollutants such as hydrocarbons and nutrients. Soils also allow metals and chemicals to sorb to soil particles and compounds within the soil, preventing their release to receiving streams. Table 7.9 summarizes the environmental performance of LID practices.

Table 7.9: Expected Performance

LID Practice (with subdrain)	Environmental Performance		
	Pollutant Removal	Peak Flow Reduction (small events)	Volume Reduction (Estimated)
Stormwater Re-use/ rainwater harvesting	N/A	Medium	Medium (40%)[1]
Grass swale/ bioswales	High	Medium	Medium (45-55%)[1]
Bioretention	High	Medium	Medium (45%)[1]
Green Roofs	Medium	Medium	Medium (45-55%)[1]
Absorptive Landscapes	High	Medium	High (varies)
Perforated Pipe Systems	Medium	High	High (89%)[1]

Adapted from Table I-3 - City of Calgary Source Control Practices Handbook (2007) and amended by TRCA/CVC 2011

7.6 Erosion and Sediment Control (ESC)

A priority of this study is to minimize environmental impacts and support the health of the watersheds in the face of increasing developments. During construction, the removal of topsoil and vegetation will expose subsoils that are more susceptible to erosion since they are not as compacted. Developments which result in an increase of runoff may also contribute to erosion if not properly managed.

Erosive agents, such as wind and water, have the ability of detaching, entraining, and transporting soil particles, thus causing erosion. This process is dependent on the cohesion and texture of the soils, as well as the erosive energy of the agent, such as gravitational and fluid forces. Deposition/sedimentation will occur when the fluid forces of the erosive agent are less than the force of gravity of the soil particles. As the soil particles can no longer be entrained in the air or water, they begin to settle and form depositions. Generally, this is caused by a reduction in flow velocity or turbulence.

If temporary construction and permanent development ESC practices are not implemented, it can lead to the transport of sediment and other contaminants thus polluting downstream waterbodies. This can result in the following negative impacts:

- Transportation of hydrocarbons, metals, and nutrients with the eroded soils to a water source
- Destruction aquatic habitats
- Sediment deposition in infrastructure and waterbodies
- Reduced quality of water supply
- Limitations to the effectiveness of flood control measures
- Affect recreational areas

The most effective and economical method of controlling erosion is at the source. This includes the implementation of methods such as controlling stormwater runoff (generally accomplished by stipulating maximum allowable area release rates) or by stabilizing exposed soils. Potential options to mitigate negative impacts of erosion are outlined below. Note that the information found in this section has been taken from the Guidelines for Erosion and Sediment Control (City of Calgary, 2011).

All developments are required to submit a detailed ESC report detailing the downstream erosion impacts caused by the proposed stormwater discharge and detail how these impacts are being mitigated.

7.6.1 Vegetative Check Dams

Vegetative check dams act as low-lying barriers within a drainage ditch or channel to decrease the flow velocity and improve water quality. These control measures are generally used for a combination of erosion and sediment control. The dams sit perpendicular to the direction of flow and only allow a certain amount of water to pass through at a time while also retaining sediment. There are limitations involved with vegetative check dams including a maximum feasible slope for implementation of approximately 8% and a minimum slope of 1% to 2%. However, this erosion mitigation measure serves this purpose and achieves the improved water quality objective.

7.6.2 Erosion Control Blankets

Erosion control blankets are the most appropriate erosion mitigation measure when runoff quantity and velocities are the driving force behind the erosion risk. They offer a typical erosion reduction of 95% to 99%. Two of these types of erosion control measures include:

- Straw Blankets:
  - Ideal for short-term erosion control
- Turf Reinforcement Mats:
  - Synthetic material
  - Recommended for additional shear resistance
  - Promotes longevity of a channel
  - Ideal for more long-term erosion control

A substantial length of erosion control blankets would be required due to the long length of steep sloping channels. This steepness may also create issues with feasibility of installation and considerations for the environmental implications must also be made. The soil characteristics of these existing channels may affect the overall performance of erosion control measures and will also need to be accounted for.

7.7 Cost Estimates

7.7.1 Recommended Stormwater Servicing Concept

Cost estimates were prepared for Crossfield's proposed stormwater system. The costs for new SWMFs, gravity sewers, and outfall structures under the future condition are in Table 7.10. Figure 7.9 illustrates the proposed concept along with the associated costs. For a detailed cost breakdown, refer to Appendix B. Separate reviews should be prepared to support each subdivision application/development permit to ensure compliance with the overarching SMP.

Table 7.10: Cost Estimates for Recommended Servicing System

Item	Cost
SWMF (Sizes Vary)	$44,520,000
300mm Trunk Sewer	$565,000
375mm Trunk Sewer	$3,115,000
525mm Trunk Sewer	$1,185,000
600mm Trunk Sewer	$1,305,000
750mm Trunk Sewer	$805,000
300mm Flared End	$25,000
375mm Flared End	$40,000
525mm Flared End	$15,000
600mm Flared End	$55,000
750mm Flared End	$15,000
Flap Gate	$410,000
Total	**$52,055,000**

7.7.2 Typical Source Control Implementation Costs

Typical unit costs for LID practices are detailed in Table 7.11. Cost may vary depending on site-specific factors, including soil infiltration rates. By performing in-situ testing of the site-specific soils using a Guelph Permeameter, double ring infiltrometers, pit tests and others, the infiltration rate of the native site soils can be scientifically verified and used in developing cost estimates, and in subsequent phases of design.

Table 7.11: Typical Source Control Unit Costs

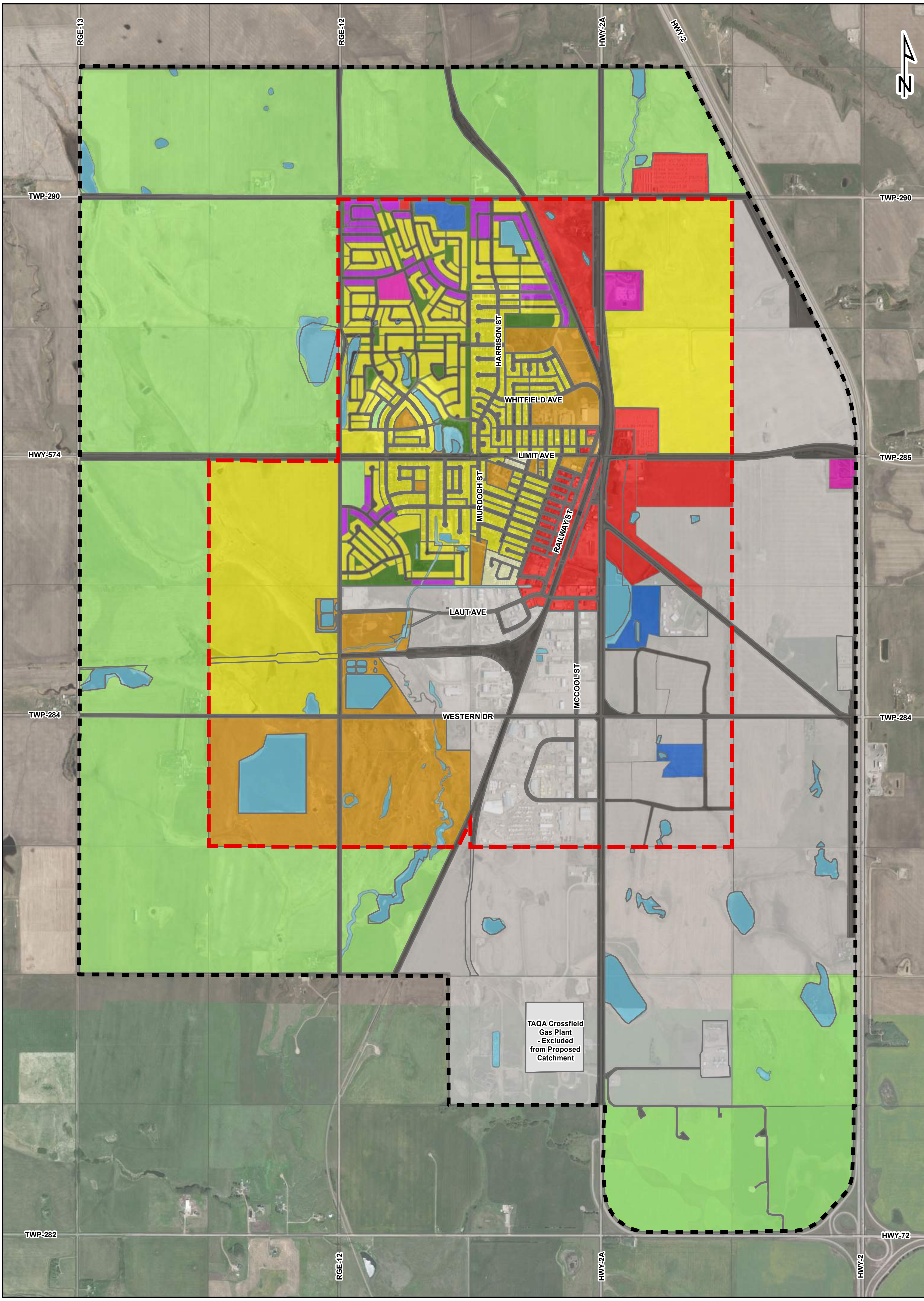
BMP Technique	Unit Construction Cost
Rainwater Harvesting (underground storage and irrigation)	\$300 to \$1,200 / m^3 stored
Green Roofs	\$145 to \$360 / m^2 roof area
Infiltration Trenches and Chambers	\$515 to \$660 / m^3 stored
Bioretention	\$720 to \$900 / m^2 of facility (\$62,400 / imp. ha treated)
Bioretention Planters (contained within concrete curbing or urban container)	Bioretention Planter (small) \$1,200 to \$1,920 / m^3 treated Stormwater Tree Pits \$2,880 to \$4,080 / m^3 treated

7.8 Phasing Plan

In terms of proposed upgrades for the identified areas of concern under existing conditions, it is recommended that phasing generally follows the priority level of the concern. That said, Priority 1 concerns should be dealt with first, followed by Priority 2 and Priority 3. As mentioned above, Priority 0 projects are in progress as of the Final Report submission of this document, and Priority N/A concerns do not require any upgrades.

The proposed network identified in the future network are mainly development-driven by the build-out of the ASP areas. The timeline of the improvements will primarily correlate with the progress of the build-out based on size and type of development, staging of development, and location of development. When new developments are planned, it is that the stormwater concepts are revisited to ensure that the proposed grading of each development site is accounted for.

SWMFs and downstream sewer infrastructure to the discharge locations should be in place prior to the new developments coming online. This will ensure that the additional flows as a result of increased impervious surfaces are accommodated. The stormwater infrastructure required for a specific proposed development site is dictated based on which stormwater catchment the proposed development site is within.



Credits:Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

0 125 250 500 750 1,000 Metres

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Legend

- Annexation Boundary
- Pre-Annexation Boundary

Land Use

- Residential
- Commercial
- Industrial
- Institutional
- Manufactured Home Residential
- Mixed Use
- Municipal
- Open Space
- Road
- SWMF
- Urban Holdings
- Waterbody

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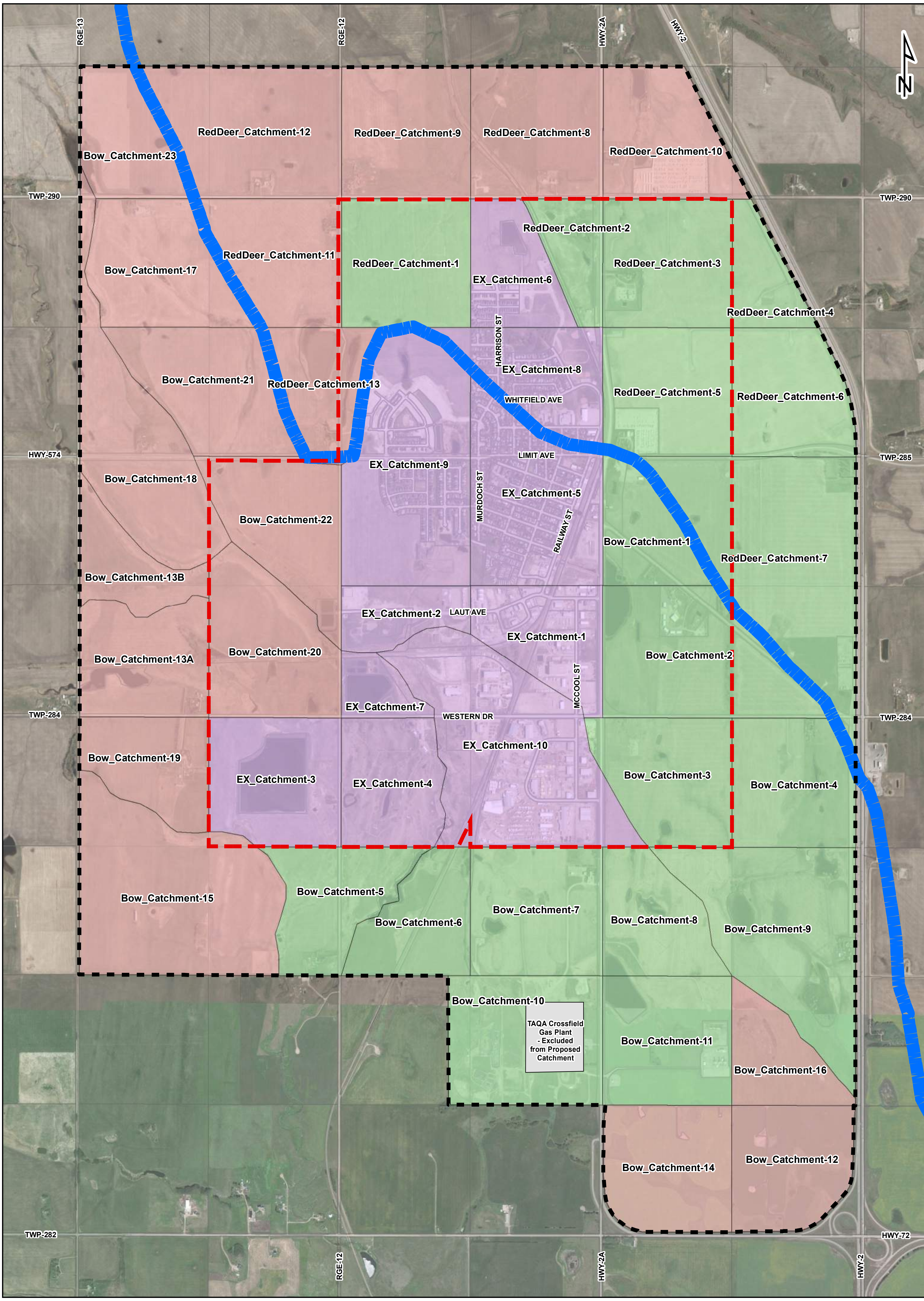
FIGURE 7.1
PROPOSED LAND USE
CROSSFIELD STORMWATER MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.



Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

0 125 250 500 750 1,000 Metres

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Legend

Annexation Boundary

Pre-Annexation Boundary

Watershed Boundary

Drainage Basin

Existing Area

No Proposed Development (Concept Design Only, No Sizing)

Proposed For Development

FIGURE 7.2
FUTURE DRAINAGE BASINS
CROSSFIELD STORMWATER
MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.

