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April 1, 2022

Our Reference: 16005

City of Humboldt
715 Main Street
Humboldt, Saskatchewan
S0K 2A0

Attention: Peter Bergquist, A.Sc.T. – Director of Public Works and Utilities

Dear P. Bergquist:

Reference: City-Wide Heavy Rainfall Stormwater Modelling Assessment – Draft Report

Enclosed is the Draft Report for the City-Wide Heavy Rainfall Stormwater Modelling Assessment. We trust that it meets your needs and expectations.

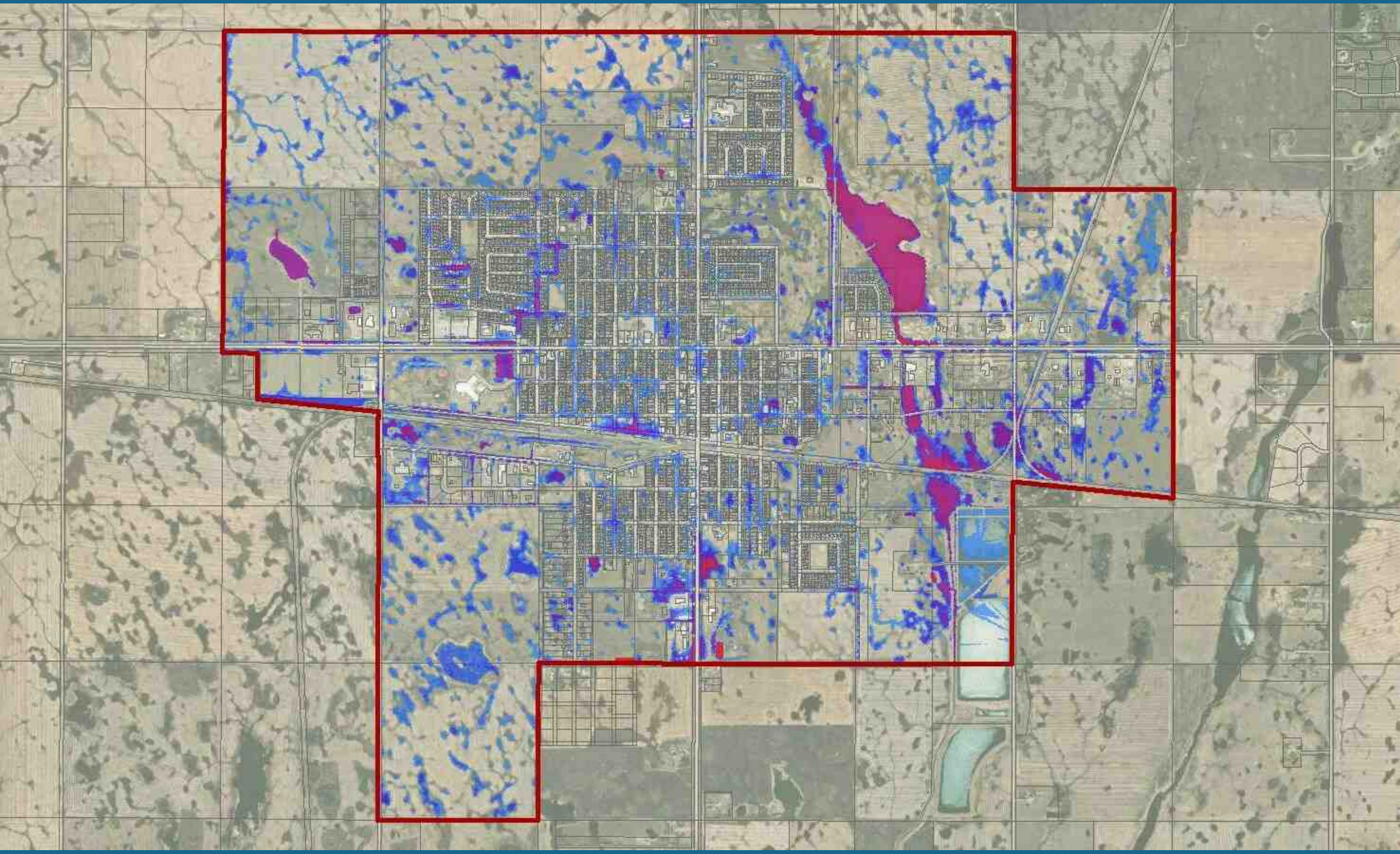
The Stormwater Modelling Assessment includes an evaluation of the City of Humboldt's current stormwater conveyance infrastructure capacity and the City's future needs to allow the City to grow without exacerbating existing stormwater system issues. A robust hydrodynamic InfoWorks ICM 1D-2D model was constructed to enable the comprehensive assessment of the stormwater system.

The project was initiated to ensure sound stormwater system planning and carry forward the work and findings of the City's previous stormwater studies and drainage improvement efforts. This project intends to establish a framework for improvements to the City's stormwater infrastructure to be made and adopted in conjunction with the City's plans for growth and quality of life improvements.

We sincerely appreciate the opportunity to undertake this project on behalf of the City of Humboldt. Should you have any questions or concerns, please do not hesitate to contact the undersigned at 306.361.2100.

Sincerely,

Jeremie Bougeois, P.Eng.
Senior Municipal/Water Resources Engineer



City-Wide Heavy Rainfall Stormwater Modelling Assessment

City of Humboldt

REPORT

April 2022

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.

Proudly certified as a leader in quality management under Engineers and Geoscientists BC's OQM Program from 2014 to 2021.

Corporate Authorization

This document entitled "City-Wide Heavy Rainfall Stormwater Modelling Assessment" has been prepared by ISL Engineering and Land Services Ltd. (ISL) for the use of City of Humboldt. The information and data provided herein represent ISL's professional judgment at the time of preparation. ISL denies any liability whatsoever to any other parties who may obtain this report and use it, or any of its contents, without prior written consent from ISL.

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General Manager, Water and Environment

Executive Summary

Background

The City of Humboldt (the City) retained ISL Engineering and Land Services Ltd. (ISL) to complete a City-Wide Heavy Rainfall Stormwater Modelling Assessment (SMA). This SMA includes an assessment of the City's current stormwater infrastructure capacity and the City'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 for existing system upgrades and future system upgrades or expansions to accommodate future growth. This project intends to provide a road map to the City for assessing the needs of and options for existing system upgrades as well as the capability of the infrastructure to accommodate new development.

The objectives of completing the SMA include:

- Assessing existing drainage conditions and determining design criteria for the stormwater drainage system, including runoff rates.
- Providing an inventory of and analyzing existing natural drainage conveyance.
- Determining if any upgrades are required to the existing system to properly meet the municipality's needs and allow future growth to occur.
- Developing stormwater infrastructure plans to manage increased runoff resulting from future development.
- Producing a stormwater management assessment that uses best management practices to minimize the effect on the natural hydrological and hydro-geological regimes and ensure the planned stormwater management system meets regulatory authority requirements.
- Providing a framework for future development and a quality control benchmark for future system design and Stormwater Management Reports (SWMRs).
- Providing cost estimates related to required infrastructure upgrades.

Conclusions

Existing System

Typically, the minor (piped) system is sized based on the 1:5 year event; however, a substantial portion of the system is considered under capacity during this event with surcharging to the surface highlighted at a large number of locations throughout the City. Similarly, many of the City's main trunk sewers are under capacity during the 1:2 year event, with various locations showing surcharging to the surface. Most notably, stretches of 2 Avenue, 3 Avenue, 5 Avenue, 6 Avenue, and 17 Street experience surcharging to the surface based on the model results and localized areas throughout the City.

The results highlight numerous areas of concern that have been observed by the City, including the area around Carl Schenn Park, the intersection of 6 Avenue and 2 Street, and the intersection of 5 Avenue and 11 Street.

The major (overland) system was assessed using the 24-hour duration storms for the 1:2, 1:5, 1:10, 1:25, and 1:100 year rainfall events. This was done to highlight the changes in the extent of surface ponding within the City and to identify building impacts under each of these event frequencies. These surface ponding areas largely correlate to the surcharging locations shown in the 1D model results, with additional ponding areas highlighted where the catchbasin inlet capacity may limit flows to the minor system and low-lying areas where an inlet to the minor system may not currently exist.

Future System

A pre-development runoff rate is required to establish an allowable release runoff rate for new development and thus properly size any future stormwater detention facilities (SWDF) in the City. Doing so helps to minimize the impact of increased runoff due to future developments on the environment by controlling flows through stormwater ponds.

The 2021 City of Saskatoon Design and Development Standards Manual recommends that SWDFs have adequate drainage outlets so that water levels return to their NWL within 48 hours after a rainfall event has ended. When these criteria are applied to the various SWDFs discussed within this SMA and their respective storage volume requirements, an average release rate of 3.0 L/s/ha was developed. A more stringent release rate of 2.1 L/s/ha could also be adopted to reduce downstream stormwater impacts from the City.

Recommendations

Several recommendations were made based on the findings of this study. This includes proposed upgrades within the existing system and future system considerations for future development areas.

Major Drainage Improvements for Existing City Areas

The proposed major drainage upgrades for flood-prone areas of the City are summarized as follows:

- Major Drainage Concept No. 1: Carl Shenn Park SWDF
  - This upgrade involves a dry pond and proposed sewer connections to the existing stormwater system on Barnes Crescent, Dust Crescent, and 12 Avenue. The estimated cost of this upgrade is $1.29 million.

- Major Drainage Concept No. 2: 16 Street North SWDF
  - This upgrade includes twinning, upsizing, redirecting, and extending the existing sewer along 16 Street and a proposed retention facility (dry pond) on the north end of 16 Street. This upgrade includes upgrading existing catchbasins along 16 Street and installing additional catchbasins at 9 Avenue and 16 Street. The estimated cost of this upgrade is $6.64 million.

- Major Drainage Concept No. 3: 5 Avenue SWDF
  - This upgrade includes the implementation of a dry pond between 5 Avenue and 6 Avenue and between 11 Street and 13 Street. The dry pond is connected to the 5 Avenue sewer at 11 Street. The estimated cost of this upgrade is $899,000.

- Major Drainage Concept No. 4: 6 Avenue
    - This upgrade involves a drainage ditch east of 1 Street from 6 Avenue to the existing south of 7 Avenue and improvements to the existing ditch east to the existing channel. The existing sewer along 6 Avenue is to be upgraded and extended east to discharge to the proposed ditch. A new culvert is proposed to connect the improved ditch across 12 Street and replace the existing culvert. The estimated cost of this upgrade is $2.33 million.

- Major Drainage Concept No. 5: St. Dominic School
    - This upgrade includes a new sewer along 12 Street and 1 Avenue from 2 Avenue to 11 Street and 1 Avenue from 11 Street to a proposed dry pond south of St. Dominic School. The dry pond outlets via a pipe to the existing ditch along the City's south boundary west of the existing 1 Avenue S outfall (OF262). New connections at Main Street are proposed to connect the existing ditches to the proposed dry pond and a culvert to tie the west ditch along Main Street to the dry pond. Additionally, catchbasins are proposed at 1 Avenue and 11 Street. A new drainage ditch is proposed along 10 Street and Saskatchewan Avenue south of 1 Avenue with a tie-in to the proposed dry pond. The estimated cost of this upgrade is $5.42 million.

Stormwater Management for Future Growth

A pre-development runoff rate is required to establish an allowable release runoff rate for new development and thus properly size any future stormwater management facilities (SWDF) in the City. Doing so helps to minimize the impact of increased runoff from future developments on the downstream watershed and environment by controlling flows through stormwater ponds.

As there is no existing Stormwater Master Plan or Master Drainage Plan for the area specifying an allowable release rate from future development, a pre-development runoff rate was estimated. A maximum recommended SWDF release rate of 3.0 L/s/ha of service/catchment area to meet the 48-hour drawdown time requirements of the City of Saskatoon's Stormwater Design and Development Guidelines (City of Saskatoon, 2021).

The Comparative Basin Formula determined an alternate pre-development release rate for the City of Humboldt. A pre-development release rate of 2.0 L/s/ha was calculated and could be adopted to provide future downstream benefits and reduce the runoff conveyance capacity requirements for the City.

Conceptual-level designs for locations, sizes, and connectivity of future SWDFs for storing, managing and attenuating runoff from nine (9) future development areas (FDA) totalling 370 ha of city growth were developed. Cost estimates and basic design parameters for dry pond and wet pond (where suitable) SWDFs were also presented.

Modelling of the East Flood Control Ditch (EFCD) was conducted and found it to generally meet the existing peak runoff discharges expected from the City, although a degree of spillover and temporary flooding of adjacent, privately owned farm/agricultural land is expected when the channel drains runoff from major rainfall events. Significant increases in direct runoff discharge (non-controlled/attenuated) to the EFCD are not recommended unless attenuation in its upper reaches within the city limits is further increased or upgrades in the conveyance capacity of the channel are made between the City and Humboldt Lake.

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ABBREVIATIONS

Acronym	Meaning
ASL	above sea level
BMP	best management practices
CETV	Canadian Environmental Technology Verification
CONC	concrete pipe
CSP	corrugated steel pipe
GIS	geographic information system
HDPE	high-density polyethylene pipe
HGL	hydraulic grade line
HWL	high water level
IDF	intensity-duration-frequency
ISC	Information Services Corporation
ISL	ISL Engineering and Land Services Ltd.
LiDAR	light detection and ranging
LID	low impact development
LP	longitudinal profile
NWL	normal water level
OCP	The City of Humboldt Official Community Plan
PVC	polyvinyl chloride pipe
QA/QC	quality assurance/quality control
RCP	reinforced concrete pipe
SMA	Stormwater Modelling Assessment
STL	steel pipe
SWDF	Stormwater Detention Facility
SWMR	Stormwater Management Report
TRCA	Toronto and Region Authority
TSS	total suspended solids
1D	one-dimensional
2D	two-dimensional

UNITS

Unit	Meaning
ha	hectares
hr	hours
km^2	square kilometres
L/s	litres per second
L/s/ha	litres per second per hectare
m	metres
m^2	square metres
m^3	cubic metres
mm	millimetres
mm/hr	millimetres per hour
m/m	vertical metres per horizontal metres
m/s	metres per second
m3/s	cubic metres per second
yr	year

1.0 Introduction

The City of Humboldt (the City) retained ISL Engineering and Land Services Ltd. (ISL) to complete a City-Wide Heavy Rainfall Stormwater Modelling Assessment (SMA). This SMA includes an assessment of the City's current stormwater infrastructure capacity, a review of the City's surface drainage and flooding, conceptual level mitigation and improvements works, and recommendations for servicing the City's future stormwater 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 for existing system upgrades and future system upgrades or expansions to accommodate future growth. This project intends to provide a road map to the City for assessing the needs of and options for existing system upgrades as well as the capability of the infrastructure to accommodate new development.