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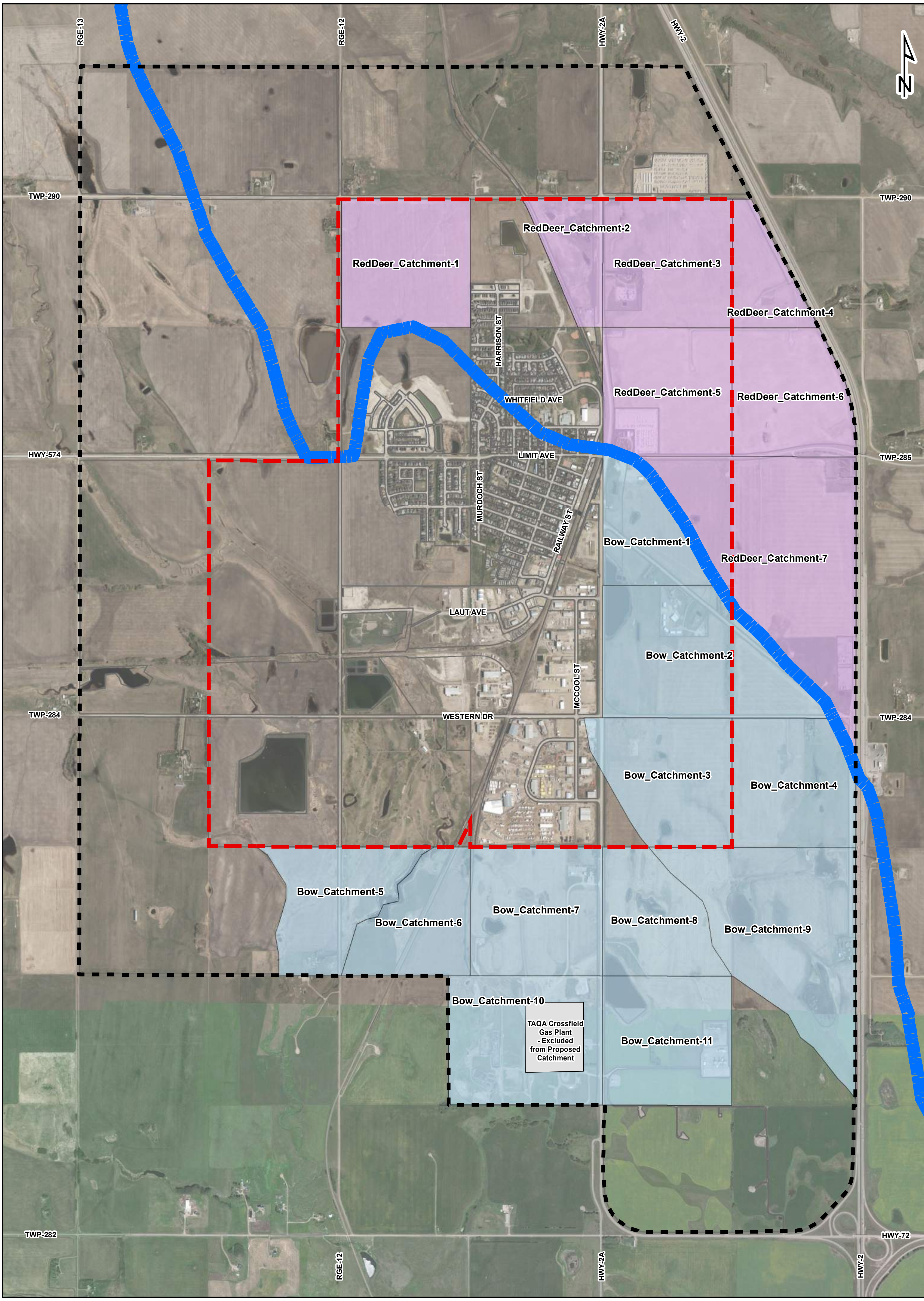

Credits:Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Date: 4/1/2020 Document: H:\27309 - Supplemental\02_CADD\251_Figures\01_Report Figures\7.0 Future System Assessment and Upgrades\Figure7.3_FutureDevelopableDrainageBasins.mxd

0 125 250 500 750 1,000 Metres

1:22,000 CANA83-3TM114

Legend

- Annexation Boundary
- Pre-Annexation Boundary
- Watershed Boundary

Watershed

- Bow River
- Red Deer River

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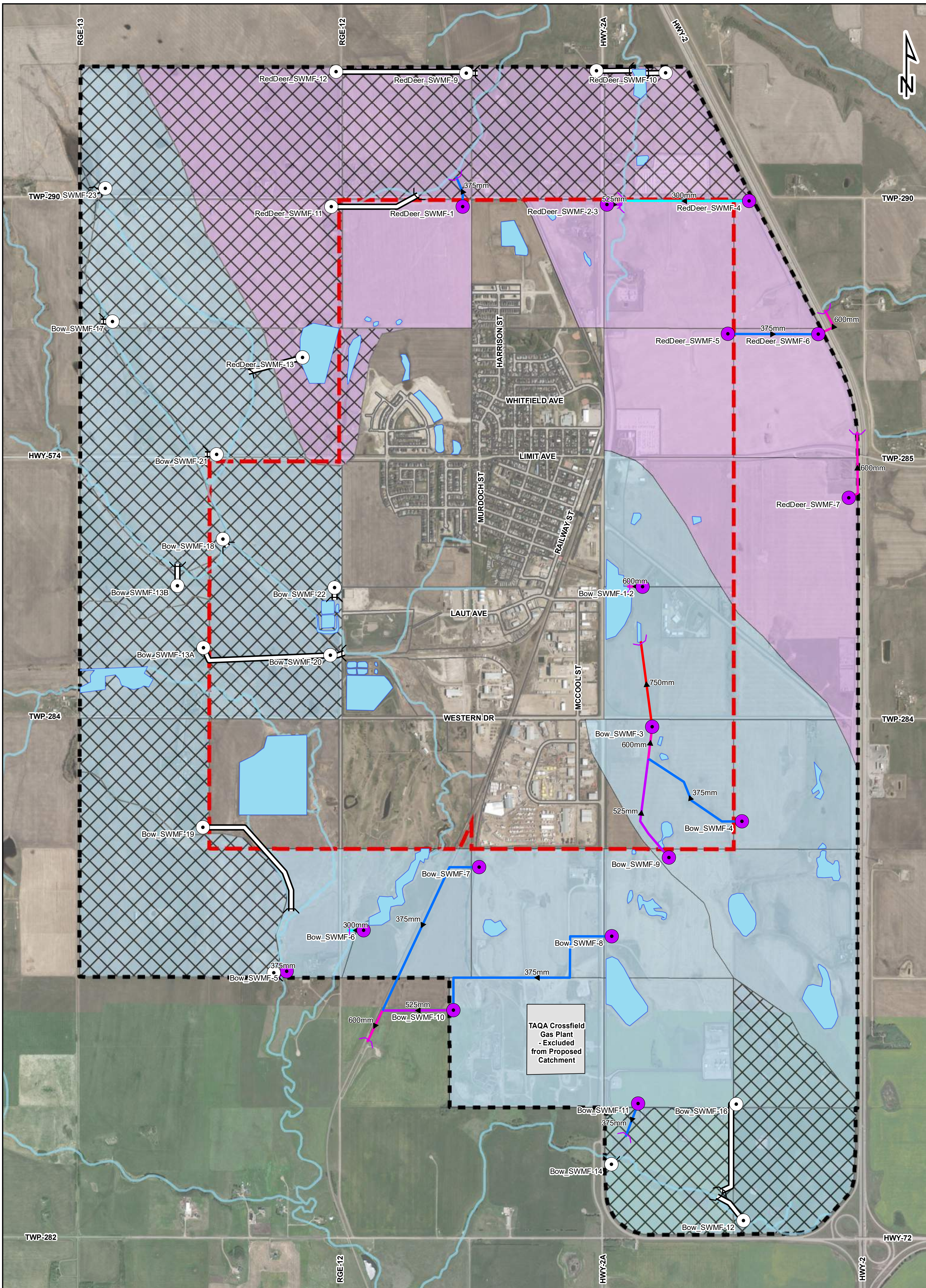
FIGURE 7.3
FUTURE DRAINAGE BASINS PROPOSED FOR DEVELOPMENT
CROSSFIELD STORMWATER MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.



0 125 250 500 750 1,000 Metres

1:22,000 CANA83-3TM114

Legend

- Annexation Boundary
- Pre-Annexation Boundary
- Bow River - No Development
- Bow River - To Develop
- Red Deer River - No Development
- Red Deer River - To Develop
- Watercourse
- Proposed Pond - Conceptual Layout Only, No Sizing
- Proposed Pond
- Proposed Outfall
- Proposed Outfall - Conceptual Layout Only, No Sizing

Sewer Size

- Conceptual Layout Only
- 300mm
- 375mm
- 525mm
- 600mm
- 750mm

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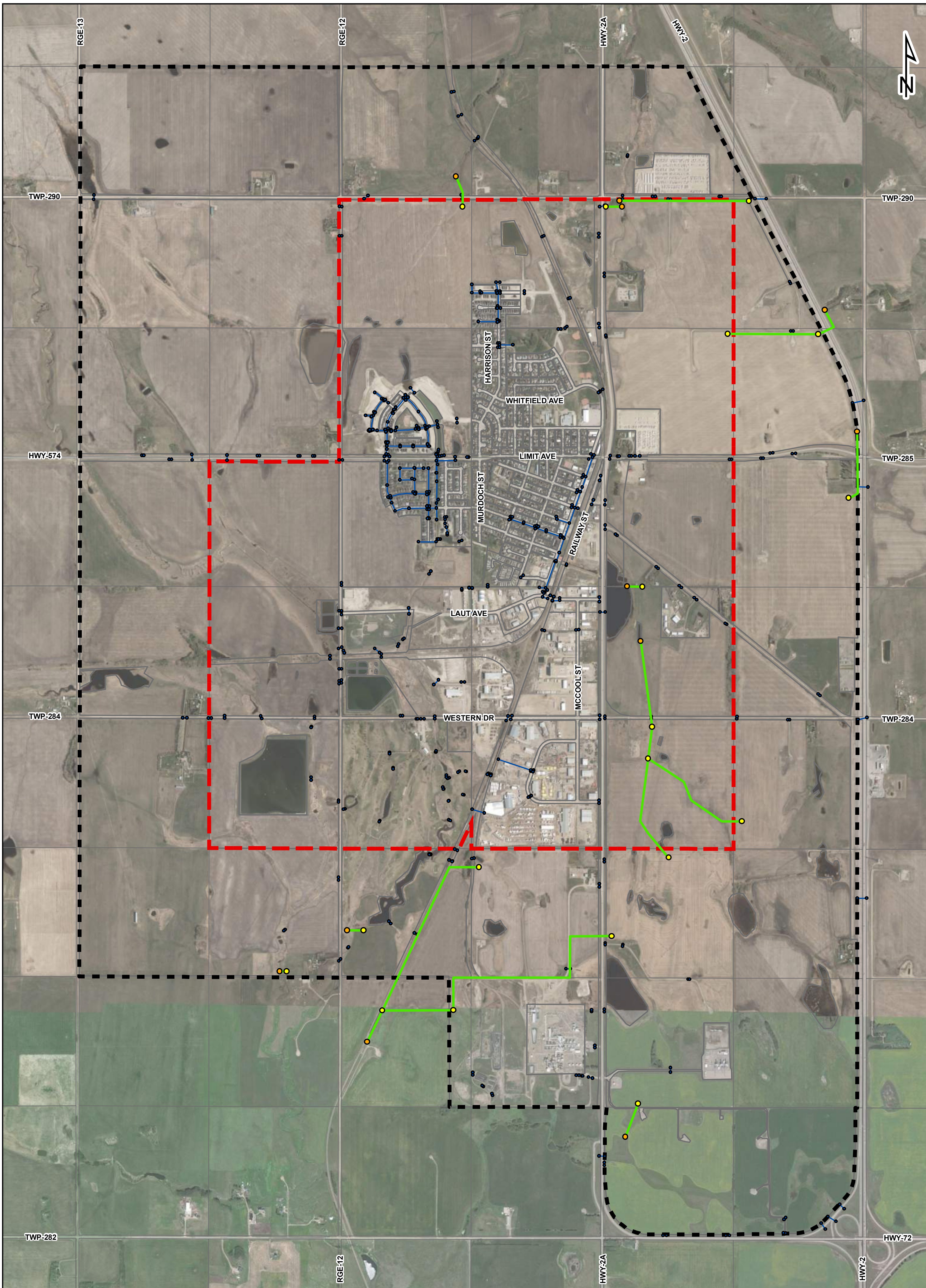
FIGURE 7.4 PROPOSED SERVICING CONCEPT CROSSFIELD STORMWATER MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.



Credits:Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEROGRID, IGN, and the GIS User Community

0 125 250 500 750 1,000 Metres

1:22,000 CANA83-3TM114

Legend

- Annexation Boundary
- Pre-Annexation Boundary
- Existing Nodes
- Existing Links

Maximum HGL Relative to Ground

- Less than -3.0m
- -3.0m to -1.2m
- -1.2m to 0.0m
- Greater than 0.0m

Peak Flow Relative to Capacity

- Less than 86%
- 86% to 100%
- Greater than 100%

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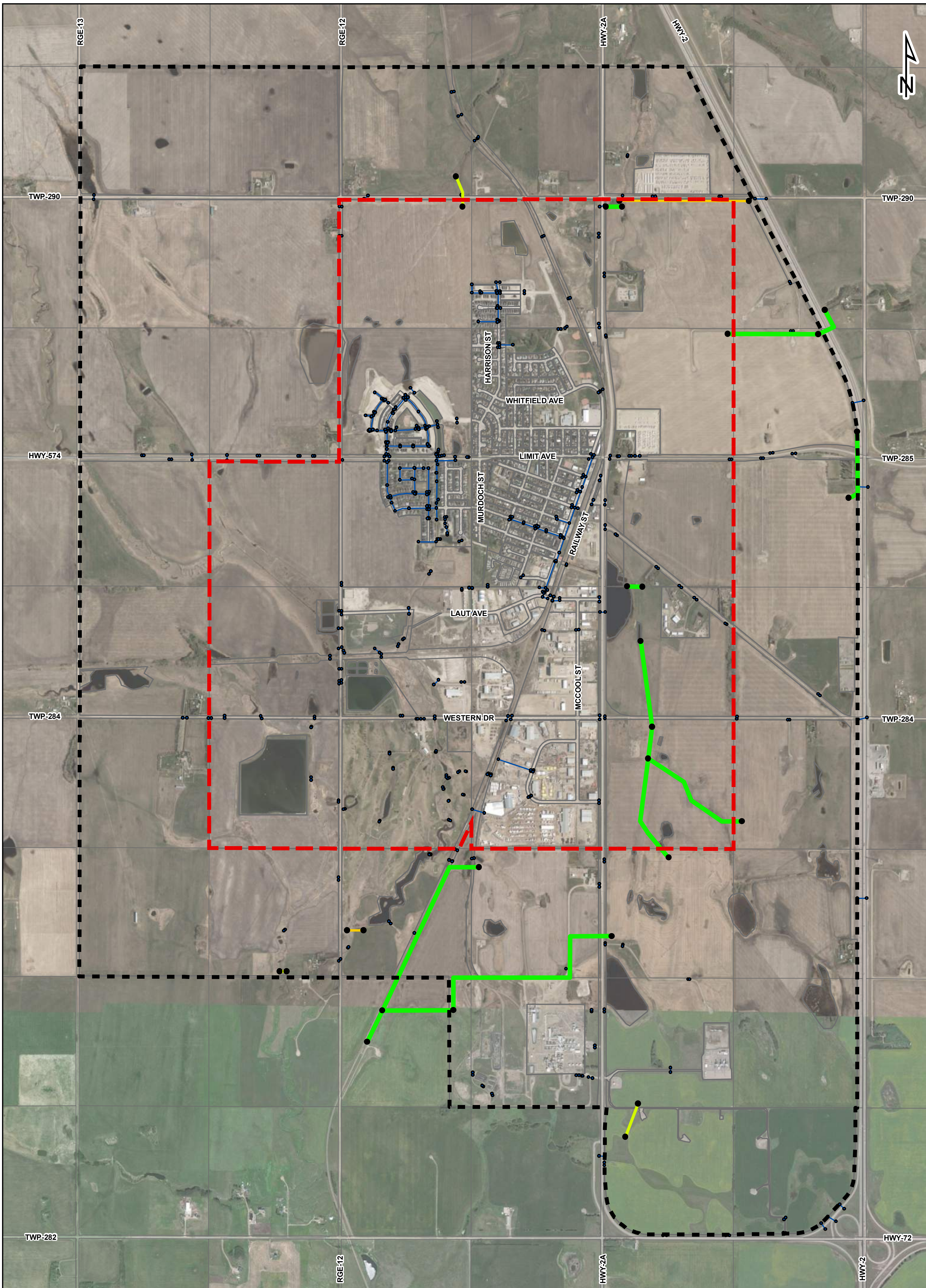
FIGURE 7.5
FUTURE ASSESSMENT RESULTS - 1D
5 YR 1 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.