1.1 Background

The City of Humboldt is one of Saskatchewan's newest and fastest-growing cities, with approximately 6,000 current residents and is expected to continue growing over the next 30 years. Humboldt experiences persistent stormwater management issues due to its typically flatter topography and grade that restricts runoff routing options and limited past consideration for proper overland surface drainage design.

These stormwater drainage issues are not unique to Humboldt and are felt by cities and municipalities across the prairies. It is expected that these issues will become more frequent and severe in the future due to the predicted impacts of climate change and additional municipal growth/densification.

In recent years, the City has experienced several major rainfall events that result in widespread and significant flooding areas. Many ponding locations result in depths up to 0.6 m resulting in extensive public and private property damage. These surface flooding events also create additional strain and property damage from excess runoff inflow/infiltration entering the City's sanitary sewer system. Additionally, previous stormwater modelling efforts and reviews of Humboldt's existing stormwater management system identified that the existing stormwater pipes in many areas are under capacity for even a routine 1:2 year storm event.

The City sought assistance in allowing its community to grow without exacerbating these issues and perpetually dealing with surface flooding. This SMA is intended to update, improve upon, and carry forward the work and findings of the City's previous stormwater studies and drainage improvement efforts. It will also establish a framework for improvements to Humboldt's stormwater management infrastructure to be made and adopted within the City's plans for growth and quality of life improvements. The SMA also intends to support the City's endeavours to secure grant funding for stormwater improvement projects to reduce the impacts of stormwater events on both public and private property.

1.2 Purpose of Study

The objectives of completing the SMA include:

- Assessing existing drainage conditions and determining design criteria for the stormwater drainage system, including runoff rates.
- Providing an inventory of and analyzing existing natural drainage conveyance.
- Determining upgrades that assist/improve the existing system's capacity to properly meet the municipality's needs and allow future growth.
- Developing stormwater infrastructure plans to manage increased runoff resulting from future development.
- Producing a stormwater management assessment that uses best management practices to minimize the effect on the natural hydrological and hydro-geological regimes and minimize downstream impacts of stormwater drainage from the City.
- Providing a framework for future development and a quality control benchmark for future system design and Stormwater Management Reports (SWMRs).
- Providing cost estimates related to required infrastructure upgrades.

2.0 Study Area

2.1 Location

The City of Humboldt is centrally located in Saskatchewan, 112 km east of Saskatoon, at Highways 5 and Highway 20. The City is surrounded by the Rural Municipality of Humboldt No. 370. The City was established in 1875 and is located along the Canadian National (CN) Railway line that connects the cities of Edmonton, Alberta and Winnipeg, Manitoba. The study area for the SMA encompasses approximately 1,400 ha of land within the City's municipal boundary. The study area is shown in Figure 2.1.

The City's above sea level (ASL) elevations range between approximately 560 m in the City's northwest corner and 575 m in the west-central area of the City. A topographic map of the City's boundary is provided in Figure 2.2. A detailed topographical map of the City's developed extents is provided in Figure 2.3.

A topographic rise generally follows 21 Street from north of Highway 5 to the northeast from the end of 21 Street divides the City between two drainage watersheds. In its northwest corner, a small portion of Humboldt's developed area naturally drains northwest towards the Waldsea/Deadmoose/Houghton Lakes basin within the Saskatchewan River Watershed. The remaining major portion of the City drains/slopes gradually southeastward of Humboldt Lake and onto the Qu'Appelle River Watershed. A map of Humboldt's placement within the major drainage basins of the province is shown in Figure 2.4.

2.2 Existing Land Use

The existing land uses within Humboldt generally consist of residential, commercial, industrial, community service, and open space areas. The development type influences stormwater runoff coefficients/imperviousness values and roughness coefficients; therefore, obtaining an appropriate classification was vital to represent stormwater runoff accurately. The City of Humboldt Official Community Plan (OCP) (Humboldt, 2016) outlines these existing and future land-use areas, shown in Figure 2.5. A summary of the existing land use types and areas is provided in Table 2.1. It should be noted that road and railway right-of-ways (ROWs) and areas that were not classified in the City's OCP are not included in the land-use area tabulations below.

Table 2.1: Existing Land Use Summary

Land Use	Area
	ha
Mobile Home Residential	4.33
Residential	223.42
City Centre Commercial	12.01
Highway Commercial	78.54
Industrial	69.65
Utilities and Infrastructure	56.20
Community Service	24.22
Parks, Recreation, and Open Space	124.96
Total	**468.36**

2.3 Future Land Use

The future land use scenario incorporates additional residential, commercial, industrial, and community service development. These additional land use areas are also based on the City's OCP (Humboldt, 2016) and are shown in Figure 2.5 and summarized in Table 2.2.

Table 2.2: Future Land Use Summary

Land Use	Area
	ha
Residential	245.11
Highway Commercial	18.45
Industrial	20.28
Community Service	11.60
Parks, Recreation, and Open Space	22.74
Total	**295.43**

The City's OCP also identifies potential future development areas outside of the City's current municipal boundary, which is shown in Figure 2.5 and summarized in Table 2.3.

Table 2.3: Potential Future Land Use Summary

Land Use	Area
	ha
Residential	173.03
Highway Commercial	71.22
Industrial	19.14
Total	**263.40**

3.0 Existing Stormwater System

The existing Humboldt stormwater system consists of both major and minor drainage systems. The major system consists primarily of overland drainage and conveys stormwater runoff that the minor system cannot immediately handle. The minor system includes any underground infrastructure, including the pipe network and associated structures.

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

- Surface (Overland) Drainage
  - Roads
  - Ditches/Swales
  - Overland Escape Routes
  - Natural Watercourses
- Storage Facilities
  - Ponds
  - Traplows

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

- Piped System
  - Gravity Sewers
  - Forcemains
- Lift Stations
- Catchbasins (Inlets and Leads)
- Manholes and Junctions
- Inlets
- Outfalls

Drainage components such as culverts, curbs and gutters, and roof leaders are considered part of both systems. 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.

Drainage within Humbodlt is mostly provided by curb and gutters that flow and drain to storm sewer systems. Most of Humboldt's existing storm sewers drain west to east and discharge to the Water Ridge Pond and the East Flood Control Ditch. The Water Ridge Pond and flood control ditch work together to attenuate the peak runoff flows from the City and convey it approximately 6.1 km south into Humboldt Lake.

Most of the highway commercial and industrial area on the City's east end is drained by roadside ditches and culverts that convey water west into the East Flood Control Ditch. The road ditches of Highway 20 leading south out of Humboldt provides an overland drainage outlet for the City's semi-developed south end.

A newer development in the City's northwest corner, north of Highway 5 and west of Peck Road, drains to a stormwater retention pond. This pond has no outlet due to its surrounding topography and being within the small portion of the City that drains to the northwest. Increased runoff from the City's northwest into the Waldsea/Deadmoose/Houghton Lakes drainage basins has not been allowed since 2008 due to a moratorium on drainage. This moratorium significantly limits the acceptable options for stormwater management for future city growth to the west and north of the existing developed areas.

3.1 Stormwater Conveyance System

Humboldt's existing minor (piped) stormwater network detailed regarding size and material is illustrated in Figures 3.1 and 3.2 and summarized below in Tables 3.1 and 3.2, respectively. It is noted that limited information was available for the minor system (for example, pipe inverts, material, installation year, and size). These gaps in the existing data stormwater system are shown in detail in the map books included in Appendix A. The assumptions that were made regarding data gaps are provided in Section 4.0.

Table 3.1: Minor Stormwater System Summary – Pipe Size

Diameter	Gravity Sewer		Forcemain		Culvert		Catchbasin Lead	
	Length	Percent of Total	Length	Percent of Total	Length	Percent of Total	Length	Percent of Total
mm	m		m		m		m	
100	0	0	0	0	0	0	49	0%
150	0	0%	0	0%	0	0%	50	0%
200	227	1%	697	100%	16	1%	7,409	69%
250	601	3%	0	0%	12	1%	1,496	14%
300	6,378	27%	0	0%	130	6%	1,057	10%
350	0	0%	0	0%	58	3%	0	0%
375	3,609	15%	0	0%	50	2%	559	5%
400	0	0%	0	0%	197	9%	0	0%
450	1,885	8%	0	0%	169	8%	0	0%
500	0	0%	0	0%	102	5%	0	0%
525	2,552	11%	0	0%	0	0%	0	0%
600	2,218	9%	0	0%	137	6%	0	0%
750	2,199	9%	0	0%	0	0%	0	0%
800	0	0%	0	0%	29	1%	0	0%
850	0	0%	0	0%	15	1%	0	0%
900	1,153	5%	0	0%	82	4%	0	0%
1000	0	0%	0	0%	10	0%	0	0%
1050	2,786	12%	0	0%	0	0%	0	0%
1200	325	1%	0	0%	0	0%	0	0%
Unknown	0	0%	0	0%	1,196	54%	64	1%
Total	**23,932**	**100%**	**697**	**100%**	**2,203**	**100%**	**10,684**	**100%**

Table 3.2: Minor Stormwater System Summary – Pipe Material

Diameter	Gravity Sewer		Forcemain		Culvert		Catchbasin Lead	
	Length	Percent of Total	Length	Percent of Total	Length	Percent of Total	Length	Percent of Total
mm	m		m		m		m	
Concrete	18,673	78%	0	0%	111	5%	0	0%
Corrugated Steel	0	0%	0	0%	765	35%	0	0%
High-Density Polyethylene	12	0%	697	100%	9	0%	0	0%
Polyvinyl Chloride	5,117	21%	0	0%	61	3%	2,968	28%
Reinforced Concrete	0	0%	0	0%	0	0%	11	0%
Steel	0	0%	0	0%	33	1%	0	0%
Vitrified Clay Tile	0	0%	0	0%	0	0%	7,273[1]	68%
Unknown	129	1%	0	0%	1,225	56%	432	4%
Total	**23,932**	**100%**	**697**	**100%**	**2,203**	**100%**	**10,684**	**100%**

[1] Pipe materials are generally based on the City's provided stormwater network information; however, the catchbasin lead material was assumed to be vitrified clay tile (VCT) whereas concrete was highlighted in the provided data based on City comments.

3.2 Existing Drainage

As previously mentioned, a plateau divides the City's northwest corner from the rest of the City in terms of overall drainage patterns. In the northwest, topography generally falls towards the northwest, while the rest of the City generally drains southeast.

Detailed catchments for modelling the existing network were delineated digitally based on catchbasin locations and downstream manhole connections combined with the surface model. All surface modelling within this study is based on the City-supplied light detection and ranging (LiDAR) data. Additional details on catchment delineation are included in Section 3.2.1. These catchments were combined into drainage basins based on the ultimate downstream outfall and network connectivity.

Within the City's current boundary, existing drainage patterns generally define five drainage basins, noting that these basins are confined within the City's boundary for illustration purposes. These basins can be seen in Figure 3.3 and are described as follows:

- East Drainage Basin
  - This drainage basin is located within the Qu'Appelle River watershed, on the east side of the municipal boundary and south of Highway 5. This basin drains east to a tributary of Humboldt Lake.
- Northeast Drainage Basin
  - This drainage basin is located within the Saskatchewan River watershed, north of Highway 5 in the City's northeast corner. This basin drains north to a tributary of Deadmoose Lake.

- Northwest Drainage Basin
  - This drainage basin is located within the Saskatchewan River watershed in the City's northwest corner and primarily north of Highway 5. This basin drains northwest to a tributary of Waldsea Lake.
- Central Drainage Basin
  - This drainage basin is located within the Qu'Appelle River watershed and incorporates most of the existing City. This basin drains southeast utilizing the City's stormwater conveyance network and flood control ditch to convey runoff to Humboldt Lake.
- Southwest Drainage Basin
  - This drainage basin is located within the Qu'Appelle River watershed, west of 16 Street and south of 3 Avenue. The highway commercial areas along Highway 20 from south of 2 Avenue also fall within this Basin as they are drained by the Highway 20 ditches, which also drain south to Humboldt Lake. This basin drains southwest to a tributary of Humboldt Lake.

3.2.1 Subcatchments

With the available LiDAR data and the locations of catchbasins (i.e., inflow nodes), individual subcatchments catchments were delineated. The initial catchments were delineated in MIKE URBAN using the Catchment Delineation Wizard by determining the high points surrounding each inflow node. The subcatchments were then thoroughly reviewed and adjusted through a robust QA/QC process to ensure appropriate and accurate delineation.

A coupled 1D-2D model has been constructed as part of the project, so subcatchments are not required or utilized for model development. However, the subcatchments were delineated to highlight the potential impact of stormwater system issues and proposed upgrades. The existing system subcatchments are shown in Figure 3.4 based on the overall catchment's downstream outfall.

4.0 Hydraulic Model Development

4.1 Modelling Software

To further advance Humboldlt stormwater system analysis and plan/design future improvements and growth, ISL has developed a comprehensive 1D-2D city-wide model for the City. The model was built and is run using InfoWorks ICM modelling software developed by Innovyze. This software was selected for its advanced 2D modelling capabilities. Advantages of using 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 required upfront.
- Triangular mesh elements mean that the surface can be modelled with incredible accuracy.
- The ability for terrain-sensitive meshing ensures that topography changes are reflected in the surface modelling mesh.
- Mesh generation effectively accounts for building footprints.
- Models are very stable; therefore, the potential for model corruption is reduced significantly. Also, the model saves automatically, so any fatal errors 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.

4.2 Missing Critical Data and Field Survey

The City's model was constructed by utilizing the City's available stormwater network AutoCAD (CAD) base map. ISL reviewed this data and identified several locations where critical data was missing and should be known to ensure accurate modelling results.

The missing data were summarized and presented to the City with a proposed survey plan/scope and budget for an extensive field data gathering and survey program for obtaining the most critical data. Potential survey locations were prioritized based on node type, type of missing data, and ease of access to the location. The City accepted ISL's proposed plan, and over a three (3) day period, ISL surveyed, measured, and documented the following:

- Locations, connected pipe materials/sizes, and rim/invert elevations of 60 stormwater manholes.
- Locations, sizes, material, and invert elevations of 60 drainage culverts.
- Locations and surface elevations for an additional 105 catchbasins and 42 sanitary sewer manholes in proximity to the 60 stormwater manholes investigated.

4.3 Basemaping and Coordinates

An issue arose during data compilation and model development when combining the City's stormwater CAD basemap with the LiDAR elevations and aerial imagery data. Firstly, the information in the CAD basemap was compiled manually and the locations of manholes and catchbasins were approximated from paper drawings. This interpretation was drawn onto a legal cadastral (property lines) CAD drawing obtained from the Information Services Corporation (ISC). The ISC basemap is the first coordinate system that needed to be rectified.

Secondly, the LiDAR and aerial imagery data that was provided was surveyed in a different coordinate system than the ISC base map. While surficial/elevation features would align properly between these two data sets (ponds, hills, buildings, etc.), the locations of stormwater facilities (manholes, catchbasins, outfalls, etc.) did not. The locations of each surveyed catchbasin had to be reviewed and adjusted horizontally (X and Y coordinates) so that those facilities were aligned and placed correctly within the LiDAR elevation data and modelled in the proper locations. This horizontal correction was also required to correct any misinterpretations from the initial CAD basemap creation.

Elevation data contained within the CAD basemap was also found to be using inconsistent datums, which would cause disjointing and misalignments of sewer inverts when reviewing pipe profiles. ISL utilized the most reliable elevation data available from the LiDAR data set and our missing information survey to review the elevations/profiles of Humboldt's storm sewer to ensure a proper representation of the existing sewer network within the model.

These issues would have been avoided if the City of Humboldt had implemented a consistent spatial reference system (X, Y, and Z coordinates) for its record data. With a unified and city-wide survey system, all physical locations can be surveyed and recorded to provide an accurate and reliable basemap that can be used for planning, maintenance, and design purposes. ISL and the City can discuss further steps, methods and budgets that would be required to implement this record data and survey control within the City of Humboldt.

4.4 Minor (1D) System Development

The minor system includes all underground piped infrastructure. InfoWorks ICM defines any point features as nodes and line features as links. In the model, nodes can represent flow into the system, and 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 and control flow such as an orifice, weir, or pump. In Humboldt, the following infrastructure was considered and is classified either by a node or a link:

- Nodes:
  - Manholes/Chamber Manholes
  - Manhole Catchbasin
  - Catchbasins
  - Inlets/Outfalls
  - Dummy Nodes
  - Lift Stations
- Links:
  - Gravity Sewers
  - Forcemains
  - Catchbasin Leads
  - Culverts
  - Orifices
  - Pumps

The City's CAD pipe network created the 1D representation of the City's minor stormwater infrastructure. As discussed in Sections 4.2 and 4.3, there were many data gaps and some potentially erroneous data in the CAD files highlighted during an initial review of the data. Therefore, potential survey locations and other data sources were required to fill these data gaps.

The stormwater schematics from the City's CAD files were exported into geographic information systems (GIS) to pre-process the data in ArcGIS before importing it into InfoWorks ICM. The Centennial Park drawings were utilized to update the pipe network in this area. This included the parameters applied to the lift station and forcemain in the area.

As previously noted, the CAD information provided did not match the aerial imagery and LiDAR data provided in terms of location. Therefore, inflow nodes (including inlets, catchbasins, and grated-top manholes) were manually relocated based on the aerial imagery and LiDAR data provided to make sure that stormwater runoff from the major (overland) system would properly enter the minor (piped) system.

Information on catchbasin leads was unavailable in the City's CAD. Therefore, the downstream invert was assumed as the upstream invert of the downstream pipe (matching inverts). The upstream inverts of catchbasin leads were estimated using their measured length and assuming a 2% slope where it could be achieved (reduced slopes used as needed to provide minimum pipe cover). A 200 mm diameter pipe size was assumed for all existing catchbasin leads.

Rating curves were assigned to each catchbasin. The catchbasin type was not identified in the City's CAD; therefore, the NF-51 catchbasin, which was utilized for the Regina City-Wide Stormwater Model project, was selected for all catchbasins and catchbasin manholes in the City. Based on discussions with the City and observations via Google Street View, most locations do not have a curb inlet; therefore, this assumption was also applied to all catchbasins. The standard capture rating data for the NF-51 catchbasin without a curb inlet and with no inlet control device considered are summarized in Table 4.2.

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. A specific detailed model review should be undertaken to optimize surface capture.

Table 4.2: NF-51 Catchbasin without Curb Inlet Capture Rating Data

Ponding Depth	Capture Rate
m	m3/s
0.0508	0.028
0.1016	0.080
0.1524	0.200
0.2032	0.220
0.2540	0.300

Inlets associated with culverts were assigned unique head discharge curves based on diameter. These curves were derived using the Orifice Equation, given the area of the culvert.

After identifying and resolving all data gaps, the node and link data 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. All manholes, catchbasins, and inlets were designated as 2D nodes to facilitate the exchange between the 1D and 2D systems (coupling).

4.4.1 Major (2D) System Development

Section 4.4.1 describes the process undertaken to develop the model's 2D (overland) model portion. This information includes discussing the features and parameters required for the mesh development process and summarizing the mesh generation itself.

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

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

The 2D Zone represents the boundary where the 2D modelling analysis will occur. 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 a unique elevation calculated using the LiDAR surface data, ultimately making each mesh element flat. Together with other mesh elements, a representation of the real-world 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. The Humboldt 2D model utilizes Mesh, Roughness, and Infiltration Zones parameters. The Mesh Zone parameters specify different mesh element densities for various zones, either increasing or decreasing a zone's resolution depending on its importance. For example, to capture pertinent features such as the crowns of roads or curbs 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 mesh areas. A roughness value is assigned to each mesh element depending on which Roughness Zone the mesh element falls within. 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 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 Runoff Coefficient
- Horton
- Constant Infiltration
- Green-Ampt

This model represents impervious surfaces through a fixed runoff coefficient, while the Horton Infiltration Type represents pervious surfaces.

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 directly to mesh' and 'Terrain-sensitive meshing' were selected. The 'Apply rainfall directly to mesh' option ensures that rainfall falls directly onto the surface, providing 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 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 reduces modelling errors due to overlaps between the different polygon layers. These polygons, differentiated based on land use type, are illustrated in Figure 4.3.

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 experience using InfoWorks ICM, optimizing model simulation time and level of detail. The Roughness Zone parameters are based on engineering best practices and are consistent with ISL's past projects. The Infiltration Zone parameters are based on a combination of the runoff coefficients stipulated in the Stormwater Design Standard (City of Regina, 2021), a review of pavement to grass ratios of various parcels throughout the City 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
Building[1]	25	5
Commercial	50	25
Industrial	50	25
Institutional	50	25
Open Space	100	50
Railway	50	25
Residential LD	50	25
Residential MD	50	25
Residential HD	50	25
Roads[1]	25	5
Urban Holdings	100	50

[1] These are the default values.

Table 4.4: Roughness Zone Parameters (Manning's n) per Land Use Type

Land Use	Roughness Coefficient
Building[1]	0.0160
Commercial	0.0181
Industrial	0.0167
Institutional	0.0195
Open Space	0.0300
Railway	0.0313
Residential LD	0.0258
Residential MD	0.0258
Residential HD	0.0258
Roads[1]	0.0160
Urban Holdings	0.0300

[1] These are the default values.

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/hr	1/hr
Building[1]	Fixed	0.950	-	-	-	-
Commercial	Fixed	0.865	-	-	-	-
Industrial	Fixed	0.865	-	-	-	-
Institutional	Fixed	0.525	-	-	-	-
Open Space	Horton	-	125	15	9	0.001
Railway	Fixed	0.270	-	-	-	-
Residential LD	Fixed	0.491	-	-	-	-
Residential MD	Fixed	0.644	-	-	-	-
Residential HD	Fixed	0.797	-	-	-	-
Roads[1]	Fixed	0.950	-	-	-	-
Urban Holdings	Horton	-	125	15	9	0.001

[1] These are the default values.

Incorporating buildings into the 2D model was a major consideration. Ultimately, as the models utilize a rain-on mesh ideology, raising the buildings on the LiDAR surface was the most conservative and effective approach. Runoff could not penetrate the buildings and allow rainfall to land and fall off naturally. Building footprints were obtained from OpenStreetMap with the locations and extents adjusted as needed, as shown in Figure 4.4. Building footprint polygons were clipped from the Mesh, Roughness, and Infiltration Zones with a thin buffer between the edge of the building footprint polygon and the edge of surrounding zones.

Mesh generation was an iterative process 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 mesh areas. These issues were mitigated by closing the gaps between polygons or removing any unnecessary vertices. This iterative process resulted in a smooth mesh without excess mesh elements.

5.0 Design Criteria

5.1 Design Rainfall Event

The design storms applied in this study are based on the City of Saskatoon's Meteorological Service of Canada (MSC) intensity-duration-frequency (IDF) curves that are stipulated in the Design and Development Standards Manual (Saskatoon, 2021). Tables 5.2 and 5.3 summarize the IDF intensities and parameters, respectively.

Table 5.2: City of Saskatoon's MSC IDF Curve – Intensity Summary (mm/hr)

Time	Return Frequency			
Minutes	2 Year	5 Year	25 Year	100 Year
10	53.0	85.0	132	168
15	41.0	67.0	104	133
30	26.4	46.1	74.0	97.0
60	16.6	28.9	46.5	60.0
120	10.7	17.5	27.3	35.0
360	4.7	7.0	10.3	12.9
720	2.73	3.90	5.59	6.91
1440	1.56	2.18	3.07	3.76

Table 5.3: City of Saskatoon's MSC IDF Parameters

Parameter	Return Frequency				
	2 Year	5 Year	10 Year	25 Year	100 Year
a	299	748	1112	1473	2336
b	2.7	6.6	8.3	9.0	11.1
c	0.694	0.776	0.809	0.820	0.861

The City of Humboldt has seen many high-intensity, short-duration rainfall events that resulted in substantial surficial flooding over the past ten years. A record of these rainfall events and their impacts were provided to ISL and is summarized in Table 5.4. These rainfalls typically last for one to four hours with 35 to 50 mm of total rainfall.

Table 5.4: Humboldt Significant Rainfall Events (2005-2021)

Date	Duration[1]	Total Rainfall	Approximate Return Frequency
	hr	mm	yr
August 31, 2021	5	47	1:25
June 30, 2020	1	50	1:50
June 17, 2020	4	47	1:25
June 14, 2020	1	44	1:25
May 24, 2018	2	50	1:25
July 18, 2015	24	122	> 1:100
April 13, 2010	N/R	41	-
June 17, 2007	N/R	52	-
September 10, 2005	N/R	54	-
June 17, 2005	N/R	62	-

[1] Storms without a record of length are denoted as “N/R”.

The WATT Consulting Group (WATT) urban area design storm for the Canadian prairie regions was used in the modelling to recreate and observe stormwater conditions in Humboldt during high-intensity, short-duration rainfalls. The Atmospheric Environment Service (AES) parameters for the 1:2, 1:5, 1:10, 1:50, and 1:100 year storm frequencies are provided in Table 5.4; however, only the 1:100 year, 1-hour storm was assessed as part of this SMA.

Table 5.4: City of Saskatoon’s AES IDF Parameters

Parameter	Return Frequency					
	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year
A	23	23	23	23	23	23
K	7	7	7	7	7	7
h	52.5	93	119.5	153	178	202.5

5.2 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 node for each assessment design storm.

In assessing the storm drainage system in an area a 1:5 year, 1-hour storm event 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.

Both the 1:2 year and 1:5 year, 1-hour storm events were analyzed to assess the current level of service of the minor system. Additionally, various 24-hour storms were utilized to compare the impacts of these events to surface flooding conditions. Therefore, the existing stormwater collection system was analyzed under the following assessment scenarios to determine system conditions:

- Minor System
  - 1:2 Year 1-Hour Chicago rainfall event
  - 1:5 Year 1-Hour Chicago rainfall event
- Major System
  - 1:5 Year 24-Hour Chicago rainfall event
  - 1:25 Year 24-Hour Chicago rainfall event
  - 1:100 Year 24-Hour Chicago rainfall event
  - 1:100 Year 1-Hour WATT urban design 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 freeboard between the maximum water elevation and ground elevation at each node when maximum flow passes through the connected pipes.

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 the surface (ponding or water flowing up and out of the manhole)
- Between -1.2 m and 0.00 m is denoted as an orange dot – maximum HGL peaks within 1.2 m below the surface.
- 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 surface
- 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, 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 may require upgrading, particularly where the length of the section is long enough to cause surcharge conditions immediately in the upstream reach.