Date: 4/1/2020 Document: H:\27309 - Supplemental\02_CADD\251_Figures\01_Report Figures\7.0 Future System Assessment and Upgrades\Figure7.5_Prop_Results_1D_5yr.mxd



Credits:Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

0 125 250 500 750 1,000 Metres

1:22,000 CANA83-3TM114

Legend

- Annexation Boundary
- Pre-Annexation Boundary
- Existing Nodes
- Existing Links
- Future Nodes

Spare Capacity

- Less than 0L/s
- 0 - 25L/s
- 25 - 50L/s
- 50 - 75L/s
- 75 - 100L/s
- Greater than 100L/s

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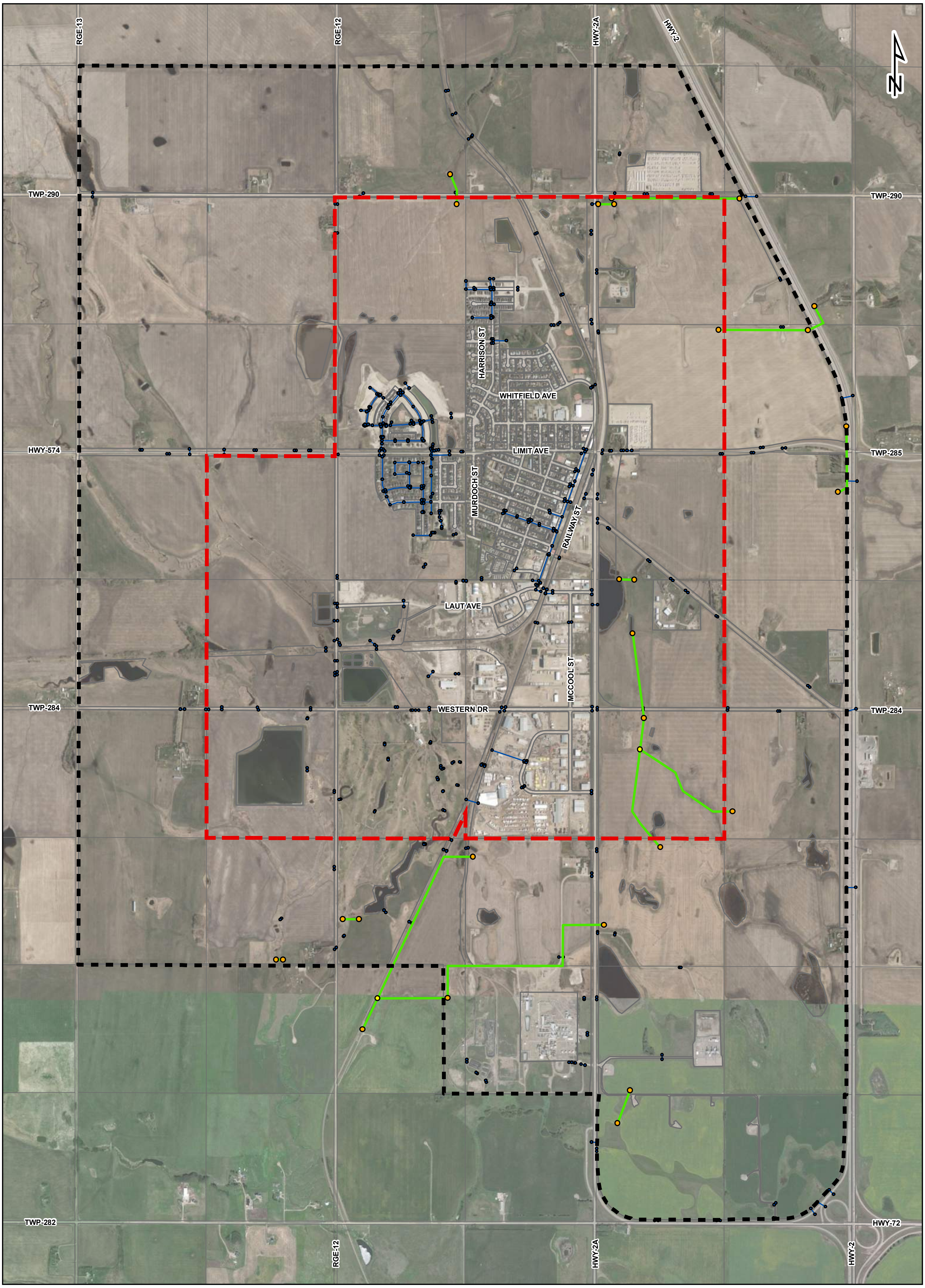
FIGURE 7.6
FUTURE SPARE CAPACITY - 1D
5 YR 1 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.

Date: 4/1/2020 Document: H:\27309 - Supplemental\02_CADD\251_Figures\01_Report Figures\7.0 Future System Assessment and Upgrades\Figure7.6_Prop_Results_1D_5yr_Spare Capacity.mxd



Credits:Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Metres
0 125 250 500 750 1,000
1:22,000 CANA83-3TM114

Legend

- Annexation Boundary
- Pre-Annexation Boundary
- Existing Nodes
- Existing Links

Maximum HGL Relative to Ground

- Less than -3.0m
- -3.0m to -1.2m
- -1.2m to 0.0m
- Greater than 0.0m

Peak Flow Relative to Capacity

- Less than 86%
- 86% to 100%
- Greater than 100%

FIGURE 7.7
FUTURE ASSESSMENT RESULTS - 1D 100 YR 24 HR DESIGN STORM
CROSSFIELD STORMWATER MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.

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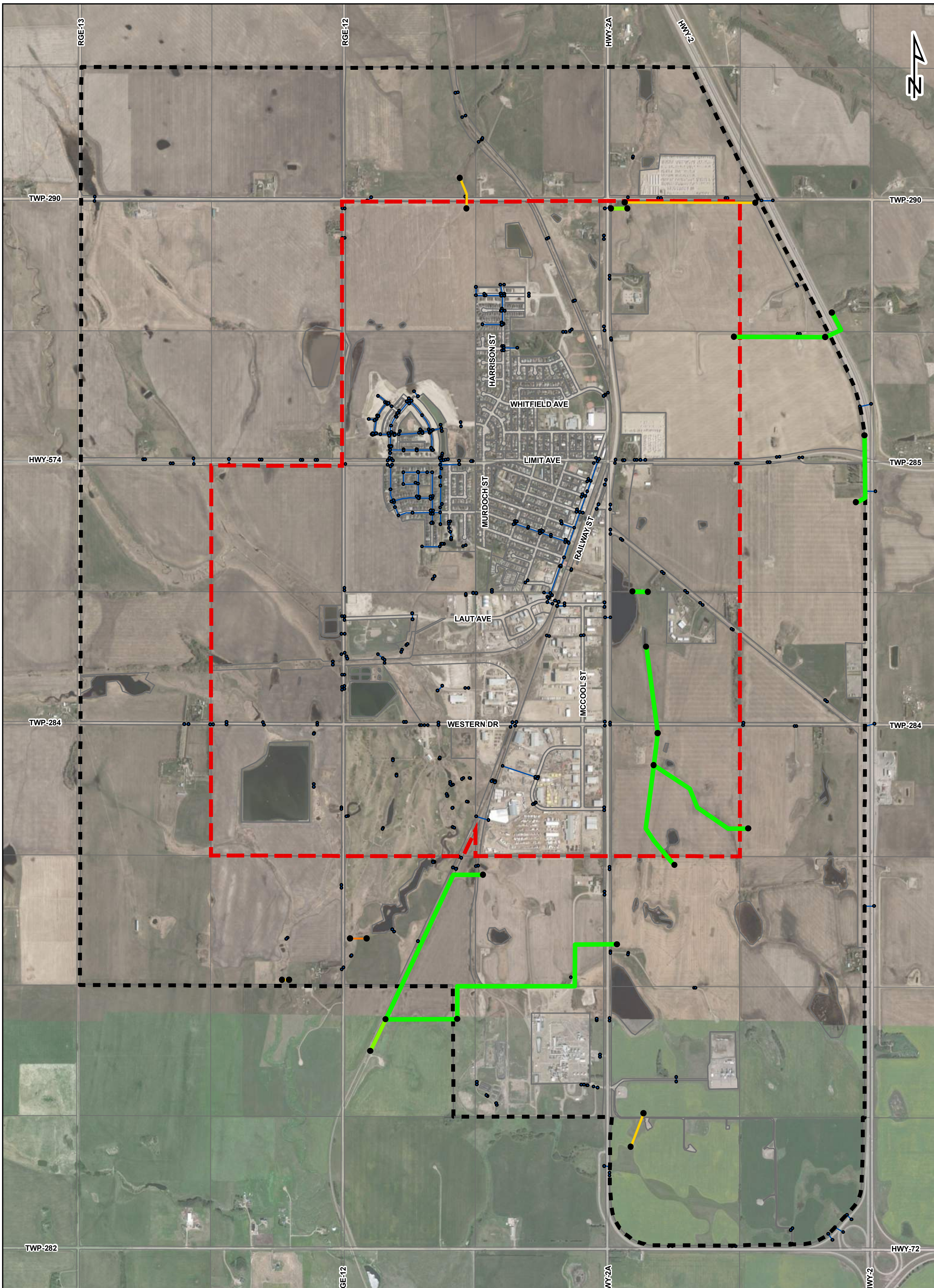

Credits:Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEROGRID, IGN, and the GIS User Community

Metres
0 125 250 500 750 1,000
1:22,000 CANA83-3TM114

Legend

Annexation Boundary
Pre-Annexation Boundary
Existing Nodes
Existing Links
Future Nodes

Spare Capacity
Less than 0L/s
0 - 25L/s
25 - 50L/s
50 - 75L/s
75 - 100L/s
Greater than 100L/s

FIGURE 7.8
FUTURE SPARE CAPACITY - 1D
100 YR 24 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.

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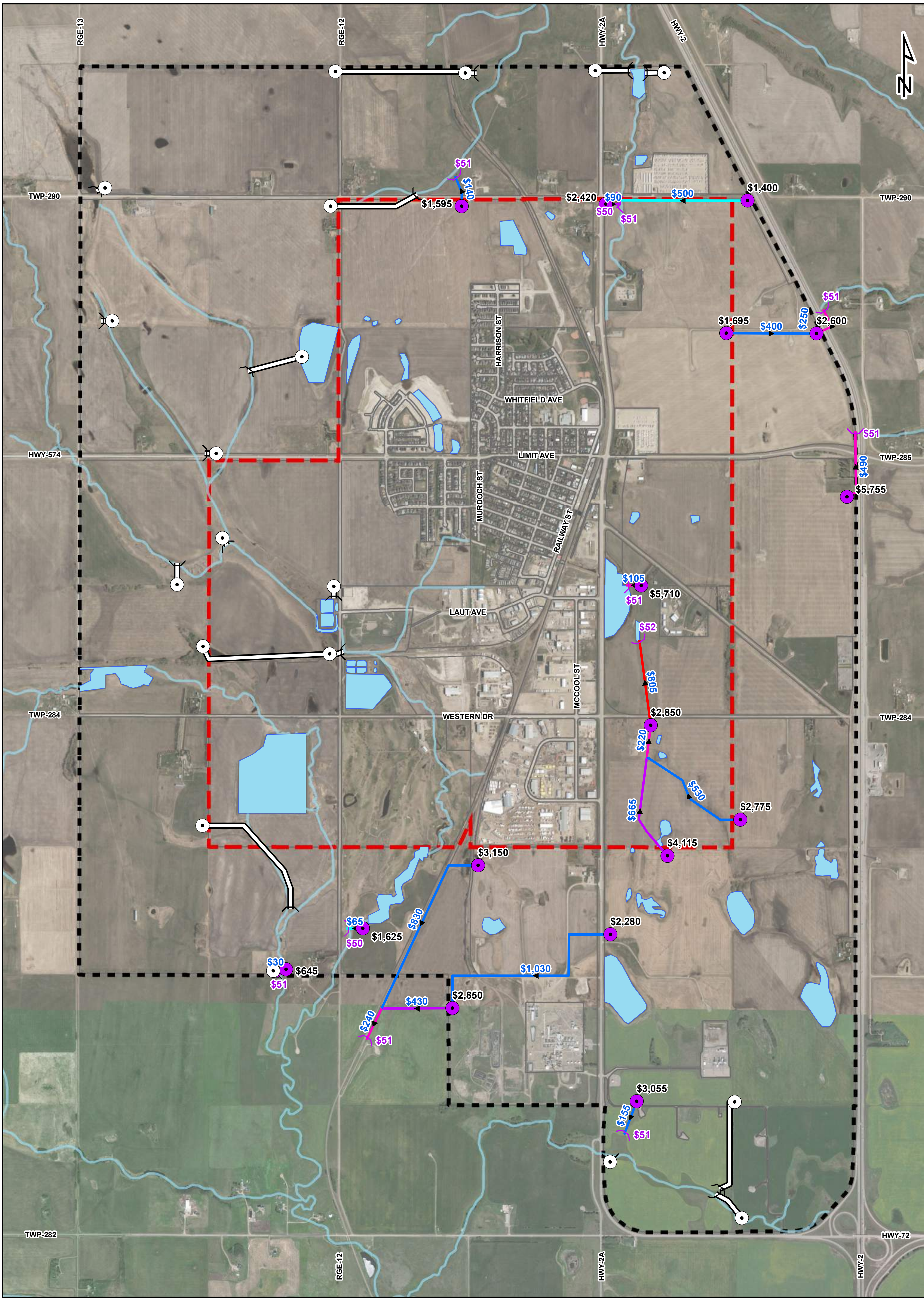

Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

0 125 250 500 750 1,000 Metres

1:22,000 CANA83-3TM114

Legend

- Annexation Boundary
- Pre-Annexation Boundary
- Watercourse
- $$$ Pipe Costs
- $$$ Outfall Costs
- $$$ Pond Costs

All costs in thousands.