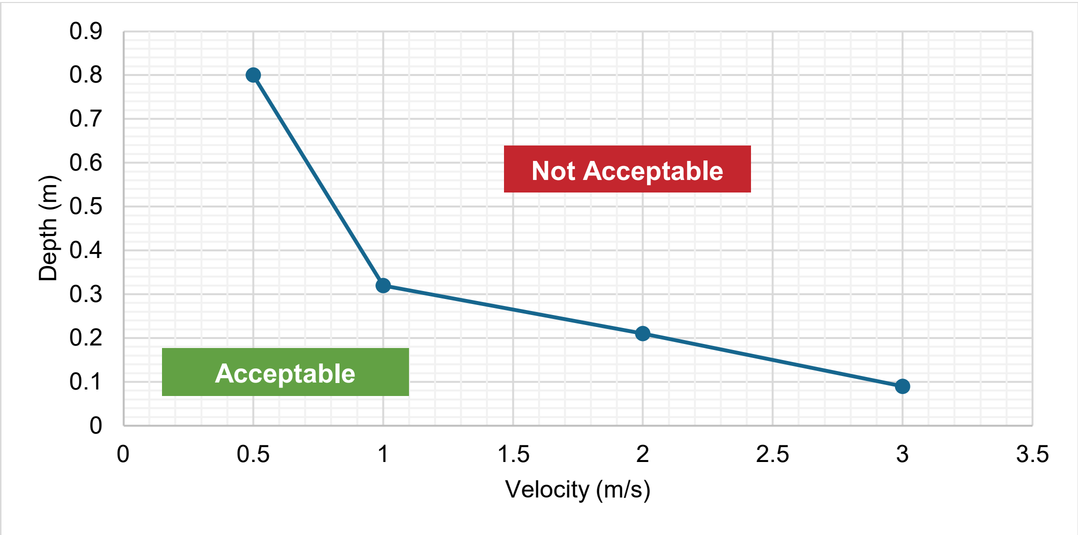
Hence, the Peak Discharge Relative to Sewer Capacity (Q/Q_{man}) with a ratio of:

- Greater than 1.00 is denoted as a red line – over capacity, or in other 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/Q_{man} 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

5.2.1 Additional Criteria

In addition to these two scenarios, the spare capacity of each sewer was determined. This measure indicates the amount of additional flow each sewer can handle before it becomes completely utilized and water levels within the system begin surcharging. The 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 and which sewers should remain untouched.

2D Model results were reviewed at the maxima (worse) conditions for depth and velocity. The complete model file contains velocity and depth properties at any time step within the simulation if they are required. Many jurisdictions, such as the Province of Alberta, have stipulated permissible depths for submerged objects with water velocity to increase public safety. The Stormwater Management Guidelines for the Province of Alberta (Alberta Environment, 1999) use the standard that a 20 kg child would withstand the force of moving water, thus preventing possible tragedies. This guideline is also referenced in the Design and Development Standards Manual (City of Saskatoon, 2021). Insert 5.1 indicates these requirements.



Insert 5.1: Permissible Depths for Submerged Objects

6.0 Existing System Assessment and Upgrades

The existing system was assessed using the design criteria and design storms outlined above in Section 5. The simulation results for both the 1D and 2D systems are described in Sections 6.1 and 6.2.

6.1 1D Model Results Summary

The minor (piped) system was assessed using the 1:2 and 1:5 year storm events with a 1-hour duration. Typically, minor systems are sized based on the 1:5 year event; however, a substantial portion of the system is considered under capacity during this event, with surcharging to the surface highlighted at many locations throughout the City.

Similarly, many of the City's main trunk sewers are under capacity during the 1:2 year event, with various locations showing surcharging to the surface. Most notably, stretches of 2 Avenue, 3 Avenue, 5 Avenue, 6 Avenue, and 16 Street experience surcharging to the surface based on the model results and localized areas throughout the City.

The 1D model results and spare pipe capacity for the 1:2 year event are shown in Figures 6.1 and 6.2, respectively. The 1D model results and spare pipe capacity for the 1:5 year event are shown in Figures 6.3 and 6.4, respectively. It should be noted that these figures show the peak results for each link and node in the model; therefore, these may not occur at precisely the same timestep.

Longitudinal profiles (LPs) for 1:2 and 1:5 year storm events at key locations within the existing stormwater network are included in Appendix B.

The combined 1D-2D city-wide model confirms and highlights the findings of Humboldt's previous 1D stormwater modelling that most of the minor drainage infrastructure is undersized even to handle a normal 1:2 year rainfall event.

As Figure 3.1 and Table 3.1 have previously highlighted, more than 40% of Humboldt's storm sewers are 375 mm (15%) and 300 mm (27%). These sizes of sewers typically can drain two to four catchbasins before larger sizes are required. There are dozens of sections of storm sewer within Humboldt where five and up to 26 catchbasins are drained by a single 300 mm storm sewer such as:

- 2 Avenue between 5 and 12 Street – 26 catchbasins on a 300 mm storm sewer
- 3 Avenue between 6 and 9 Street – 23 catchbasins on a 300 mm storm sewer
- 8 Avenue between 10 and 16 Street – 16 catchbasins on a 300 mm storm sewer

Current stormwater standards specify and utilize 300mm pipe size as their minimum catchbasin lead size. The combination of undersized local-level storm mains that drain to undersized trunk sewers/outfalls results in system-wide flow constraints in Humboldt's storm sewer network. As discussed in Section 6.2, these drainage system constraints result in significant amounts of surface flows and ponding, even from normal 1:2 year rainfalls.

6.2 2D Model Results Summary

As discussed, the major (overland) system was assessed using the 24-hour duration storms for the 1:2, 1:5, 1:10, 1:25, and 1:100 year rainfall events and the 1:100 1-hour. These design storms were selected and modelled to highlight areas and extents of surface ponding during and following normal to extreme rainfall events.

The surface ponding reported/observed within the 2D surficial portion of the model correlates to the surcharging locations shown in the 1D (piped system) model results. The 2D model also recreates and identifies the flooding area extents and overland flow routes that excess runoff activates when volumes exceed the capacity of the 1D piped system. Flow velocities and depths are simulated as the 2D model calculates the routes and transport of surface runoff.

Ponding and flood areas develop at locations where:

- The minor system is undersized for the flows flowing there.
- Undersize and clogged catchbasin structures and small (200 mm diameter) lead pipes restrict flow into the piped system.
- Flow surcharges within the minor system cause water discharge from the underground pipe network to the surface.
- In low-lying, trap lows where an inlet to the minor system may or may not be present without proper surface grading to drain the area before significant and damaging water levels rise enough for volume to “spill over” the edges of the flood bowl.

Maximum water depth and surface flow velocity results for each modelled storm event are presented in Figures 6.5 to 6.16. It should be noted that the maximum water depths and peak velocities are shown for each mesh element over the entirety of each storm; therefore, these may not occur at precisely the same timestep.

Many of the City's frequent and problematic flooding areas were recreated and reported in the modelling results. Table 6.1 summarizes eleven (11) locations of frequent, disruptive and damaging flood locations either reported by the City or observed in the 2D model.

Table 6.1: Observed Flooding in 2D Model Results (24 hr Design Storm)

Map Location No.	Location	Ponding Depth	
		1:25 yr	1:100 yr
		m	m
1	Dust Crescent	0.4	0.43
2	Barnes Crescent	0.66	0.88
3	16 Street and 9 Avenue	0.69	0.8
4	17 Street and 7 Avenue	0.37	0.46
5	11 Street and 5 Avenue	0.67	0.72
6	9 Street and 6 Avenue	0.25	0.32
7	5 Street and 6 Avenue	0.45	0.47
8	2 Street and 6 Avenue	0.3	0.37
9	12 Street and 2 Avenue	0.45	0.47
10	Main Street and 2 Avenue	0.32	0.35
11	5 Street, 6 Street, and 7 Street – Between 2 Avenue and 3 Avenue	0.45	0.49
12	Sunset Estate Mobile Home – 9 Street and Saskatchewan Avenue	0.55	0.61

The city-wide 1D-2D modelling results were presented to and reviewed with City personnel to compare the predicted flooding areas and extents to what is typically observed and dealt with in the field. Upon reviewing and confirming that the model is producing acceptable and realistic results, a set of priority locations was selected for conceptual level design and modelling of potential major drainage system improvements. The priority locations were selected based on the most frequent, problematic, often raised by residents and within or near roadways that will soon require rehabilitation works. These locations are highlighted in Table 6.1.

6.2.1 Building Impact Assessment

Impacted building footprints are shown in each noted ponding depth figure above. A building was considered impacted if any portion of the building experienced a ponding depth greater than 200 mm. This assessment was utilized in conjunction with the 24-hour model results to prioritize existing system upgrade options that could be developed and implemented to help mitigate stormwater flood damage and disruptions. A summary of the number of buildings identified as impacted by flooding in the city-wide model assessment results is provided in Table 6.2. The locations of each identified impacted building are highlighted in orange in Figures 6.5, 6.7, 6.9, 6.11, 6.13, and 6.15.

Table 6.2: Building Impact Assessment Results

Return Frequency yr	Number of Impacted Buildings
1:2	19
1:5	47
1:10	71
1:25	100
1:100	158
1:100 (AES)	107

6.3 Major Drainage Areas

Exiting major drainage areas and patterns with Humboldt were identified using the combined 1D-2D model. These areas delineate where excess runoff and surface flows gather and flow to common areas/outlets, are isolated due to physical barriers such as topography and built structures, and areas where any major drainage improvements would potentially impact/improve. These criteria divide Humboldt's existing developed area into eight (8) major drainage. These areas and the general overland flow patterns that define them are identified in Figure 6.17.

7.0 Drainage Improvements

The results of the City-wide 1D-2D modelling identified and confirmed the locations, extents and mechanics that create the widespread and long-lasting flooding in the city. As previous 1D modelling of Humboldt's minor system found, the City's existing storm sewer network is largely undersized, overextended and not designed with the capacity required to intercept and drain runoff generated by frequent 1:2 year storms.

When rainfall events occur in Humboldt, overland surface drainage is often the primary means of managing runoff. Overland management of runoff is not an inherently bad or incorrect method of managing stormwater runoff. However, extensive planning and engineering must identify overland patterns and provide controlled flow routes that direct runoff to areas capable of storing it. Modern municipal design and development standards (after approximately 1990) require that new subdivisions and neighbourhoods are constructed with engineered overland drainage systems. These systems primarily utilize area and road grading that limit surface ponding depths to 0.3m to 0.5m in controlled locations and direct runoff to dedicated stormwater management facilities (i.e. wet/dry ponds, greenspace) or capable discharge outlets (i.e. rivers, lakes, wetlands).

Effective overland major drainage systems have been designed and constructed within Humboldt's newer neighbourhoods and developments on its west, north, and southwest peripheries. Unfortunately, most of the existing city established before 1980 was not designed with controlled/engineered major drainage systems. Growth and development were largely built using the existing natural topography with flow patterns that converge to isolated traplow areas. These areas are largely developed and are where frequent and problematic flooding occurs. The significant flooding locations identified in Table 6.1 result from uncontrolled surface drainage patterns that shed runoff to low-lying areas lacking sufficient outlet means.

The 1D-2D modelling was combined with Humboldt's previous 1D stormwater modelling findings and conceptually proposed solutions and input from the City of Humboldt to develop, test, and recommend drainage improvement concepts for reducing surface flooding, damage and disruptions currently experienced in the community.

7.1 Previously Derived and Discussed Drainage Improvement Concepts

Before this study, the City of Humboldt has commissioned studies and brainstormed internally several a comprehension set of potential stormwater system improvements which could be explored and implemented if required and feasible. The scope and timelines of this study could facilitate full modelling and testing of all previously devised solutions. However, ISL and City Engineering personnel discussed and reviewed a comprehensive list of its previously derived solutions in conjunction with the results from the existing conditions 1D-2D city-wide stormwater model to identify those with the greatest overall potential to reduce flooding from heavy/major rainfall and are most feasible to implement. The findings of this collaborative review are summarized below in Table 7.1

Table 7.1 - Summary of Previously Derived Drainage Improvement Concepts

Considerations Assessed	Source	Observation
Twin Outfall on 14 Avenue (ST.S.P2)	C&W -Storm Sewer Capacity Report 2012	Provides Benefits, and preliminary development concepts to the west suggest that the City may want to consider expanding and upsizing the project to accommodate development to the west. The solution is a minor system upgrade and extension. Major rainfall events would require significantly larger piping or area regrading.
Twin Outfall on 13 Avenue (ST.S.P3)	C&W - Storm Sewer Capacity Report 2012	Provides Benefits, consider improving with other work in the area. The pipe is on the north side of the Golf clubhouse and runs through the putting green. Golf course impacts would need to be considered. The solution is a minor system upgrade and extension. Major rainfall events would require significantly larger piping or area regrading.
New Outfall on 6 Avenue (ST.S P7)	C&W - Storm Sewer Capacity Report 2012	Provides Benefits, Utility conflicts evolved the solution and have resulted in several revisions since the 2012 study took place. The newest concept is proposed in this study (Section 7.3.4) and provides relief to the minor system trunk main and major rainfall drainage improvements in 5 Street and 6 Avenue flood area with potential for future extension(s).
Overflow Ditch Along 17 Street	C&W - Storm Sewer Capacity Report 2012	This concept was implemented at Centennial Park by converting a ball diamond into a lowered sports field in 2016.
Surge Tank/Dry Pond/Twin Outfall	C&W - Storm Sewer Capacity Report 2012	A sanitary sewage surge tank was installed for the sewage lift station in 2012 for $2M. This tank is not connected to the storm sewer network. The needed capacity for stormwater storage was too large to justify further consideration. A dry pond solution on private land was explored but ultimately abandoned as suitable areas are actively utilized. Historical land negotiations were not successful. Alternative options were to be sought. The north pond option as well as the Carl Schenn pond improve the outcome for the cost and are being recommended (Sections 7.3.1 and 7.3.2).
Storm Sewer along Hwy 20 from 2 Avenue and 1 Avenue South	C&W - Storm Sewer Capacity Report 2012	Provides benefits however modelling for more intense storms will require more storage in the area. A storm pond is being recommended. A revision of this concept was considered in this report which notes a dry pond south of St. Domonic School (Section 7.3.5). Overland flows from 2nd Avenue surcharging are anticipated for larger events. The south pipe along 1st Avenue South (ST.S.P9) is being reserved for future development capacity in the south area.
Carl Schenn Park Dry Pond	C&W Storm Sewer Assessment Dec. 2020	This concept was suggested by residents of Barnes Crescent to limit flooding in that area. The dry pond is significant to the area and would address the majority of current issues. This concept originally included a pumping system. A newer concept has been developed in this report which removes the need for a pumping system to limit O&M and allows the system to work with gravity (Section 7.3.1).
11 Avenue Twinning	C&W Storm Sewer Assessment Dec. 2020	Modelling was modified to address higher intensity storms compared to the 2012 report. Piping would be twinned from 16th St to 4th St. The option is appealing however very costly due to depth, size and road replacement costs. Ponding for heavy rainfalls remains due to the long piping and limitations of flow. Ponds are still recommended with this concept (Section 7.3.2). This improvement is still being recommended as a long-term approach to allow minor drainage system upgrades for all later stormwater sewers drained by the 11 Avenue Trunk.

Construct South Pond	C&W Storm Sewer Assessment Dec. 2020	This concept was introduced to relocate flows from 17 Street and 9 Avenue to a pond south of the industrial area which would then flow by pump to the 1 Avenue South Storm Main. The option was is appealing however costly and challenging with the rail yard. In heavy rainfall events, the ponding was still seen as the system and congested due to the long piping and limitations of capable flow. The option was dismissed in favour of a north pond on 16 Street (Section 7.3.2) as the lower cost-higher benefit solution.
Dry Pond - 5 Avenue between 3 Street and 5 Street.	Internal Concept	Devised to reduce surcharging along 6 Avenue and ponding at 5th St and 6th Avenue intersection. A connection pipe was anticipated to run south from 6th Avenue into the pond and controlled/drained by gravity. Upon review, the option was dismissed as there is more benefit for investment to replace the piping from 2 Street to 5 Street with a large pipe as noted in this report (Section 7.3.4).
Dry Pond - East of 2 Street, South of 6 Avenue	Internal Concept	Devised to reduce surcharging along 6th Avenue and ponding at 5 Street and 6 Avenue intersection. Upon review, the option was dismissed because more benefit for investment would be to replace the piping from 2nd St. to 5th St with larger pipe (Section 7.3.4) or else to route a new channel/ditch to the nearby East Flood Control Ditch.
Storm Dry Pond - North of 5 Avenue, West of 11 Street.	Internal Concept	Meant to reduce surcharging along 5, 6, 7 and 8 Avenue and ponding at 5 Avenue and 11 Street intersection. Benefit from the pond exists as significant overland water goes to this location from the area during a heavy rainfall event (Section 7.3.3). This study recommends using the land between 11 and 13 Streets for a larger storage area. These locations are privately owned and were used for industrial purposes in the past. Environmental assessments are recommended if pursued.
Storm Piping along 11 Street from 6 Avenue to 8 Avenue	Internal Concept	Install a storm pipe to connect with a potential 11th St & 5th Avenue pond (if constructed) to further relieve the surcharged mains in 7th and 8th Avenue. This location was selected as it is close to having a water main replacement and its proximity to underutilized land at 5th Avenue for a potential storm pond. 5 Avenue & 11 Street pond also has limited volume capacity without either lowering the 5 Avenue storm sewer or using pumping. This option however was dismissed in comparison to other costs/benefit projects.
Storm Piping along 6 Avenue from 9 Street to 11 Street	Internal Concept	Install a storm pipe to connect with a potential 11th St & 5th Avenue pond (if constructed) to further relieve the surcharged 6th Avenue main. This location was selected as it is close to having a road rehabilitation and its proximity to underutilized land at 5th Avenue for a potential storm pond. 5 Avenue & 11 Street pond also has limited volume capacity without either lowering the 5 Avenue storm sewer or using pumping. This option however was dismissed in comparison to other costs/benefit projects.
Storm Piping on 5 Avenue from 11 Street to 17 Street	Internal Concept	Install a storm pipe to connect with a potential 11th St & 5th Avenue pond (if constructed) and to drain into the conceptual south pond located south of the industrial area. This location was selected due to the proximity of both conceptual projects. Overland drainage is already effective in transporting water along this span to 5 Avenue and 11 Street, so piping upgrades were not recommended.
Storm Dry Pond - North End of 16 Street	Internal Concept	The concept discussed in this study (Section 7.3.2) to provide a surge outlet for 11 Avenue and 16 Street underground piping system. The option is very effective with the installation of large pipes from 11th Avenue to the pond. A future second phase can include a twinning along 16th St from 9th Ave to 11th Avenue to also help reduce surcharging further. This option is recommended in this report.

16 Street Twinning - 9 Avenue to 11 Avenue	Internal Concept	When reconstructing the road in 2021, modelling took place for the benefits of twinning this section. It was determined at that time that there was no significant benefit to the upgrade unless all of 11th Avenue was twinned at the same time which was cost-prohibitive. The twinning was a costly addition to the project with no certainty of twinning 11th Avenue. A new idea along with modelling for the addition of a large north pond to the north of 16th St notes the benefit of the twinning along 16th St in the future as a second phase of the project to move water to the north pond. The total recommended solution is costly and requires land acquisition as well as development concept planning to determine where the pond should be placed. The north pond and piping is the primary objective to significantly reduce surcharging. The twinning of 16th St would be considered a second phase and should wait until a future rebuild of 16th Street occurs for cost-effectiveness.
Storm Dry Pond - West of 14 Avenue and Hwy 20	Developer Concepts	Development concepts note storm ponds for new development which then drain east along 14 Avenue. This option is still plausible depending on when/where future development starts. Otherwise, development could tie into a larger 16th north pond and share the ponding benefits for heavy rainfall events as noted in this report.
Storm Dry Pond - AE Kiltcher Park	Internal Concept	The concept included a moon-shaped or triangle dry pond to avoid the superpipes and save the ball diamond. Playground structures would have to be relocated. The park layout would be significantly changed which would limit activities at the location. As the size was limited and the anticipated cost was not enough benefit for the volume stored, the concept was dismissed in favour of the 16 Street Northend pond.
Lower Existing Centennial Park Storm Dry Pond	Internal Concept	Lowering the existing dry pond lower to retain more water was discussed. Adding larger pipes to the pond and grading swales, removing existing (small diameter) underground pipes and the use of a pump system are also considered. This option was dismissed as the pond is limited in size, newer in construction and fully developed. The surface swales may not be desired for debris, regular flows from the parking lots and resulting standing water potential. Long pump-out times may also conflict with the users of that field.
Valve at the Existing Centennial Park Storm Dry Pond - Concept 1	Resident Idea/Internal Concept	Concerns from residents in the Barnes Crescent area prompted modelling to see if a valve to hold back more runoff from the area south of the highway and slow or delay its draining. Barnes Crescent residents were concerned that the dry pond was creating backflows into their neighbourhood. After modelling, the pond is lower in elevation than the lowest Barnes Crescent drain and receives/stores water throughout the storm. A valve would not be beneficial by itself as the pond would no longer be able to receive surcharge flows from the 17th St storm mains. In addition, the release of the pond after the storm would be dependent on operations staff manually opening/closing the valve to the expectations of the concerned citizens as well as the users of the sports field.
Valve on 17 Street main near Existing Centennial Park Storm Dry Pond - Concept 2	Resident Idea/Internal Concept	Concerns from residents in the Barnes Crescent area prompted modelling to see if a valve to hold back water would be beneficial to downstream users in the 9th Avenue and 17th Street area. Barnes Crescent residents were concerned that the dry pond was creating backflows into their neighbourhood. The concept was dismissed as the valve could potentially hold back all water creating a flooding situation along 17th Street after the pond filled. Releasing the water at the right time would be dependent on City staff to operate the valve during the storm which is not optimal. Risk/unpredictability would be too high for 17th Street neighbouring properties for this procedure to be executed faithfully to the expectations of the public.

Modification of Existing Centennial Park Storm Dry Pond - Concept 3	Internal Concept	Similar to Concept 1, but adds a 600mm storm pipe only allowing water one way into the pond with a backflow valve from 17 Street storm main. This way the existing pipe (375mm) can be isolated with a valve and flows can still be received from the surcharging system. The modelling demonstrated minimal benefits to the system during the heavier storms. As ponding drawdown times at Barnes Crescent were only reduced by about 9 minutes. A better investment would be focused on the Carl Schenn pond as the benefits are far more significant.
Barnes Crescent Backflow Valve (Interim solution)	Internal Concept	Barnes Crescent Residents expressed concerns regarding water backflowing into Barnes Crescent. Modelling did potential for minor amounts of backflow from 9th Avenue. City staff have ordered a backflow valve designed for storm sewers to be installed in the spring of 2022. This eliminates backflows from the downstream system but will result in no noticeable reduction in overall ponding issues at Barnes Crescent. When/if the Carl Schenn Pond is constructed, plans would be to remove the check valve and allow the water to backflow to the pond to help the overall area. New pipes to the pond would be designed to accommodate the backflows and flows in the immediate area.
Barnes Crescent Storm Piping Upsizing	Internal Concept	Consideration was given to upsizing piping in the Barnes Crescent streets when roadwork is being completed. The overall benefit would be to replace and potentially backslope portions of the pipe towards the Carl Schenn Storm Dry Pond to relieve some of the 9th Avenue surcharging so it can go into the new pond at a higher flow rate. The pipe from Barnes to the pond would then be designed to accommodate the additional flows and local volumes. This would be evaluated/considered further in the Carl Schenn pond detailed design process.
2 Avenue Twinning or Upsizing from 12 Street to East Drainage Channel	Resident Concern	2nd Avenue has small diameter pipes and could benefit from a main upsizing, however, the cost is very high for the pipe and roadway reconstruction. Alternatives to address the majority of the concerning issues during a heavy rainfall event in this report such as a storm pond and overland drainage in heavy rainfall events (Section 7.3.5).
Storm Piping - 2 Avenue from 12 Street to 14 Street	Internal Concept	To mitigate ponding concerns at the 12th Street and 2nd Avenue intersection, a pipe was proposed to go from 12th St to the storm sewer at 14th St. A path for the pipe between 13th St and 14th St is challenging as overhead power and limited space creates challenges for the installation. In addition, the preference to not overload the 14th St storm and redirect to a different location/pond is recommended in this report (Section 7.3.5).
Storm Pond - South side of 1 Avenue and 13 Street	Internal Concept	Converting the existing MR low spot to a storm pond for water piped from the 12th St and 2nd Avenue intersection. This location wasn't explored in great detail due to its limited size. Future considerations may be made when the area develops. Though a pond added to this location could reduce the size of the proposed pond on the east side of Highway 20 and reduce the length of major drainage piping needed to route runoff from 12 Street and 2 Avenue. Splitting storage locations/volumes across multiple locations could be explored in the preliminary design of south area drainage improvements.
Storm Dry Pond - South of St. Domonic School	Internal Concept	The naturally low topography and known issues along 2nd Avenue made the location desirable for a storm pond in the area. The area ponds now and holds water. The pond would receive water from the 2nd Avenue pipe through overland means as well as relief further west. The pond can also accept future water from the east developments and tie pipes from 2nd Ave if desired. Several concepts have been considered including a pump system for a deeper pond. A gravity concept (not needing a pump) is described in this report

		(Section 7.3.5). The project can be phased. The City does not own the land and would need to purchase it.
2nd Avenue and Main Street Intersection Improvements	Internal Concept	Ponding has been observed at the 2nd Avenue and Main Street Intersections. Sidewalk lowering/swale creation as well as culvert upsizing would improve the ability for overland water to relocate from the intersection during a heavy rainfall event. City staff are exploring upgrades in coordination with highway improvements in 2022 (Section 7.3.6).
2 Avenue and Main Street Overflow Pipe Upsizing	Resident Concern	The existing overflow pipe on the east side of the intersection was installed in 2014. A Resident in the area is concerned that the pipe is too small for the storm events and should be larger. Staff intend to look at possibly upsizing the pipe with a larger outfall. The main in 2nd Avenue is small (only 300mm), so limited benefits will be realized as a result however if the storm pond south of St. Domonic School is built, significant flows could be diverted to the pond from 2nd Avenue (Section 7.3.5 & 7.3.6).
West Drainage Channel Concept	Internal Concept	Discussions of possibly a second drainage channel to Humboldt Lake were discussed. Land purchase, approvals and cost to create a 4.7 Km channel would make the project costly relative to the benefit. Dry/wet ponds are the most cost-effective mitigation systems for localized surface ponding and major event stormwater management. This option has been dismissed at this time.
5 Avenue Drainage Ditch/Pipe Concept	Internal Concept	Discussion of possibly running a pipe and ditch system along 5 Avenue from 17 Street towards the east drainage channel as well as installing a large main along 17 Street from 9 Avenue flowing to 5 Avenue. This option was anticipated to relieve areas of ponding along the 5th Ave corridor and redirect water from 9th Ave, south, then east. The cost of the project was high and complexities with crossings, road reconstruction, curb costs, landscaping and possible land acquisition or easements would add complexity to the project. Railways seldomly agree to have drainage ditches and additional runoff added to their right-of-ways.
5 Avenue Storm Dry Pond	Internal Concept	Discussion of possibly creating a shallow storm pond in the green area north of 5 Avenue from 15 Street to 17 Street. Discussions were had when the watermain was replaced along 6th Avenue (2018). Modelling at that time indicated that the benefit would be minimal for the cost due to the pond being at the high end of the system. Holding volume would be minimal and difficult to slope due to the existing grades in the area.
St. Elizabeth Park Storm Dry Pond	Internal Concept	Discussion of possibly running a large diameter pipe in 11th Street from 11th Avenue to St. Elizabeth Park. As the park would have limited hold capacity, would change the intent of the park, and is not near the most significant problem areas the concept was dismissed.
NW Drainage Channel to Waldsea Lake	Internal Concept	A drainage channel could service future north development as well as relieve the 16th Street and 11th Avenue area (after a collection pond). Land acquisition and construction of a 5.5 Km channel to Waldsea Lake would be costly. The concept was dismissed as a Drainage Moratorium exists from the Water Security Agency where higher runoff volumes are not allowed in that watershed due to historical flooding issues of the basin.