- Proposed Pond - Conceptual Layout Only, No Sizing
- Proposed Pond
- Proposed Outfall
- Proposed Outfall - Conceptual Layout Only, No Sizing

Sewer Size

- Conceptual Layout Only
- 300mm
- 375mm
- 525mm
- 600mm
- 750mm

FIGURE 7.9
PROPOSED SERVICING CONCEPT WITH ASSOCIATED COSTS
CROSSFIELD STORMWATER MASTER PLAN

The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.

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8.0 Conclusions and Recommendations

ISL was commissioned by the Town to complete an SMP, including an assessment of the Town's current stormwater conveyance infrastructure capacity and the Town's future stormwater infrastructure needs. The SMP was initiated to account for the changes to the Town's planning direction over time and the development of new infrastructure projects and the new annexed areas. The intent of this project is to provide Town Council a road map of existing infrastructure upgrades that are required, as well as new stormwater infrastructure to service proposed developable areas.

The SMP was prepared to achieve the following objectives:

- Assessing existing drainage conditions and determining design criteria for the stormwater drainage system, including runoff rates and volumes.
- Providing an inventory of and analyzing existing natural drainage conveyance.
- Determining if any upgrades are required to the existing system to properly meet the needs of the municipality and to allow future growth to occur.
- Developing stormwater infrastructure plans, including SWMF sizing, to manage increased and redirected runoff resulting from future development. Locations and timing may depend on:
  - Availability of sufficient servicing needs
  - Undeveloped land locations
  - District planning
- Producing a drainage basin specific stormwater management plan that uses best management practices to minimize the effect to the natural hydrological and hydro-geological regimes, and to ensure the planned stormwater management system meets regulatory authority requirements.
- Providing cost estimates related to required infrastructure upgrades, which will also provide inputs to an off-site levy bylaw.
- Commenting on possible staging options of upgrades for the most effective infrastructure implementation.

8.1 Conclusions

The Town's stormwater system consists of both major and minor drainage systems. In terms of major infrastructure, the system is comprised of a series of overland drainage routes that convey stormwater ultimately to either Crossfield Creek or Nose Creek. There are three drainage basins that convey stormwater runoff to Crossfield Creek, and two drainage basins that convey stormwater to Nose Creek. Crossfield Creek is within the Red Deer Watershed, while Nose Creek is in the Bow River Watershed. There are six notable wet/dry ponds in the Town, and two notable wetlands, as summarized below:

- Vista Crossing Wet Pond 1
- Vista Crossing Wet Pond 2
- Vista Crossing Wet Pond 3
- Vista Crossing Wetland
- Iron Ridge Wet Pond
- Westgate Dry Pond
- Fish Pond
- Black Bull Industrial Park Wetland

The minor system is comprised of gravity sewers, manholes, catchbasins, catchbasin leads, and outfalls, with the majority of this infrastructure located in newer areas of the Town. Pipe sizes range from 150 mm to 2400 mm in size. Drainage components such as culverts, gutters and roof leaders facilitate the exchange of stormwater runoff between the major and minor systems.

A coupled 1D-2D model was constructed in InfoWorks ICM to assess the Town's stormwater system. Development of the model occurred in two phases; the first was to build the minor (1D) portion of the system and the second consisted of generating a mesh to represent the major (2D) portion of the system. The process that was used to generate the model is described in detail in Section 4.0.

Design rainfall events produced from The City of Calgary's IDF parameters were utilized to assess the Town's stormwater drainage system. The minor system was assessed using a 1:5 year 1-hour Chicago rainfall distribution while the major system was assessed using a 1:100 year 24-hour Chicago rainfall distribution.

Results of the piped (minor) stormwater drainage system within Crossfield under existing conditions for both the 1:5 and 1:100 year storm conditions are summarized below:

- Model results under the 1:5 year 1-hour Chicago design storm indicate that surcharging remains isolated to four locations. These locations include along Railway Street, in the easement west of Stevens Place, the sewers along Stevens Place that discharge to Westgate Dry Pond, and at the intersection of Mossip Avenue and Harrison Street. As well, various catchbasin leads throughout the Study Area are surcharged.
- Model results under the 1:100 year 24-hour Chicago design storm indicate that similar surcharging is noted as in the 1:5 year scenario, with the main difference being that surcharging extends further upstream of Westgate Dry Pond.

Results of the overland (major) stormwater drainage system within Crossfield under existing conditions for both the 1:5 and 1:100 year storm conditions are summarized below:

- Model results of the overland drainage system under the 1:5 year 1-hour Chicago design storm indicate that areas with notable water depths largely focus around ditches, creeks, and ponds.
- Model results of the overland drainage system under the 1:100 year 24-hour Chicago design storm suggest that there are a number of locations throughout Crossfield that would experience surface flooding. Nine notable areas of concern were flagged for further investigation and potential remediation measures.

A proposed stormwater system concept was developed for Crossfield. It is comprised of SWMFs, along with sewers that discharge into either Nose Creek or Crossfield Creek, or one of their tributaries. Discharge into Nose Creek is limited to a rate of 1.257 L/s/ha while the discharge rate into Crossfield Creek is 1.4 L/s/ha. These discharge rates adhere to the Nose Creek Watershed Water Management Plan (Palliser, 2008) for Nose Creek, and the past Master Drainage Plan (Stormwater Solutions Inc., 2008) for Crossfield Creek.

Volume targets have been omitted for both watersheds. This is due to the uncertainty of the criteria stipulated in the Nose Creek Watershed Management Plan (Palliser, 2008) moving forward, as stringent targets have led to delays in new developments. To provide a baseline comparison, two scenarios were developed with identical control parameters to illustrate the difference between implementing and not implementing volume targets. The results indicated that implementing volume targets to 16 mm would be approximately nine times more costly than not using these targets.

The proposed stormwater system concept was modelled in InfoWorks ICM (1D modelling only) to determine if there is adequate capacity in the system. Assessment results indicate that the conceptual network would be sufficient in managing stormwater runoff from the future developments.

8.2 Recommendations

A number of recommendations were made based on the findings of this study. This includes the findings of the existing system assessment, and development of the proposed stormwater concept for new areas.

Of the ten locations flagged as notable concerns during the existing system analysis, six locations were flagged for improvement. The proposed upgrades and associated costs for the existing system are shown in Figure 6.13 and summarized below:

- Implementation of a catchbasin on Limit Avenue, west of Harrison Street, and a tie to the existing culvert to the west.
- Upgrading the existing culvert on Ross Street to 600 mm.
- Upgrading the existing pipes on Nanton Avenue between Ross Street and Railway Street to 525 mm.
- Upgrading the existing pipe on Stevens Place, south of Smith Avenue, to 450 mm.
- Upgrading the pipe in the easement west of Stevens Place to 675 mm.
- Upgrading the pipes at the intersection of Mossip Avenue and Harrison Street to 600 mm.

The future stormwater system should be designed based on the design criteria presented in this SMP, as well as The City of Calgary's Stormwater Management and Design Manual. The future stormwater system should be constructed as denoted in Figure 7.4. The costs of these additions are shown in Table 7.10 and Figure 7.9, and amount to a total cost of $53.2 million. Future SWMFs should follow the parameters identified in Table 7.5.

Drainage to the SWMFs should be considered at the time of the subdivision application/development permit. Separate reviews should be prepared to support each subdivision application/development permit to ensure compliance with the overarching SMP.

The proposed SWMFs should be equipped with outlet control structures, while the downstream sewers should include an outfall structure at the downstream discharge location. It is recommended that stormwater outlet backflow preventers be installed at any outfall servicing catchment areas with ground or basement elevations below the local 1:100 year creek flood level. LID measures should be considered on a site-specific basis and should be reviewed by the Town to determine if their implementation is desired.

It is also recommended that the SMP should be reviewed and updated after significant periods of growth or every five years to update the hydrodynamic model and analysis with any capital upgrades completed by the Town, and the most up-to-date growth plans. This could provide clarity on the planned location of development, the density of the proposed development, and the potential corresponding upgrades. This should also be undertaken when considering densification within the established area.

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9.0 References

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TRCA/CVC. 2010. *Low Impact Development and Stormwater Planning and Design Guide.* Ontario.

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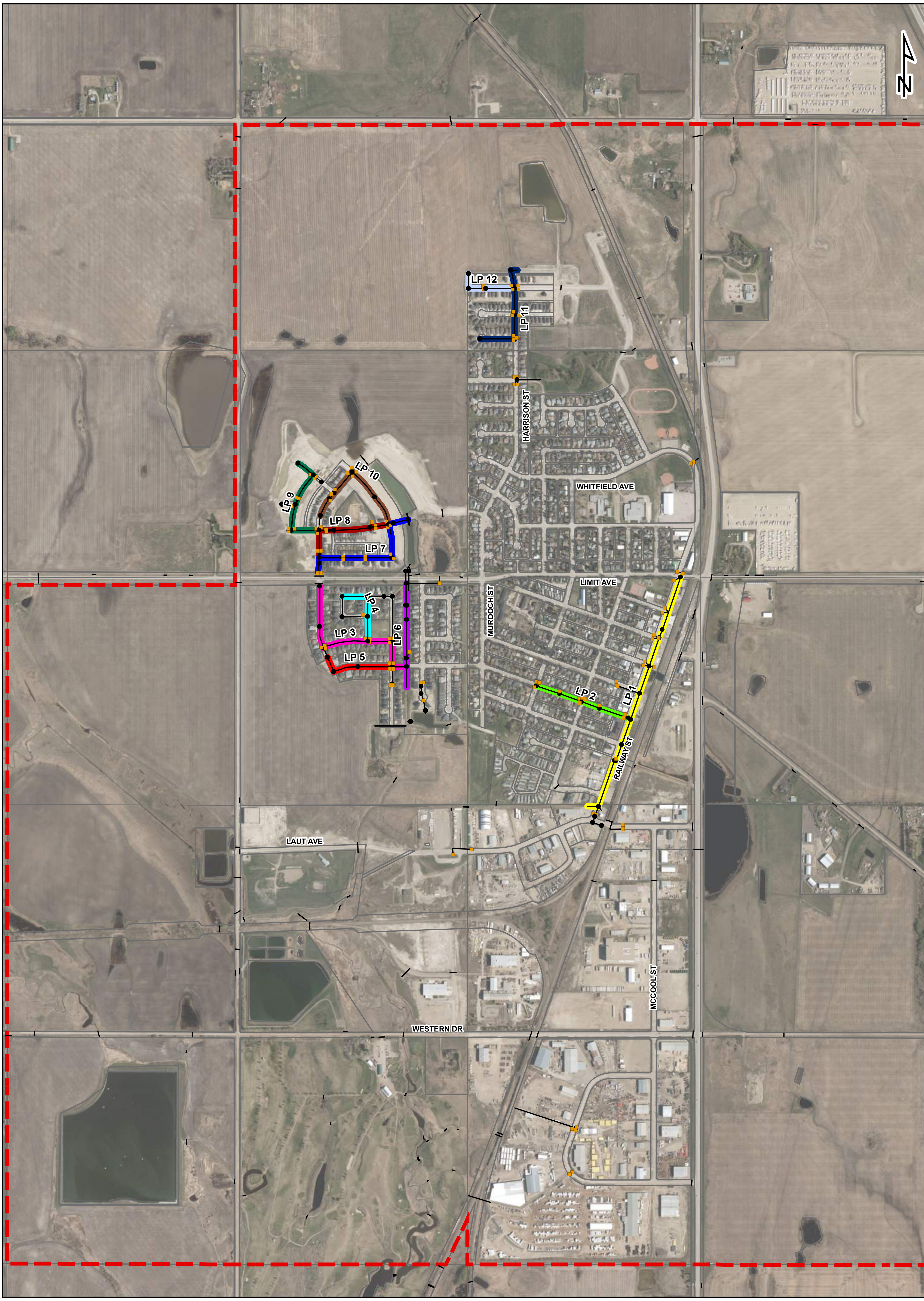
APPENDIX
Existing System Assessment Longitudinal Profiles

A



Credits:Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

0 70 140 280 420 560 Metres

1:12,500 CANA83-3TM114

Legend

- Manhole
- Catchbasin
- Conduit
- Annexation Boundary
- Pre-Annexation Boundary

Longitudinal Profile

- LP 1
- LP 2
- LP 3
- LP 4
- LP 5
- LP 6
- LP 7
- LP 8
- LP 9
- LP 10
- LP 11
- LP 12

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FIGURE A.1 LONGITUDINAL PROFILE KEY PLAN CROSSFIELD STORMWATER MASTER PLAN

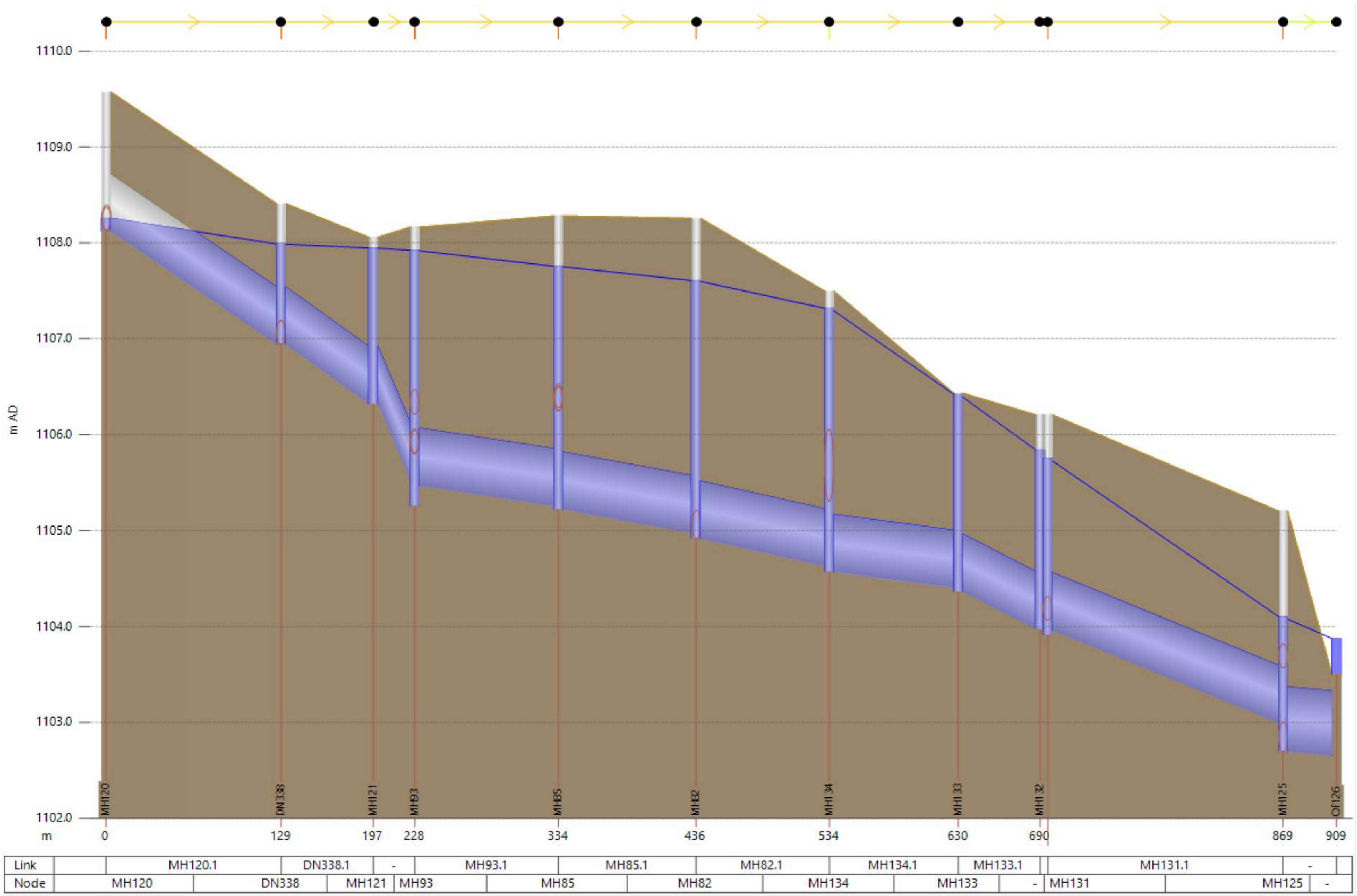
The Aerial imagery displayed is from ESRI's ArcGIS in-house Basemap presenting a collection of satellite world imagery. The southern portion is based on imagery procured in 2016 while the northern portion imagery was procured in 2018.