7.2 Minor System Upgrades

The 1D-2D modelling confirms the City's previous 1D modelling results and observations that most of the existing underground storm sewer system that drains the city's runoff to Water Ridge Pond and the East Flood Control Ditch is undersized to manage the 1:2 year rainfall without significant system surcharges and surface flooding.

Regardless of whether any of the proposed major drainage system improvements presented below are implemented, the City of Humboldt should continue to increase the capacity of its minor drainage system. This is a long-term endeavour that would begin with twinning or upsizing storm trunks to have the capacity to, at a minimum, drain runoff from 1:2 year rainfall events without surcharge. Ideally, if budgets and physical constraints allow, a 1:5 year design standard should be adopted and implemented for minor system improvements per the City of Humboldt's current servicing standards for new developments.

The designs of these trunk improvements should be made assuming that all existing and potential future connected upstream storm sewers are or will be sized and flowing adequately to drain their sub-catchment areas for the adopted design event (1:2 or 1:5 year). This approach ensures that improved trunk sewers have the capacity for upstream improvements to be made.

All future roadway and infrastructure improvements should include a review of stormwater improvements that utilize the new 1D-2D model to identify required minor system improvements within each project area and implement them (if feasible).

7.3 Major System Drainage Improvement Concepts

Adequately sized and designed minor drainage systems can normally provide effective drainage for routine and slightly more intense 1:2 and 1:5 year events. However, managing runoff from major events, especially within traplow areas, using buried piping requires significantly increasing how quickly water can enter the system (installing multiple and larger catchbasins) and using large diameter, oversized storm trunks. Piped major drainage outlets/trunks are also only effective for shorter distances of up to a few hundred metres without very large diameters or installation depths (high construction costs) or steep pipe grades (> 0.25%).

The 1D-2D combined storm sewer model was used to devise and test several conceptual level designs that may be further developed and implemented to mitigate flooding from major rainfalls. This study tested these concepts utilizing a 1:100 year design storm event. However, many Canadian municipalities have adopted a 1:25 year design storm for sizing major stormwater improvement works and retrofits within existing and older areas to balance system improvements and construction costs.

The solutions presented in this SMA are meant to provide conceptual-level design and test their potential flood mitigation benefits. Any improvement concept selected for implementation will still need preliminary and detailed design engineering to ensure complete feasibility and construction requirements. Conceptual level cost estimates are also provided in Section 7.3 to understand the costs of implementing major storm sewer and drainage improvements within already developed urban areas.

Three basic methods are typically used when major stormwater improvements within existing areas are formulated.

- Improving runoff conveyance away and out of flooding areas,
- Directing and storing runoff from flood areas to nearby, non-destructive storage areas, and
- Intercepting/preventing runoff from upstream areas from flowing to and convalescing in traplow and flooding areas.

Each of these methodologies has been utilized within the five proposed and tested major stormwater improvement concepts within this study. These design concepts are illustrated in Figure 7.1. The expected results and improvements to Humboldt's minor and major systems following the implementation of the five improvement concepts are shown in Figures 7.2 through 7.11.

The 1D model results and spare pipe capacity of the minor system for the 1:5 year event are shown in Figures 7.2 and 7.3 for the existing system with the proposed major drainage improvement concepts incorporated into the model. It should be noted that this figure shows the peak results for each link and node in the model; therefore, these may not occur at precisely the same timestep.

Maximum water depth and peak surface flow velocity are shown for the 1:5 year, 1:25 year, and 1:100 year 24-hour design storm events and the 1:100 year 1-hour AES stormwater event in Figures 7.4 7.11. It should be noted that the maximum water depths and peak velocities are shown for each mesh element over the entirety of each storm; therefore, these may not occur at precisely the same timestep.

7.3.1 Barnes Crescent Diversion and Carl Schenn Park Stormwater Storage

This major drainage improvements concept centers on utilizing a dry-bottom stormwater storage pond within the northern portions of Carl Schenn Park to attenuate and store runoff from the city's northwest corner. The new dry pond would connect to the existing 525 mm stormwater trunk along 12 Avenue and provide an outfall for this main during heavy rainfalls instead of relying solely on the overloaded 11 Avenue trunk.

Large-diameter piping (600 to 750 mm diameter) connections would be made between low-lying flood areas in the southeast corner of Dust Crescent and the northwest corner of Barnes Crescent. These large pipes provide high-capacity flow routes from these flood-prone areas to direct and store runoff within the Carl Schenn Park pond.

Implementation of this drainage improvement will provide the following immediate and potential future improvements within its effective service area:

- Reduced surcharging of the 12 Avenue storm sewer and lateral connections to it (Figure 6.3 versus Figure 7.2).
- Significant reductions in surface flooding in Dust Crescent and the north end of Barnes Crescent (Figures 6.7, 6.11, and 6.13 versus Figures 7.4, 7.6, and 7.8, respectively).
- Ability to provide future surface flooding reductions through the rest of Barnes Crescent by extending the large diameter piping from the Carl Schenn Pond.
- Allows future storm trunk and piping improvements along 12 Avenue and within the identified drainage improvement service area.

- The Carl Schenn Park dry pond could provide attenuation and storage to develop the greenfield space between Peck Road and 21 Street without negatively affecting downstream areas.

The Carl Schenn Park pond's estimated potential service and impact area is approximately 23 ha. Ideally, the pond would be sized to accommodate and store the runoff from a 1:100 year, 24-hour rainfall event for the service area. Assuming a total 1:100 year, 24-hour rainfall amount of 92 mm and a conservative runoff coefficient of 0.60, the Carl Schenn Park detention pond should provide at least 13,000 m^3 of storage capacity. The pond bottom elevation should be set near and graded towards the invert elevation of the existing storm sewer manhole at 12 Avenue and Flory Place to maximize storage volume while allowing the pond to drain by gravity.

7.3.2 16 Street Trunk Twinning and North Stormwater Storage

Some of the most widespread and significant surface flooding in Humbolt are experienced along 16 Street from 9 Avenue to 12 Avenue. This stretch of road is a traplow that collects runoff from an approximately 50 ha catchment area, roughly consisting of the area north of 8 Avenue, west of 13 Avenue and east of Barnes Crescent. This catchment and flood zone currently relies solely on the capacity of 11 Avenue for drainage. As this trunk is undersized and drains nearly the entire northern (north of 8 Avenue) half of the city, floodwaters along 16 Street can exceed 0.60 m in depth and remain there for several hours after the rain has ended until the 11 Avenue trunk eventually drains them.

The City of Humboldt has begun twinning the 11 Avenue stormwater trunk to provide minor system drainage improvements in the city's northern half. These improvements have only been completed between the outfall to Water Ridge Pond and 4 Street. An additional 1,200 m of trunk twinning along 11 Avenue is needed until it reaches 16 Street and has any noticeable benefit on drainage there.

Previous stormwater modelling exercises (Catterall & Wright, 2020) showed that twinning the 11 Avenue trunk between 16 Street and Water Ridge Pond only improves the design capacity of the trunk to handle the 1:2 year minor design storm properly. The twinning of the 11 Avenue trunk with another 1050 mm line is considered a minor system improvement. Significant surface flooding is still expected in the 16 Street low area during major rainfalls even after the full twinning of the 11 Avenue trunk is completed.

A higher capacity flow route to a closer outlet/storage area is required from the 16 Street flood area to improve its major drainage. This need could be addressed by constructing a stormwater pond at the north end of 16 Street and connecting the pond to the 11 Avenue and 16 Street stormwater trunks at that intersection, as shown in Drainage Improvement Concept No. 2, Figure 7.1.

This upgrade would include twinning the existing 900 mm sewer along 16 Street from 9 Avenue to 11 Avenue with a 1200 mm pipe as well as redirecting, upsizing, and extending the existing 300 mm and 600 mm sewer along 16 Street from 11 Avenue to the north of Swain Crescent to a 1500 mm pipe. This upgrade also includes reconfiguring the existing catchbasins along 16 Street and installing additional catchbasins at the intersection of 9 Avenue and 16 Street.

Implementation of this drainage improvement will provide the following immediate and potential future improvements within its effective service area:

- Reduced surcharging of the 16 Street trunk and its lateral connections (Figure 6.3 versus Figure 7.2).
- Significant reductions in surface flooding along 16 Street and Centennial Crescent (Figures 6.7, 6.11, and 6.13 versus Figures 7.4, 7.6, and 7.8, respectively).
- Adding a stormwater retention pond at the north end of 16 Street and connecting it to the 11 Avenue trunk provides a secondary outlet at the upstream end of the 11 Avenue trunk by backflowing into the new storage area.
- Having two available outlets allows the 11 Avenue trunk to serve the immediate drainage needs of the north end of the city east of 12 Street.
- Once downstream capacity within the 11 Avenue trunk is available, the runoff stored within the 16 Street pond can be released at a controlled rate and drained to the Water Ridge Pond and East Flood Control Ditch.
- The 16 Street stormwater pond could also receive, store and attenuate runoff for an almost 60 ha future development area along the city's north boundary.

The estimated potential service and impact area of the 16 Street pond is approximately 140 ha of existing and future developed area. Ideally, the pond would be sized to accommodate and store the runoff from a 1:100 year, 24-hour rainfall event for the service area. Assuming a 1:100 year, 24-hour rainfall amount of 92 mm and a conservative runoff coefficient of 0.60, the 16 Street pond should provide at least 72,000 m^3 of runoff storage capacity. This stormwater storage facility could be implemented using either a dry pond or wet pond configuration but has been modelled and cost estimated assuming a dry pond.

7.3.3 5 Avenue Stormwater Storage Pond

The third drainage improvement concept explored and presented centres on reducing the amount of street flooding occurring in the southwest end of Humboldt's central commercial area along 5 Avenue between 10 Street and 13 Street. The existing minor drainage system mains between 5 Avenue and 8 Avenue and west of Main Street are overextended and undersized sewers, especially in the far west/upstream ends of those sewers (between 11 Street and 15 Street).

Due to these undersized mains, the minor systems within Drainage Concept Service Area No. 3 in Figure 7.1 are quickly overwhelmed with surface drainage conveying most runoff. The surface runoff patterns direct and collect this water in the traplow area along 5 Avenue, between 10 Street and 13 Street, causing flooding depths of up to 0.60 m that remain for several hours following heavy rainfalls.

The City of Humboldt identified two currently vacant commercial area lots bounded by 4 Avenue and 5 Avenue and 11 Street and 13 Street as potentially viable land to be purchased and utilized to divert and store runoff away from streets and adjacent land. A dry pond constructed at this location could be used to safely store runoff from the approximately 28 ha area, as shown by Drainage Concept and Service No. 3 in Figure 7.1. Using the same general storage facility sizing criteria as previous drainage concepts, approximately 15,000 m^3 of storage would be made available in this new pond to store the 1:100 year, 24-hour rainfall.

The physical space available as pond area from the two vacant parcels is 1 ha if the portion of 12 Street separating them is closed and developed into the pond. If the 5 Avenue pond is to be drained by gravity (without having to pump out), it will connect to the existing 525 mm storm sewer at

5 Avenue and 11 Street. The City of Humboldt storm sewer records shows the depth from street level to the storm sewer inverts is only 1.2 m (shallow pipe).

This ideal gravity drained configuration limits the amount of effective storage depth/volume of the 5 Avenue pond to approximately 1.0 m before water levels reach and begin ponding within the 5 Avenue and 11 Street intersection. These depth and area constraints result in a total available runoff storage volume of 10,000 m^3 for the 5 Avenue pond.

Modelling a 10,000 m^3 gravity-drained pond at this location resulted in significant street flooding reductions with no street ponding within the 5 Avenue traplow for a 1:100 year, 1-hour rainfall event and up to a 1:25 year, 24-hour rainfall event. However, a small amount (0.20 m) of street flooding could still result from a 1:100 year, 24-hour event depending on the rainfall intensity and pattern.

Despite the size and depth limitations of this proposed stormwater storage location, a significant reduction in flooding along 5 Avenue is still gained. The 5 Avenue pond eliminates flooding of its surrounding area except in extreme rainfall scenarios, where an overall significantly smaller amount of street flooding may result. The minimal flooding at the 5 Avenue and 11 Street intersection would still be easily passable for passenger vehicles.

Implementation of this drainage improvement will provide the following immediate and potential future improvements within its effective service area:

- Removal of surface/street ponding along 5 Avenue during most major rainfall and significant reductions for very heavy events (Figures 6.7, 6.11, and 6.13 versus Figures 7.4, 7.6, and 7.8, respectively).
- Adding a stormwater retention pond along the 5 Avenue storm sewer provides a secondary outlet for the sewer to allow surcharging runoff to backflow and outlet into the new storage area.
- Attenuation of runoff from an approximately 28 ha catchment area.

This upgrade includes constructing a detention facility (dry pond) on the north side of 5 Avenue between 11 Street and 13 Street. The dry pond is connected to the 5 Avenue storm sewer at 11 Street via a 600 mm pipe to reduce surcharging in the 5 Avenue sewer by offloading stormwater to the dry pond. This connection allows the pond to drain by gravity.

A block of 12 Street between 5 Avenue and 6 Avenue is proposed to be closed to maximize the storage volume available from the proposed pond. This block's existing 300mm storm sewer line would be abandoned/removed. The existing water and sewers would have insulation installed within the pond excavation area. Existing catchbasins would discharge to the new pond at the 6 Avenue and 12 Street intersection. The approximate capacity of this dry pond is 10,000 m^3 with an approximate surface area of 1 ha.