Date: 4/1/2020 Document: H:\27309 - Supplemental\02_CADD\251_Figures\01_Report Figures\Appendix A\Figure A.1_Longitudinal Profile Key Map.mxd

Legend

Existing - Water Level

Ground Elevation



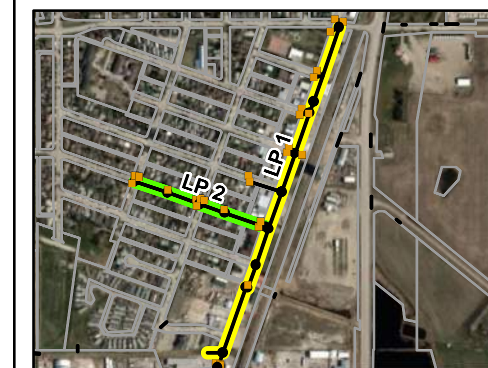


FIGURE A.2
EXISTING CONDITIONS - LP 1
5 YR 1 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

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Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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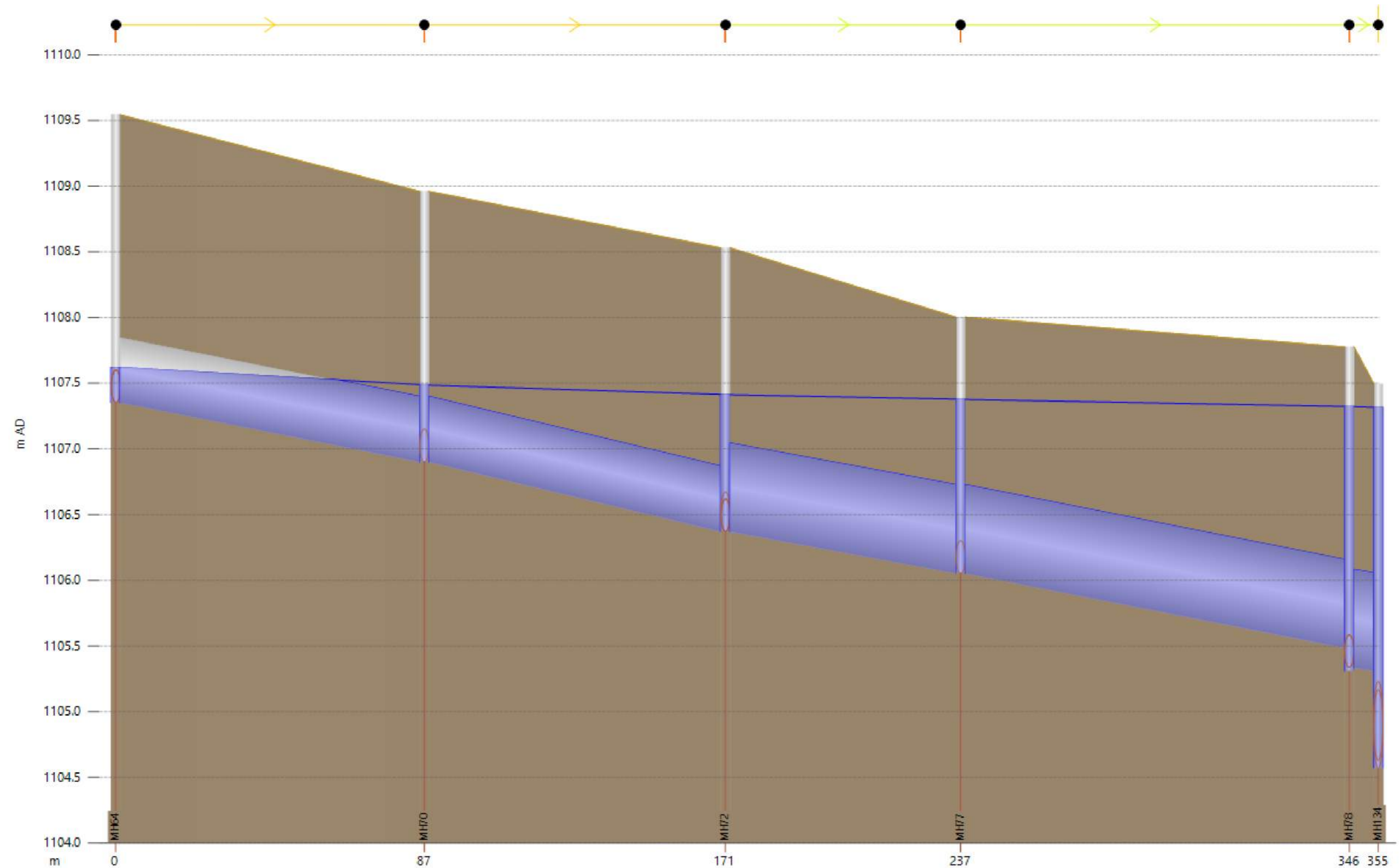
Date: 4/9/2020



Link	MH64.1	MH70.1	MH72.1	MH77.1	-
Node	MH64	MH70	MH72	MH77	MH78

Legend

Existing - Water Level

Ground Elevation

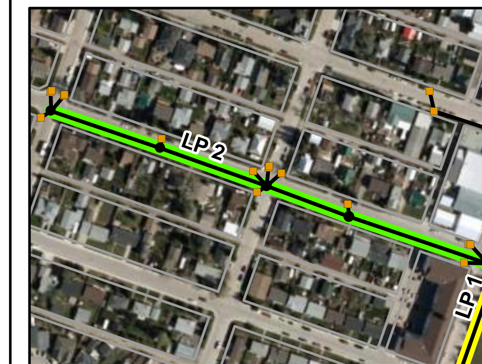


FIGURE A.3
EXISTING CONDITIONS - LP 2
5 YR 1 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

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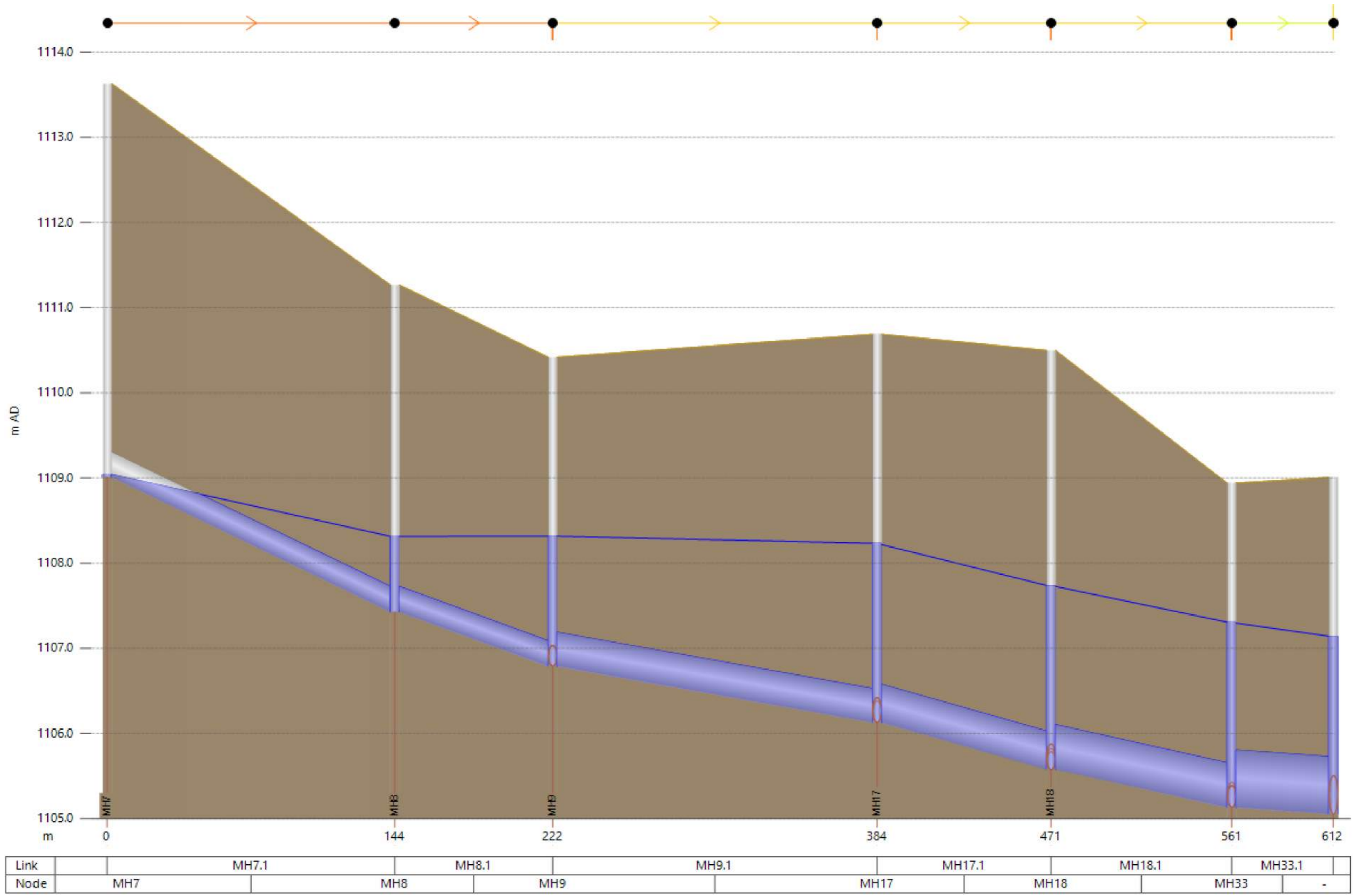


Legend

Existing - Water Level

Ground Elevation

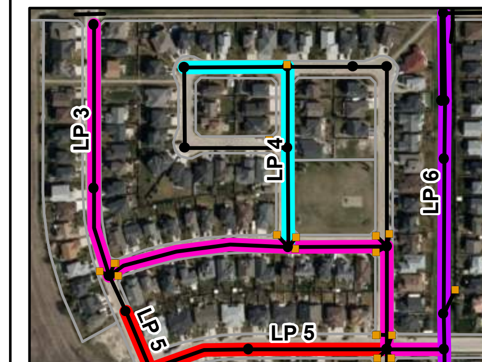
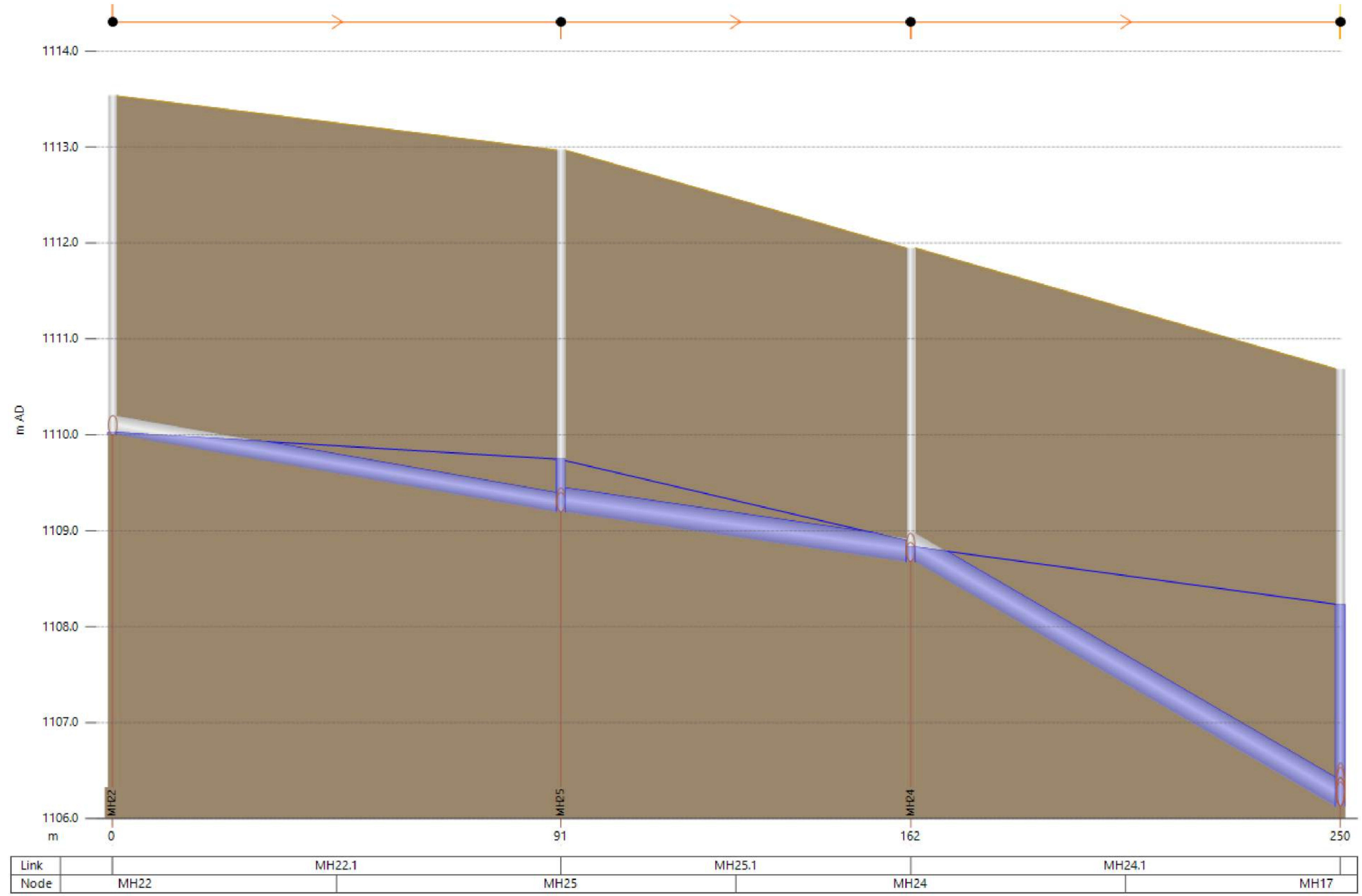


FIGURE A.4
EXISTING CONDITIONS - LP 3
5 YR 1 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN



Legend

- Existing - Water Level
- Ground Elevation

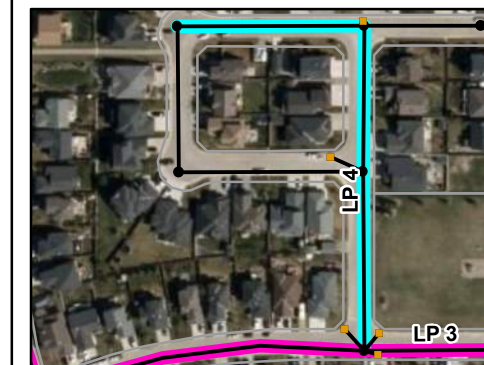


FIGURE A.5
EXISTING CONDITIONS - LP 4
5 YR 1 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

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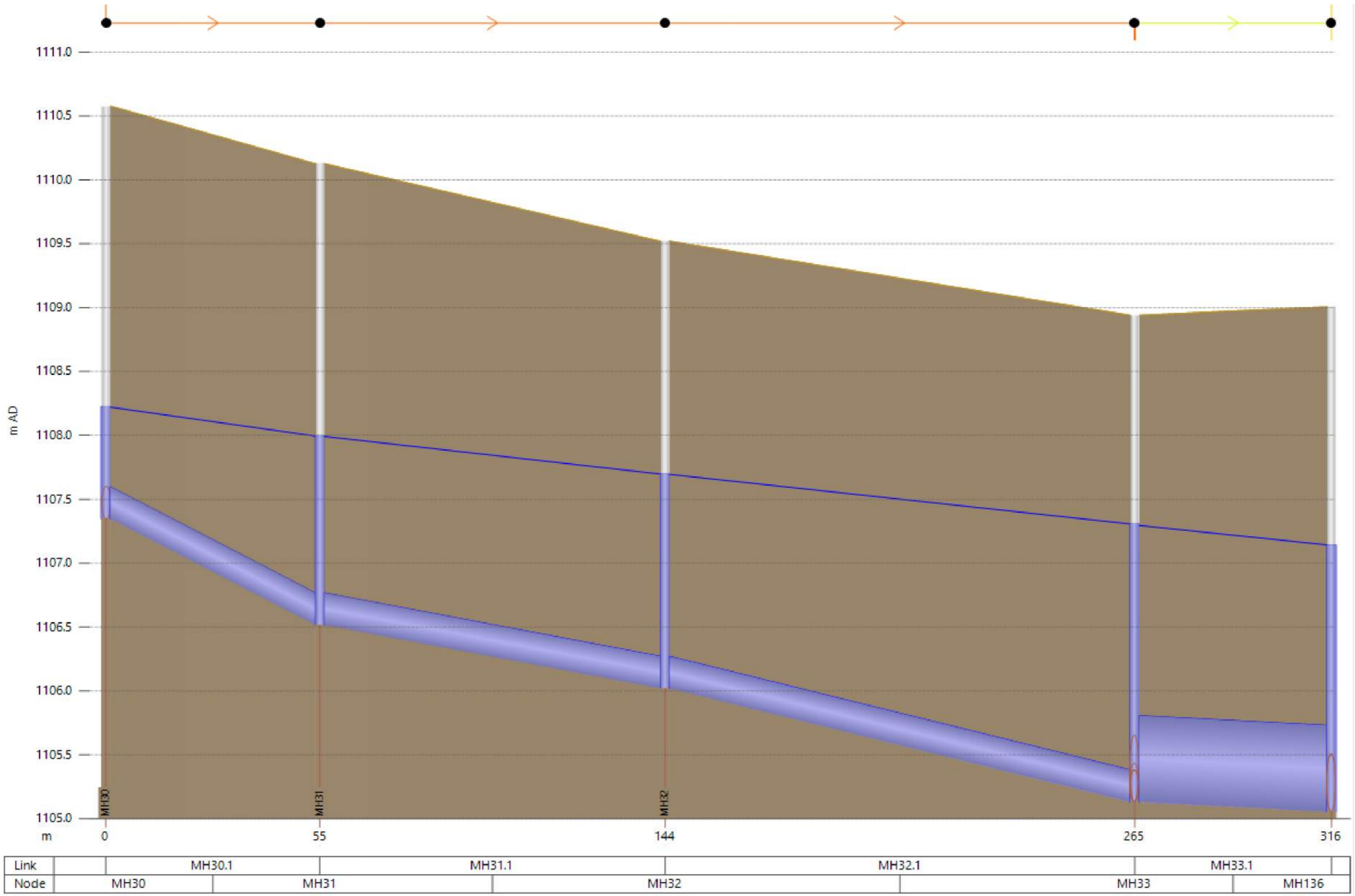
ISL



Legend

Existing - Water Level

Ground Elevation

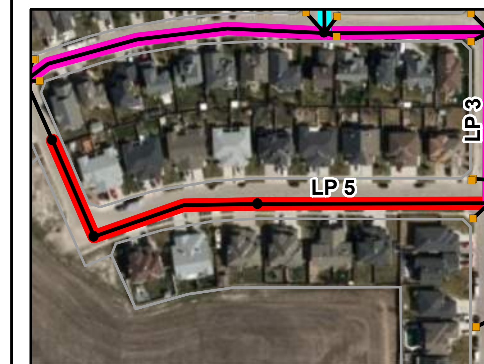


FIGURE A.6
EXISTING CONDITIONS - LP 5
5 YR 1 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

Document: H:\27309 - Supplemental\02_CADD\251_Figures\01_Report Figures\Appendix A\Figure A.6_LP 5.mxd
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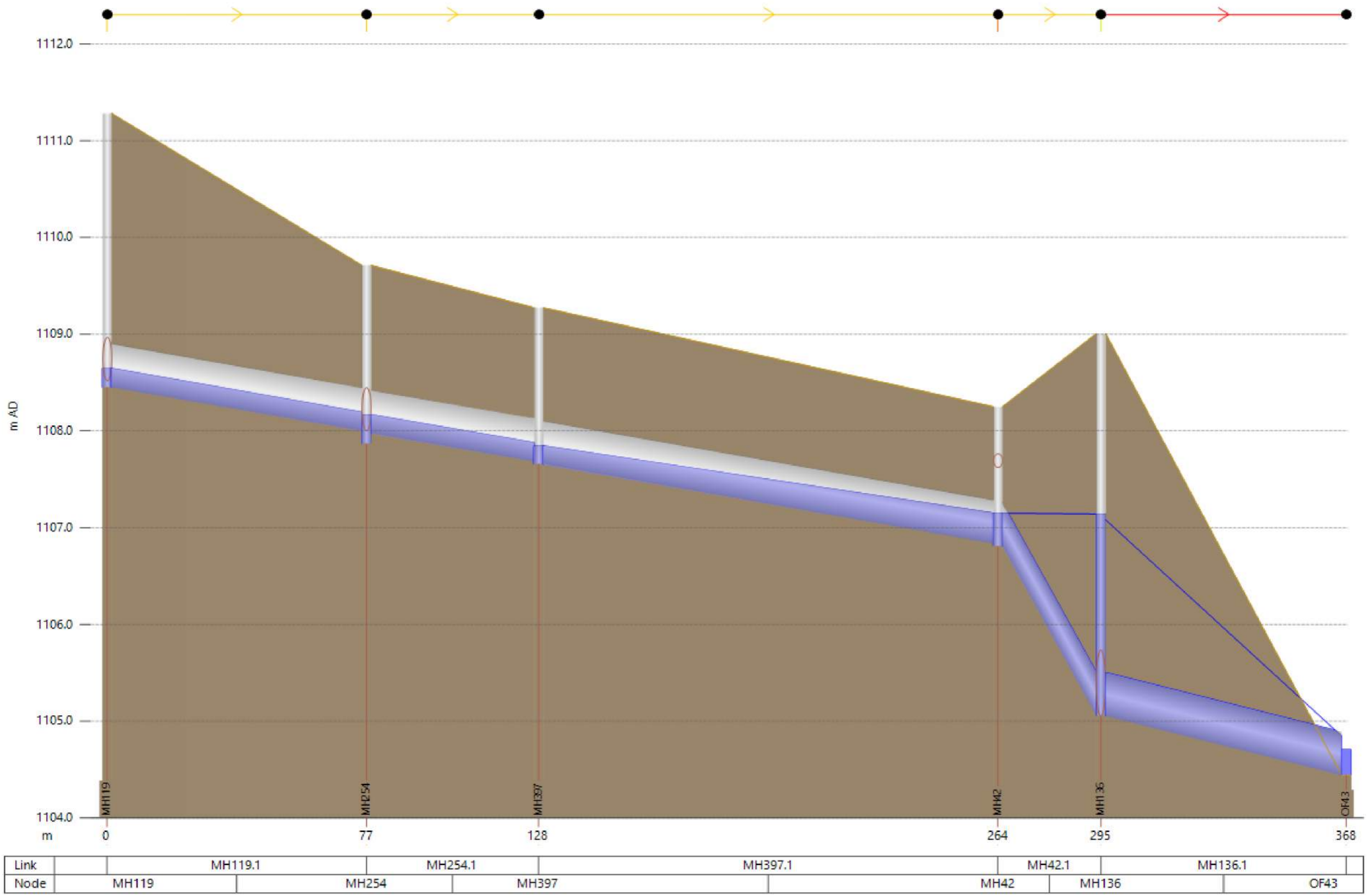

Legend

Existing - Water Level

Ground Elevation

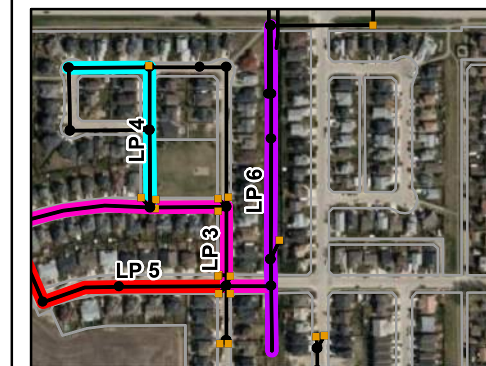

FIGURE A.7
EXISTING CONDITIONS - LP 6
5 YR 1 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

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Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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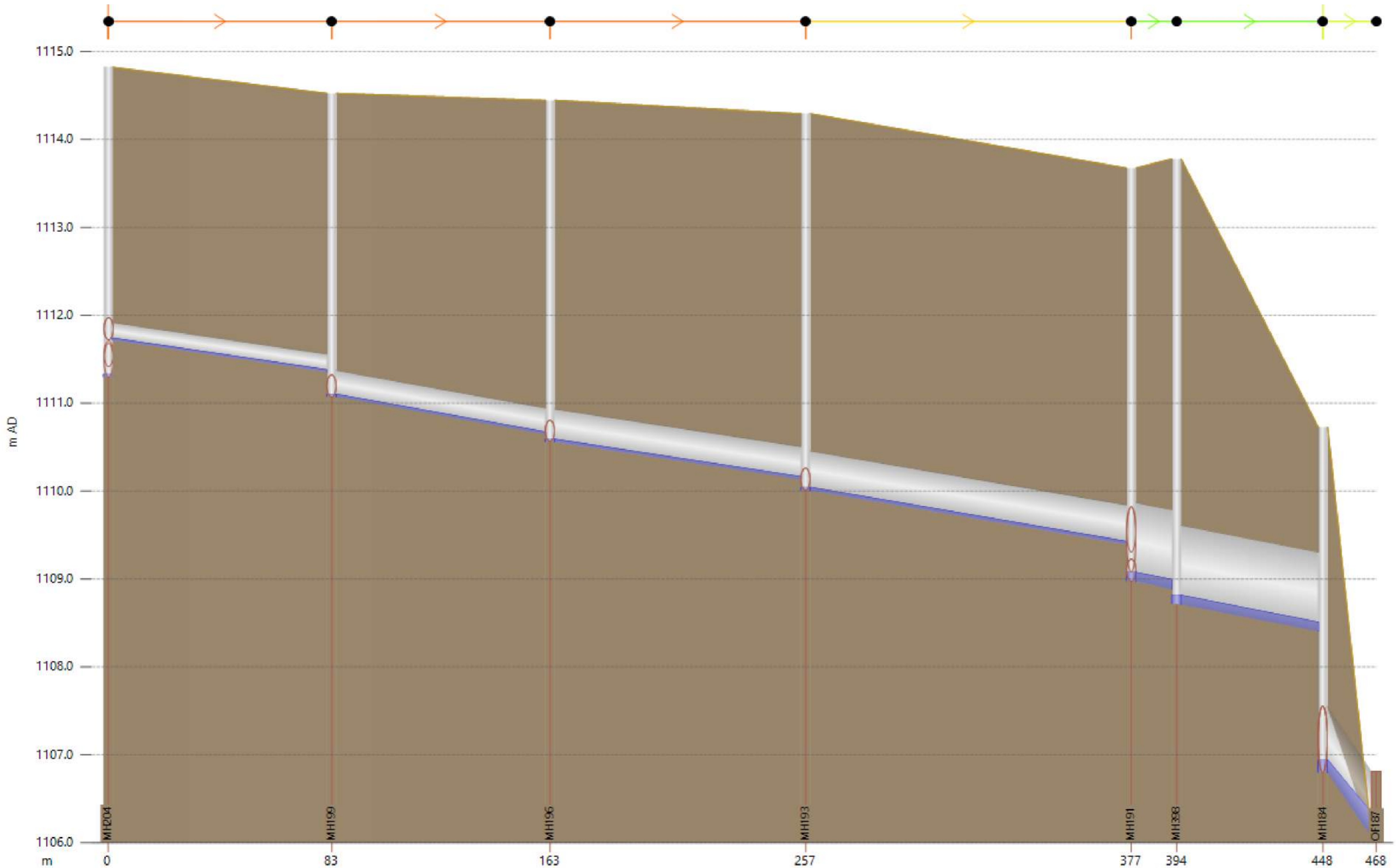

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Node	MH204	MH199	MH196	MH193	MH191	MH398	MH184	-