7.3.4 6th Avenue Stormwater Trunk and Outfall Upgrades

Drainage Concept and Service Area No. 4 in Figure 7.1 shows a combination of major/minor piping upgrades of the storm sewer along 6 Avenue between 1 Street and 5 Street and a southward extension of a drainage channel along 1 Street between 6 Avenue and Saint Augustine Cemetary.

Two 750 mm storm trunks along 6 Avenue and 7 Avenue converge into one 750 mm trunk at the 7 Avenue and 2 Street intersection. The combined 750 mm trunk flows east through private property to 1 Street and is discharged to an open channel along the south side of the cemetery. The channel flows east, crossing 102 Street and discharges to the East Flood Control Ditch.

The combined 750 mm trunk between 2 Street and 1 Street severely constricts runoff flows for the minor drainage systems that extend west from 2 Street along 6 Avenue and 7 Avenue. These minor drainage systems roughly drain the entire portion of the city south of 8 Avenue, north of 5 Avenue, east of 16 Street, and west of 2 Street (Areas 3 and 4 in Figure 7.1).

The proposed 6 Avenue trunk and outfall upgrades in Drainage Concept and Service Area No.4 work to remove the flow constriction from two 750 mm trunks feeding into one, provide major drainage improvements along 6 Avenue to mitigate flooding at the 6 Avenue and 5 Street intersection and to lay the groundwork for future extensions of minor and major drainage piping improvements in and west (upstream) of Area 4 in Figure 7.1.

Implementation of this drainage improvement will provide the following immediate and potential future improvements within its effective service area:

- Mitigation of surface/street ponding at the 6 Avenue and 5 Street intersection from major rainfall events (Figures 6.7, 6.11, and 6.13 versus Figures 7.4, 7.6, and 7.8, respectively).
- Separation and flow capacity improvement of the 6 Avenue and 7 Avenue minor system trunks.
- Ability to extend minor and major pipe drainage improvements further upstream from 2 Street that could reach as far west as 16 Street.

This upgrade involves improving the cemetery drainage channel and extending it south along 1 Street to reach the 6 Avenue and 1 Street intersection. A new section of trunk sewer will be installed along 6 Avenue between 1 Street and 2 Street to provide a new outfall for the 6 Avenue storm sewer network and separate it from the 7 Avenue network. This drainage concept also includes extending the 6 Avenue major drainage pipe for three (3) blocks west along 6 Avenue from 2 Street to mitigate flooding experienced at the 6 Avenue and 5 Street intersection.

7.3.5 South Stormwater Storage, Trunks and Channel Upgrades

Drainage Concept and Service Area No. 5 in Figure 7.1 is a conceptual level set of major drainage improvements and infrastructure that could be further developed to manage and mitigate flooding within an approximately 80 ha service area in the city's south. This area is generally defined by the CN railway, west of 3 Street, north of Saskatchewan Avenue and east of 13 Street.

The only minor/piped drainage infrastructure within the Area 5/south service area is undersized and overextended storm sewer lines along 2 Avenue and 3 Avenue that combine into one 525 mm storm sewer along 2 Avenue from east of 5 Street and its outfall east of 101 Street. If this span of the existing minor system were properly sized to meet the 1:2 year design storm for its upstream service area, it would be 750 mm in diameter, and for this trunk to meet the 1:5 year minor system design storm, it would be 900 mm in size.

Overland drainage is the principal means of managing runoff within this southern service area. The only drainage outlets from the area are via the limited capacity minor drainage system along 2 Avenue and 3 Avenue and the Highway 20 ditches (draining south). These outlets are not adequately sized and graded to remove runoff from the area effectively, and as a result, widespread surface ponding is occurring for major and minor rainfall events.

Simply increasing flow rates out of the south drainage service area to the East Flood Control Ditch is not recommended for two principal reasons. Firstly, these upgrades would require several thousand metres of large diameter storm sewer to be installed along multiple streets and would cost upwards of $10 to $15 million to complete. Secondly, stormwater conveyance to the portion of the East Flood Control Ditch south of the CN railway will result in more noticeable peak flow rates of runoff from the city and increased potential for downstream flooding in private lands/fields along the channel between Humboldt and Humboldt Lake. For these reasons, a major drainage concept for the south service area provides a means of directing, collecting, and attenuating runoff volumes within the area and controlling their release to the East Flood Control Ditch is recommended.

The largest ponding occurs in the south-central portion of the south service area around Saskatchewan Avenue and Highway 20 and is shown in Insert 7.1 below. This intersection and the area surrounding it are the lowest-lying elevations within the south service area and are the natural collection zone for runoff. The proposed major drainage improvement concept for the south service area centres on upgrading and developing engineered and controlled runoff storage near the Saskatchewan Avenue and Highway 20 intersection and then using conveyance improvement (ditches and large-diameter piping) to convey runoff to the new centrally located runoff storage area.

Insert 7.1: Existing Flooding in South Region of Humboldt in a 1:100 year – 24 hour Major Rainfall

A logical location for a new runoff storage area is within the undeveloped slough and greenfield area immediately east of Highway 20 between Saskatchewan Avenue and St. Dominic School. This new pond would collect and store runoff for approximately 80 ha of existing and future developed areas. Ideally, the pond would be sized to accommodate and store the runoff from a 1:100 year, 24-hour rainfall event for the service area. Assuming a 1:100 year, 24-hour rainfall amount of 92 mm and a conservative runoff coefficient of 0.60, the Highway 20 pond should provide at least 44,000 m^3 of runoff storage capacity. This stormwater storage facility could be implemented using either a dry pond or wet pond configuration but has been modelled and cost estimated assuming a dry pond.

The new pond would be drained by gravity via a new 525 mm storm sewer exiting from the southeast corner of the pond. The new main would run for 430 m until it reaches the exiting 1050 mm storm trunk along 1 Avenue S. A new 120 m long drainage channel section would be created by extending the 1 Avenue S drainage channel from where these mains meet. The existing span of the 1 Avenue S trunk would be removed along this stretch.

Once a centrally located stormwater storage facility is in place, major runoff drainage improvements could be made within the south service area. Conveyance improvements to the storage area could be completed in phases to target flooding areas as budgets allow. The list of conveyance improvements that were explored, modelled, and cost estimated within the scope of this SMA (shown in Figure 7.1) were:

- Installation of large diameter culverts under Highway 20 to allow ponded runoff and highway ditches on the west side of Highway 20 to drain into the new storage facility.
- Extending a 600 m long large-diameter pipe west from the storage facility along 1 Avenue and north along 12 Street to convey runoff from a traplow area in the 2 Avenue and 12 Street intersection.
- New drainage ditches along Saskatchewan Avenue (between Highway 20 and 10 Street) and 10 Street (between 1 Avenue and Saskatchewan Avenue) to intercept and direct street/surface runoff that collects along 1 Avenue to the new pond.

Other potential improvements that could be made (but not yet modelled or costed) to provide additional major drainage upgrades within the south service area include:

- Ditch and culvert upgrades along the Highway 20 corridor to better direct/convey runoff to the storage facility.
- Intersection regrading/adjustments within the 2 Avenue and Highway 20 intersection to direct runoff to the Highway 20 ditches.
- Extended large-diameter drainage piping north from the storage facility to provide major drainage improvements to the traplow ponding areas in the 4 Street, 5 Street, 2 Avenue, and 3 Avenue areas.

7.3.6 Highway 20 and 2 Street Intersection

The City of Humboldt has noted that the intersections of Highway 20/Main Street and 2 Avenue frequently flood during medium and heavy rainfall events. The 1D-2D model recreated and reported an approximately 0.3m ponding depth at the intersection for the three modelled major rainfall events (25yr - 24 hr, 100 yr – 24 hr and 100 yr - 1hr events). However, the City noted that the extents of flooding are often larger than what the model reports. As discussed below, this discrepancy is likely due to local-level grading issues within the intersection that are too small in scope to be accurately represented within the city-wide scale of the current modelling exercise.

Flooding in the intersection is caused by a stream of surface runoff generated and flowing from the areas north and northwest. Runoff flows south along Main Street/Highway 20 to 2 Avenue, where rises in the intersection grading, curb and surrounding area impede flows and create ponding. Ponding depths increase until high enough to overtop the rises and continue into the Highway 20 culvert system to the south.

Many of the highway culverts immediately downstream of the intersections are undersized and/or in poor condition (noted by ISL during the field data gathering survey). The City has noted that the Saskatchewan Ministry of Highways plans upgrades and improvements for the Highway 20 corridor between 2 Avenue and 1 Avenue South in 2022. This construction could offer the City and Ministry an opportunity to work together and upgrade and correct the Highway 20 culverts within the project corridor. Improved drainage along Highway 20 south of the intersection with 2 Avenue combined with the local-level redesign/correction of the intersection grading issues will provide significant surface water ponding at the intersection.

It is not within the scope and available data within this study to adequately formulate and test highly-detailed, local intersection grading improvements needed to mitigate flooding at the 2 Avenue and Highway 20 intersection. However, the 1D-2D model can provide vital information on the routes, flow rates, and runoff volumes that the improved intersection grading will have to accommodate.

7.4 Major Drainage Concepts Results Improvements

Developing and adding the five major drainage improvements to the City of Humboldt's stormwater management system will offer significant reductions in the depths, extents and duration of flooding that results from heavy rainfall events. These improvements were devised mainly to address and mitigate flooding observed within the six (6) selected priority flooding locations (highlighted locations in Tables 6.1 and 7.1). The concepts show average reductions in observed flood ponding depths of 50% and 40% for the 1:25 year and 1:100 year (respectively), 24-hour design storms at five of the six priority locations and benefits to nearby flood locations nearby or influenced by the improvements. These improvements are summarized in Table 7.2 below.

Table 7.2: Observed Flooding in 2D Model Results (24-hr Design Storm) for Existing Conditions vs. With Proposed Major Drainage Improvement Concepts

Map Location No.	Location	Ponding Depth			
		Existing Conditions		With Major Drainage Improvement Concepts	
		1:25 yr	1:100 yr	1:25 yr	1:100 yr
		m	m	m	m
1	Dust Crescent	0.40	0.43	0.26	0.31
2	Barnes Crescent	0.66	0.88	0.27	0.33
3	16 Street and 9 Avenue	0.69	0.80	0.30	0.40
4	17 Street and 7 Avenue	0.37	0.46	0.25	0.28
5	11 Street and 5 Avenue	0.67	0.72	0.06	0.20
6	9 Street and 6 Avenue[1]	0.25	0.32	0.25	0.32
7	5 Street and 6 Avenue	0.45	0.47	0.24	0.35
8	2 Street and 6 Avenue	0.30	0.37	0.18	0.24
9	12 Street and 2 Avenue	0.45	0.47	0.20	0.35
10	Main Street and 2 Avenue[1]	0.32	0.35	0.31	0.34
11	5 Street, 6 Street, and 7 Street – Between 2 Avenue and 3 Avenue[1]	0.45	0.49	0.45	0.49
12	Sunset Estate Mobile Home – 9 Street and Saskatchewan Avenue	0.55	0.61	0.3	0.3

[1] No dedicated drainage improvements were modelled for these flood areas within this SMA. Additional expansion of proposed concepts could be developed to provide mitigation in later modelling studies.

In addition to the significant reduction in ponding depths, the proposed major drainage concepts shorten the drawdown time needed for runoff at these locations to be completely drained (zero ponding) from the surface after rainfalls have subsided. Table 7.3 highlights how many of the existing flood zones are observed to remain in place for several hours after rains have ended due to the limited flow capacity of the existing minor system to drain them. Once major drainage improvements are implemented, most areas they service are completely drained within an hour after the peak rains.

Table 7.3: Observed Drawdown Time in 2D Model Results (24-hr Design Storm) for Existing Conditions vs. With Proposed Major Drainage Improvement Concepts

Location	Drawdown Time			
	Existing Conditions		With Major Drainage Concepts	
	1:25 yr	1:100 yr	1:25 yr	1:100 yr
	hr	hr	hr	hr
Dust Crescent	3.0	4.0	< 1.0	< 1.0
Barnes Crescent	>6.0	> 6.0	< 1.0	< 1.0
16 Street and 9 Avenue	3.0	4.0	1hr	1.0
17 Street and 7 Avenue	3.0	5.0	< 1.0	1.0
11 Street and 5 Avenue	> 6.0	> 6.0	< 1.0	< 1.0
9 Street and 6 Avenue	1.0	1.0	< 1.0	< 1.0
5 Street and 6 Avenue	3.0	4.0	< 1.0	< 1.0
2 Street and 6 Avenue	3.0	3.0	1.0	1.0
12 Street and 2 Avenue	> 6.0	> 6.0	< 1.0	< 1.0
Main Street and 2 Avenue	2.0	2.0	1.5	1.5
5 Street, 6 Street, and 7 Street – Between 2 Avenue and 3 Avenue	> 6.0	> 6.0	> 6.0	> 6.0
Sunset Estate Mobile Home – 9 Street and Saskatchewan Avenue	> 6.0	> 6.0	<1.0	<1.0

The proposed major drainage concepts also substantially decrease the number of buildings impacted by a ponding depth of 200 mm or more. Table 7.4 highlights the reduction in impacted buildings expected from the proposed major drainage concepts for the 1:5 year, 1:25 year,1:100 year, 24-hour storm events and the 1:100 year, 1-hour AES storm event.

Table 7.4: Number of Impacted Buildings in 2D Model Results for Existing Conditions vs. With Proposed Major Drainage Improvement Concepts

Return Frequency	Number of Impacted Buildings	
yr	Existing Conditions	With Major Drainage Concepts
1:5	47	17
1:25	100	45
1:100	158	66
1:100 (AES)	107	56

7.5 Major Drainage Improvement Concepts Cost Estimates

Table 7.5 summarizes the estimated costs required to design and construct each of the five (5) major drainage improvement concepts as previously described and shown in Figure 7.1. These estimates are based on unit rates and pricing that ISL has received for similar projects and work from recently closed tenders. A 30% contingency cost is also included with a 10% engineering cost to account for additional work items and scope that might arise within the subsequent preliminary and detailed design work. Detailed breakdowns of the work items, quantities and prices for each major drainage concept can be found in Appendix C.