Legend

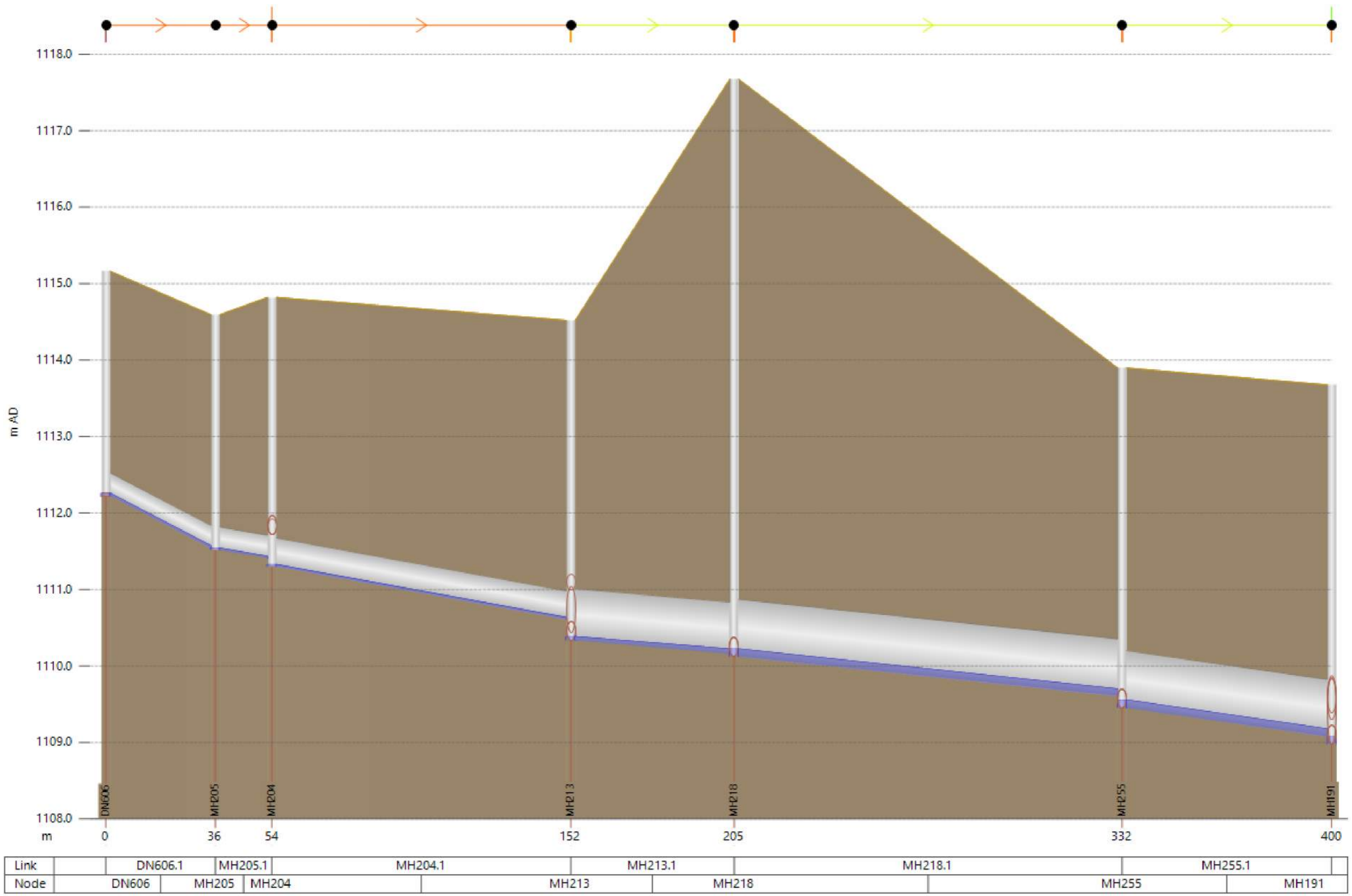
Existing - Water Level

Ground Elevation

FIGURE A.8
EXISTING CONDITIONS - LP 7
5 YR 1 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

Document: H:\27309 - Supplemental\02_CADD\251_Figures\01_Report Figures\Appendix A\Figure A.8_LP 7.mxd

Date: 4/1/2020



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Existing - Water Level

Ground Elevation

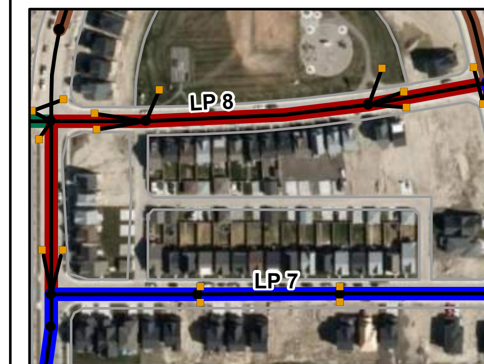

FIGURE A.9
EXISTING CONDITIONS - LP 8
5 YR 1 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

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Date: 4/1/2020 Document: H:\27309 - Supplemental\02_CADD\251_Figures\01_Report Figures\Appendix A\Figure A.9_LP 8.mxd

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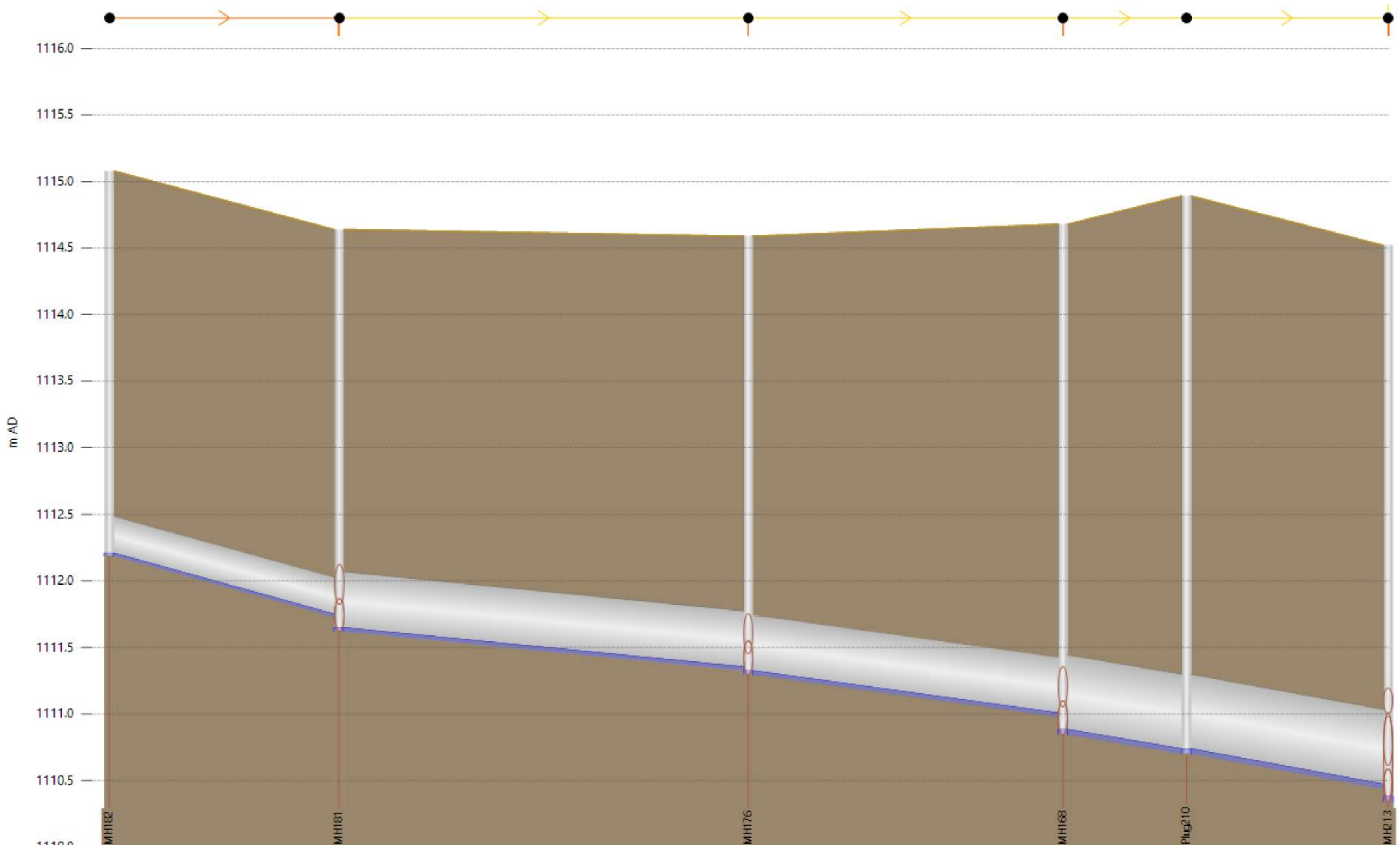

Link	MH182.1	MH181.1	MH176.1	MH168.1	Plug210.1
Node	MH182 / MH181	MH176	MH168	Plug210	MH213

Legend

- Existing - Water Level
- Ground Elevation

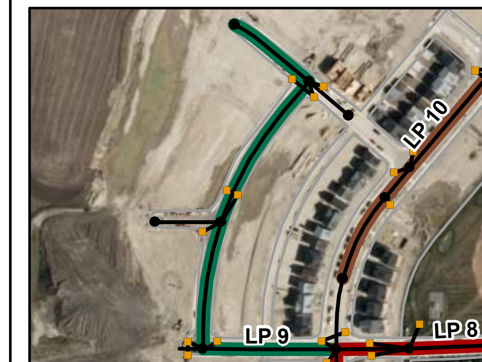

FIGURE A.10
EXISTING CONDITIONS - LP 9
5 YR 1 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

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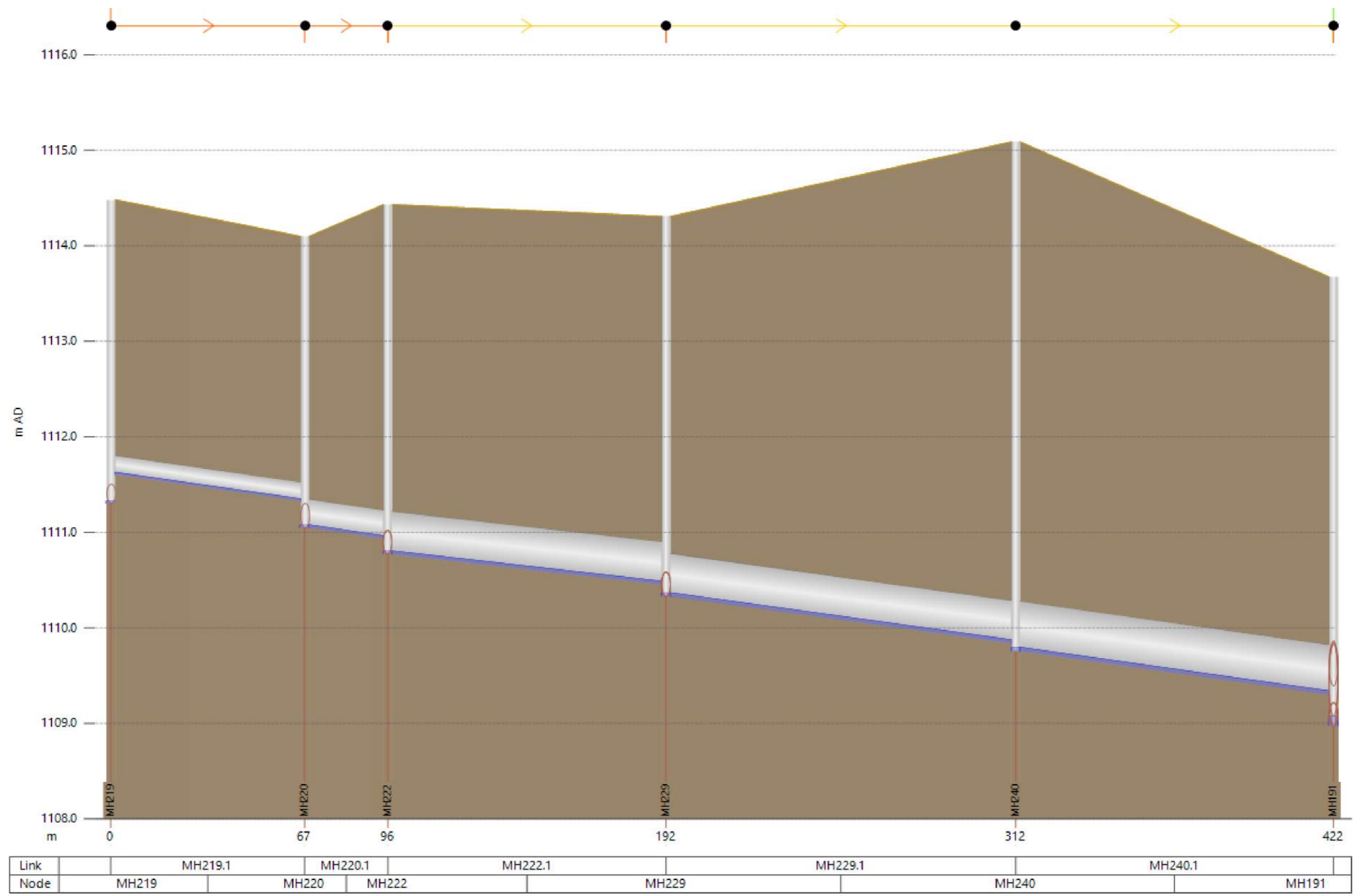
Date: 4/1/2020



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Existing - Water Level

Ground Elevation

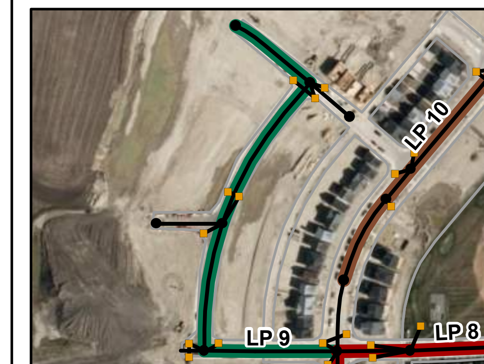

FIGURE A.11
EXISTING CONDITIONS - LP 10
5 YR 1 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

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Date: 4/1/2020

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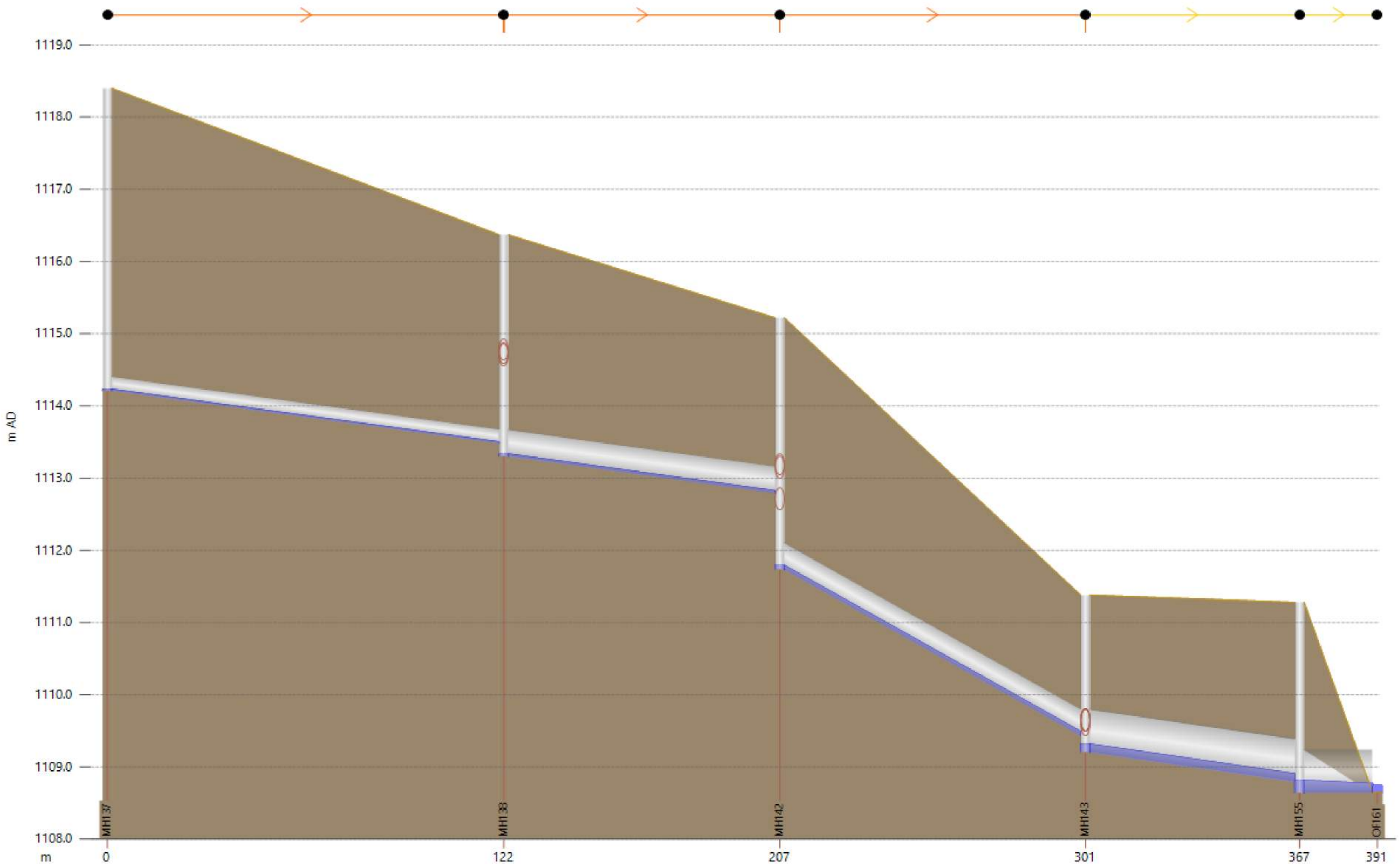

Link	MH137.1	MH138.1	MH142.1	MH143.1	MH155.1	
Node	MH137	MH138	MH142	MH143	MH155	-

Legend

Existing - Water Level

Ground Elevation

FIGURE A.12
EXISTING CONDITIONS - LP 11
5 YR 1 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

THIS is CROSSFIELD EST 1907

ISL

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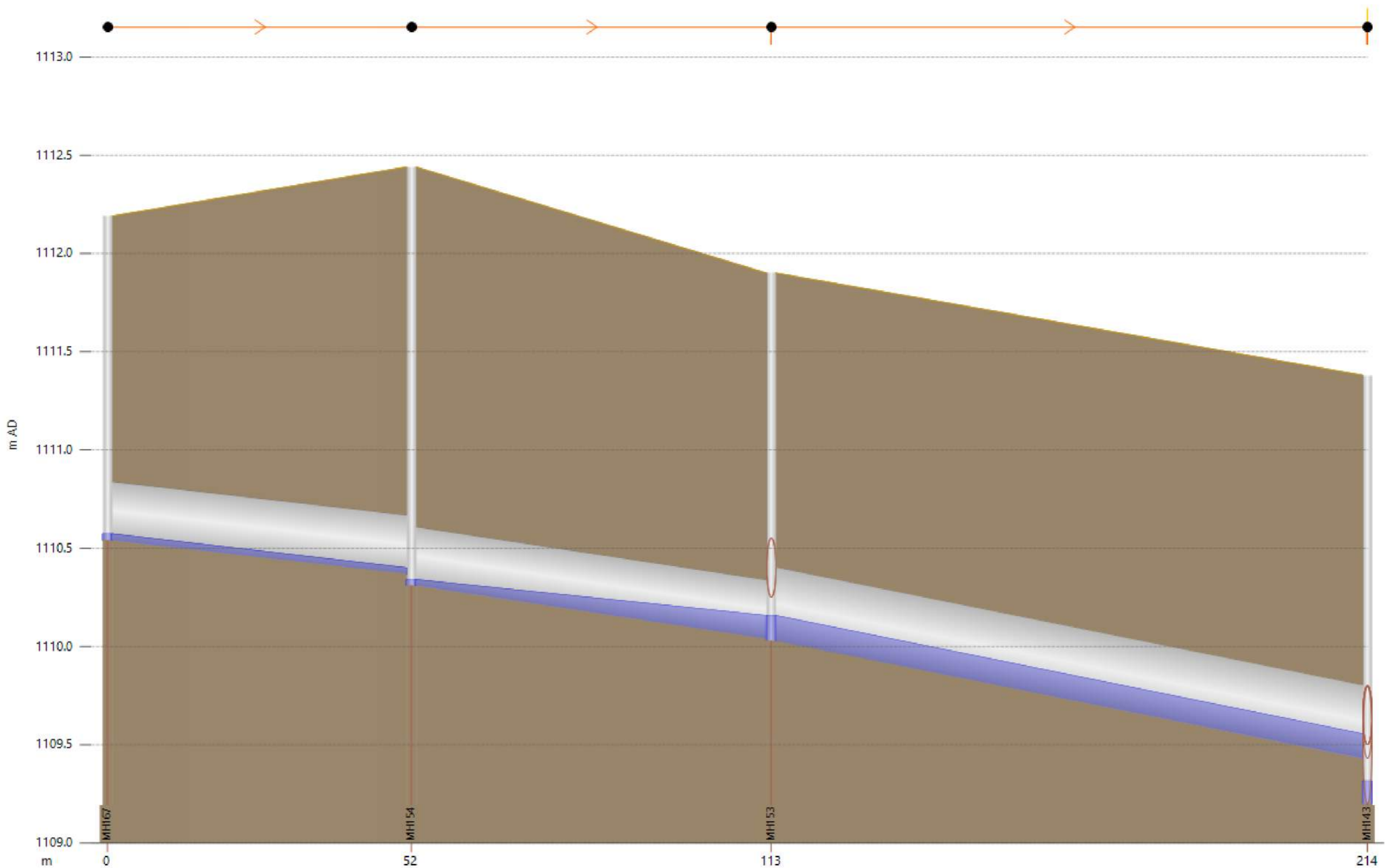
Date: 4/1/2020

Legend

Existing - Water Level

Ground Elevation



Link	MH167.1	MH154.1	MH153.1
Node	MH167 / MH154	MH153	MH143

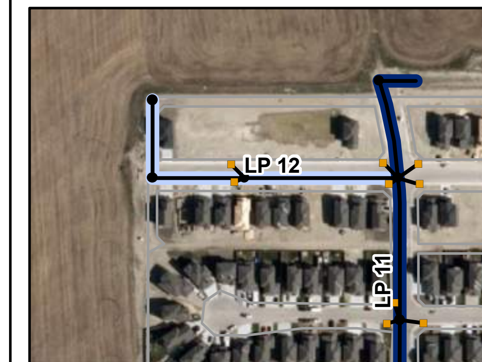


FIGURE A.13
EXISTING CONDITIONS - LP 12
5 YR 1 HR DESIGN STORM
CROSSFIELD STORMWATER
MASTER PLAN

APPENDIX
Detailed Cost Estimates

B

Table B1: Cost (Existing Upgrades)
Stormwater Master Plan
Town of Crossfield

ID	Description	Items	Quantity	Units	Unit Cost	Sub-Total	Contingency 30%	Engineering 15%	Total Cost
1	Implement catchbasin on Limit Avenue, west of Harrison Street, and tie to existing culvert to the west.	Twin C Catchbasin	1	Item	$ 11,000	$ 11,000	$ 3,300	$ 1,650	$ 16,000
		250 mm Catchbasin Lead	30	m	$ 380	$ 11,000	$ 3,300	$ 1,650	$ 16,000
		Pavement Rehabilitation	30	m	$ 1,125	$ 34,000	$ 10,200	$ 5,100	$ 49,000
		Curb and Gutter Rehabilitation	30	m	$ 200	$ 6,000	$ 1,800	$ 900	$ 9,000
					Sub-Total:	**$ 62,000**	**$ 18,600**	**$ 9,300**	**$ 90,000**
2	Upgrade the existing culvert on Ross Street to 600 mm.	600 mm Culvert	19	m	$ 740	$ 14,000	$ 4,200	$ 2,100	$ 20,000
		Existing Pipe Removal	19	m	$ 220	$ 4,000	$ 1,200	$ 600	$ 6,000
					Sub-Total:	**$ 18,000**	**$ 5,400**	**$ 2,700**	**$ 26,000**
3	No upgrades recommended for this area of concern as it is within a wetland.								
4	Costing not provided as these upgrades are currently in progress.								
5	Upgrade the existing pipes on Nanton Avenue between Ross Street and Railway Street to 525 mm.	525 mm Gravity Sewer	90	m	$ 650	$ 59,000	$ 17,700	$ 8,850	$ 86,000
		Pavement Rehabilitation	90	m	$ 1,125	$ 101,000	$ 30,300	$ 15,150	$ 146,000
		Existing Pipe Removal	90	m	$ 195	$ 18,000	$ 5,400	$ 2,700	$ 26,000
					Sub-Total:	**$ 178,000**	**$ 53,400**	**$ 26,700**	**$ 258,000**
6	Upgrade the existing catchbasinleads on Stevens Place South of Smith Avenue to 450 mm.	450 mm Gravity Sewer	30	m	$ 575	$ 17,000	$ 5,100	$ 2,550	$ 25,000
		Pavement Rehabilitation	30	m	$ 1,125	$ 34,000	$ 10,200	$ 5,100	$ 49,000
		Existing Pipe Removal	30	m	$ 175	$ 5,000	$ 1,500	$ 750	$ 7,000
					Sub-Total:	**$ 56,000**	**$ 16,800**	**$ 8,400**	**$ 81,000**
7	Upgrade the pipe in the easement west of Stevens Place to 675 mm.	675 mm Gravity Sewer	73	m	$ 830	$ 61,000	$ 18,300	$ 9,150	$ 88,000
		Existing Pipe Removal	73	m	$ 250	$ 18,000	$ 5,400	$ 2,700	$ 26,000
					Sub-Total:	**$ 79,000**	**$ 23,700**	**$ 11,850**	**$ 115,000**
8	No upgrades recommended for this area of concern as it is on private property.								
9	Upgrade the pipes at the intersection of Mossip Avenue and Harrison Street to 600 mm.	600 mm Gravity Sewer	72	m	$ 740	$ 53,000	$ 15,900	$ 7,950	$ 77,000
		Pavement Rehabilitation	40	m	$ 1,125	$ 45,000	$ 13,500	$ 6,750	$ 65,000
		Existing Pipe Removal	40	m	$ 220	$ 9,000	$ 2,700	$ 1,350	$ 13,000
					Sub-Total:	**$ 107,000**	**$ 32,100**	**$ 16,050**	**$ 155,000**
10	Costing not provided as these upgrades are currently in progress.								
					Total	**$ 500,000**	**$ 150,000**	**$ 75,000**	**$ 725,000**

Table B2: Pond Cost Estimates for Recommended Stormwater System
Stormwater Master Plan
Town of Crossfield

Pond ID	Active Pond Volume (m^3)	Permanent Pool Volume (m^3)	Stripping Cost	Excavation Cost	Landscaping Cost	Outlet Control Structure Cost	Sub-Total (Rounded)	Contingency (Rounded) 30%	Engineering Fees (Rounded) 15%	Total Cost (Rounded)
Bow_Pond-1-2	101,000	116,000	$351,000	$3,255,000	$33,400	$180,000	$3,819,000	$1,146,000	$745,000	**$5,710,000**
Bow_Pond-3	49,000	53,000	$174,000	$1,530,000	$22,800	$180,000	$1,907,000	$572,000	$372,000	**$2,850,000**
Bow_Pond-4	48,000	51,000	$169,000	$1,485,000	$22,400	$180,000	$1,856,000	$557,000	$362,000	**$2,775,000**
Bow_Pond-5	7,000	7,000	$33,000	$210,000	$8,600	$180,000	$432,000	$130,000	$84,000	**$645,000**
Bow_Pond-6	27,000	26,000	$94,000	$795,000	$16,000	$180,000	$1,085,000	$326,000	$212,000	**$1,625,000**
Bow_Pond-7	54,000	60,000	$194,000	$1,710,000	$24,200	$180,000	$2,108,000	$632,000	$411,000	**$3,150,000**
Bow_Pond-8	38,000	41,000	$139,000	$1,185,000	$20,200	$180,000	$1,524,000	$457,000	$297,000	**$2,280,000**
Bow_Pond-9	73,000	80,000	$251,000	$2,295,000	$27,800	$180,000	$2,754,000	$826,000	$537,000	**$4,115,000**
Bow_Pond-10	49,000	53,000	$173,000	$1,530,000	$22,800	$180,000	$1,906,000	$572,000	$372,000	**$2,850,000**
Bow_Pond-11	52,000	58,000	$188,000	$1,650,000	$23,600	$180,000	$2,042,000	$613,000	$398,000	**$3,055,000**
RedDeer_Pond-1	16,000	34,000	$120,000	$750,000	$18,400	$180,000	$1,068,000	$320,000	$208,000	**$1,595,000**
RedDeer_Pond-2-3	42,000	43,000	$145,000	$1,275,000	$20,400	$180,000	$1,620,000	$486,000	$316,000	**$2,420,000**
RedDeer_Pond-4	22,000	22,000	$82,000	$660,000	$14,800	$180,000	$937,000	$281,000	$183,000	**$1,400,000**
RedDeer_Pond-5	28,000	28,000	$99,000	$840,000	$16,400	$180,000	$1,135,000	$341,000	$221,000	**$1,695,000**
RedDeer_Pond-6	45,000	47,000	$157,000	$1,380,000	$21,600	$180,000	$1,739,000	$522,000	$339,000	**$2,600,000**
RedDeer_Pond-7	103,000	116,000	$351,000	$3,285,000	$33,200	$180,000	$3,849,000	$1,155,000	$751,000	**$5,755,000**
		Total (Rounded):	**$2,720,000**	**$23,835,000**	**$345,000**	**$2,880,000**	**$29,780,000**	**$8,935,000**	**$5,810,000**	**$44,520,000**

Assumptions:

Mobilization and demobilization costs not included.

Unit prices:

Excavation	*$15.00*	*/m^3*
Stripping	*$5.00*	*/m^2*
Landscaping	*$2.00*	*/m^2*
Outlet Control Structure	*$180,000.00*	*/unit*
Fill Cost	*$25.00*	*/m^3*

Table B3: Conveyance Cost Estimates for Recommended Stormwater System - Future Conditions
Stormwater Master Plan
Town of Crossfield

Item	Quantity	Units	Unit Cost	Sub-Total (Rounded)	Contingency (30%) (Rounded)	Engineering (15%) (Rounded)	Total Cost (Rounded)
300mm Trunk Sewer	911	Metres	$415	$378,000	$113,000	$74,000	**$565,000**
375mm Trunk Sewer	4386	Metres	$475	$2,083,000	$625,000	$406,000	**$3,115,000**
525mm Trunk Sewer	1220	Metres	$650	$793,000	$238,000	$155,000	**$1,185,000**
600mm Trunk Sewer	1180	Metres	$740	$873,000	$262,000	$170,000	**$1,305,000**
750mm Trunk Sewer	537	Metres	$1,000	$537,000	$161,000	$105,000	**$805,000**
300mm Flared End	2	Items	$8,500	$17,000	$5,000	$3,000	**$25,000**
375mm Flared End	3	Items	$8,750	$26,000	$8,000	$5,000	**$40,000**
525mm Flared End	1	Items	$9,250	$9,000	$3,000	$2,000	**$15,000**
600mm Flared End	4	Items	$9,500	$38,000	$11,000	$7,000	**$55,000**
750mm Flared End	1	Items	$10,000	$10,000	$3,000	$2,000	**$15,000**
Flap Gate	11	Items	$25,000	$275,000	$83,000	$54,000	**$410,000**
			Total (Rounded):	$5,040,000	$1,510,000	$985,000	$7,535,000

Assumptions:

Mobilization and demobilization costs not included.

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