Table 7.5: Drainage Improvement Concepts Cost Estimates Summary

No.	Major Drainage Improvement Concept	Construction	Engineering	Contingency	Total
			10%	30%	
1	Carl Schenn Park Storage Pond	$899,000	$90,000	$297,000	$1,286,000
2	16th Street North Storage Pond and Major Drainage Piping	$4,640,000	$464,000	$1,532,000	$6,636,000
3	5th Avenue Storage Pond[1]	$628,000	$63,000	$208,000	$899,000
4	6th Avenue Major Drainage Piping and Outfall Improvements	$1,627,000	$163,000	$537,000	$2,327,000
5	South Storage Pond, Ditches and Major Drainage Piping	$3,789,000	$379,000	$1,251,000	$5,419,000
	Total	**$11,264,000**	**$1,128,000**	**$3,720,000**	**$16,112,000**

[1] Estimate assumes pond construction at the proposed location does not require extensive environmental remediation from historical contamination. Thorough historical and environmental site assessments should be carried out before any parcels are purchased and full design work to ensure the environmental and economic feasibility of developing a storage pond.

These major drainage improvement concepts are independent of each other and can be implemented in any order and timeframe as budgets, demands and development dictate. Land control and purchasing costs we not included in these estimates. A breakdown and summary of the amounts of impacted properties estimated to be mitigated for the respective 25 yr and 100 yr design events of each of the major drainage improvements, their estimated cost and cost per mitigated (formerly impacted) property reduction is presented in Table 7.6 as a preliminary cost-benefit analysis.

Table 7.6: Drainage Improvement Concepts Cost-Benefits

Drainage Concept Areas Impacted Buildings Estimates, Reductions and Cost-Benefits										
Major Drainage Concept	Estimated Cost	25yr, 24 Design Event				100yr, 24 Design Event				Other Benefits, Notes
		Existing	Proposed	Reduction	Cost per Reduction	Existing	Proposed	Reduction	Cost per Reduction	
1 - Schenn Pond	$1,280,000	11	1	10	$128,000	16	1	15	$85,000	Relief outlet for 9 Avenue Trunk.
2 - 16 Street Pond	$6,640,000	12	0	12	$553,000	28	4	24	$277,000	Accommodates Future City Growth on the North end of the city. Reduces length of 11 Avenue trunk needing to be twinned.
3 - 5 Ave Pond	$900,000	12	6	6	$150,000	15	8	7	$129,000	Costs could increase if contaminated soils are present.
4 - 6 Street Outfall	$2,330,000	14	6	8	$291,000	19	11	8	$291,000	Future minor/major piping upgrades extensions to Central Commercial Area
5 - Highway 20 Pond	$5,420,000	29	14	15	$361,000	44	20	24	$226,000	Further flooding reductions are possible in the area northeast of the pond. Accommodating future development.

7.6 East Flood Control Ditch

The East Flood Control Ditch (EFCD) and the Water Ridge Pond on its upstream (north) end receive and attenuate almost all the runoff from Humboldt's northern half and convey nearly all generated runoff volume from the city for the 6.0 km span between its southern boundary and Humboldt Lake. The EFCD underwent major upgrades and improvements in 1995, which saw an engineered dyke and outlet control structure constructed on the south end of Water Ridge Pond to control and contain runoff in the natural slough. The 1995 upgrades included twinning and upgrading the seven culvert crossings along the EFCD alignment, cleaning up the ditch bottom and creating a defined channel cross-section with consistent side slopes.

ISL was provided with a set of the engineering drawings/plans for the 1995 EFCD project used as the base, along with the 2D city-wide stormwater model results to conduct a preliminary assessment of the capacity, performance, and recommendations regarding future/expanded use to support city-growth. A set of the 1995 Flood Control Ditch drawings is found in Appendix E.

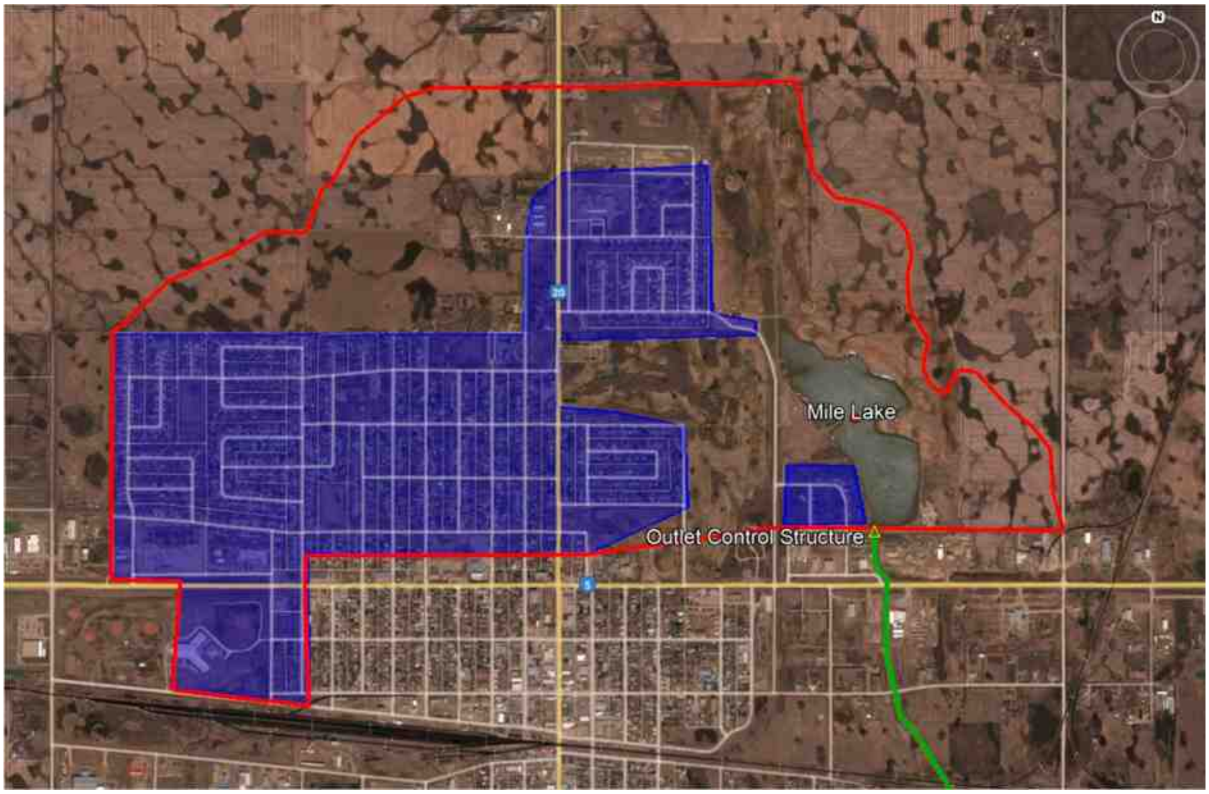
7.6.1 Water Ridge Pond Storage Capacity

Water Ridge Pond is a 15 ha natural low-lying and slough area situated in Humboldt's northeast corner. The natural slough was developed into a semi-engineered wet pond SWDF in 1995 by installing a southern dyke/embankment and an outlet control structure to contain and control water levels in the slough north of 9 Avenue. According to the 1995 EFCD project drawings, Water Ridge Pond has:

- A normal water level (NWL) of 562.0 m
- A 25-year high water level (HWL) of 562.5 m
- A 100-year HWL of 562.9 m (design storage depth = 0.90m)
- These design water levels result in available storage volumes within Water Ridge Pond of 75,000 m^3 for a 1:25 year event and 135,000 m^3 for a 1:100 year event.

The estimated existing catchment area for Water Ridge Pond is outlined in Insert 7.2 below. The total catchment area is 365 ha in size (red outline) and generally comprises 270 ha of the existing urban area (blue shaded area) and 95 ha of undeveloped/greenspace. An estimated composite major event runoff coefficient of C=0.41 was derived and used to estimate the following runoff volumes for the Water Ridge Pond:

- 1:25 year, 24-hour Event – 110,000 m^3, Storage Depth = 0.73 m
- 1:100 year, 24-hour Event – 138,000 m^3, Storage Depth = 0.92 m



Insert 7.2: Water Ridge Pond Total (Red) and Developed (Blue) Service Areas

The modelled water depths for Water Ridge Pond in the 2D model were reviewed for comparison with the calculated depths above and were:

- 1:25 year, 24-hour Event – Storage Depth = 0.65 m
- 1:100 year, 24-hour Event – Storage Depth = 0.73 m

The 2D model reports a lower water level since it accounts for the volume of water that concurrently drains to the EFCD over the simulation period. When modelled with zero outflows from Water Ridge Pond (as assumed in the higher calculated depths), the 1:25 year and 1:100 year, 24-hour event storage depths in the lake become 0.70 m and 0.90 m, respectively and is a good confirmation of the estimated and modelling results.

Using the conservative zero-outflow condition for Water Ridge Pond, these findings suggest that this SWDF is already operating under maximum design conditions. No new or significant redevelopment within the existing Water Ridge Pond service area should be made. However, new developments can be accommodated if the additional runoff can be completely stored and attenuated in place and upstream of Water Ridge Pond and then discharged at a controlled rate and time when water levels within the lake are suitable. This is the servicing strategy the FDA 8, the only FDA within the Water Ridge Pond service area in the city's north, utilizes with the proposed SWDF at the north end of 16 Street and Major Drainage Improvement Concept No.2 (Section 7.2.2).

7.6.2 EFCD Flows

The Combined 1D-2D city-wide model was used to estimate the peak flow rates and water levels within the EFCD between Water Ridge Pond and Humboldt Lake. It was found that under existing conditions, the peak flows in the EFCD within the city limits begin with a 0.5 m^3/s discharge exiting from the Water Ridge Pond outlet/control structure (typical for all significant rainfall events due to the configuration of the Water Ridge Pond outlet structure). The flow rate in the ditch increases as flow moves south through Highway 5, 6 Avenue, the CN Railway as more and more minor and major stormwater conveyance outfalls discharge into the ditch. The peak flow rate of runoff from Humboldt is reached after the 1 Avenue S trunk and ditch are discharged into the EFCD. Table 7.7 summarizes the peak flows observed in the 1D-2D modelling measured immediately after the 1 Avenue S channel.

Table 7.7: Peak Flows From Humboldt to EFCD

Model Condition	EFCD Peak Flows		
	1:5 yr	1:25 yr	1:100 yr
	m^3/s	m^3/s	m^3/s
Existing Conditions	1.7	2.5	3.0
With Major Drainage Concepts	2.2	3.2	3.7

Most of the major drainage concepts described and proposed in Section 7.2 add runoff storage/attenuation within the city. However, the piping conveyance increase and direct discharge to the EFCD from the 6th Avenue Stormwater Trunk and Outfall Upgrades (Major Drainage Concept No. 4 – Section 7.2.4) result in a noticeable rise in the flow rate from the City to the EFCD. These results show the important role of maintaining all suitable stormwater runoff storage and attenuation areas and adding additional SWDFs. Unless major improvements are made to the EFCD, just getting the runoff from the city into the channel faster is not a viable flood mitigation strategy.

The upper reaches of the EFCD within the city limits between Highway 5 and Tameling Drive are within low-lying, flatter wetlands and field space. The 6 Avenue, CN Railway and Tameling Drive road/rail embankments and culverts through them, along with the topography of the areas immediately upstream, resulting in a significant amount of runoff being stored and attenuated within the City. This attenuation is critical for keeping the runoff outflows from the city to the ECFD lower and manageable for the existing ditch.

The 1995 EFCD drawings noted design flow capacities of between 3.7 m^3/s and 5.8 m^3/s for the channel from the south limits of Humboldt to Humboldt Lake. These flow rates appear to have been set and determined on each section's open channel flow calculations based on the slope, bottom width, and side slopes. No information is provided on the design capacities of the culvert crossings.

A separate 2D model was developed for the EFCD to observe and evaluate its performance under various flow demands. The EFCD model spans the 6 km length of the channel between the Water Ridge Pond outfall and Humboldt Lake. The LiDAR data from the City of Humboldt was used to create a surface model mesh of the channel and the surrounding area of the channel (varying modelling scope offset of 100 m to 300 m). Culvert locations, sizes, and configurations from the 1995 project drawing set were assumed as the existing conditions of these facilities and modelled.

Modelled peak flows from Humboldt to the EFCD for current and future conditions range from 1.7 m^3/s from a 1:5 year minor rainfall under current conditions to 4.0 m^3/s for 1:100 year major rainfall with a major conveyance upgrade at the 6 Avenue outfall added. Therefore peak ECFD flow scenarios between 2.0 m^3/s and 4.0 m^3/s discharge from the city and through the ditch were modelled.

The plan and profile drawings show several locations where the channel high water level (HWL) is above the east and west channel top embankments. Water levels would be expected to spill out of the channel and flood adjacent low-lying areas at these types of locations. The 2D EFCD model results confirm and report several locations along the channel alignment. Fortunately, the City of Humboldt controls/owns nearly all of the land in which the EFCD channel runs and those expected to flood when the channel flows are under 3.0 m^3/s. However, 2D modelling shows that when flows approach and exceed 3.0 m^3/s, channel flow depths will become high enough to cause flooding in low sections of privately owned lands adjacent to the City's owned flood control ditch easement/lands. EFCD overflow flooding areas and impacted privately owned lands for channel flows between 2.0 m^3/s to 4.0 m^3/s are shown in Figure 7.12.

7.6.3 EFCD Recommendations

As Figure 7.12 shows, when flows to the EFCD ditch approach and exceed roughly 3.0 m^3/s, overtopping of the channel embankments will occur and encroach/affect adjacent private property. Table 7.2 shows that the channel's expected current and potential future flows are often between 3.0 m^3/s and 4.0 m^3/s.

Flows to the EFCD are largely limited or throttled by the undersized minor drainage piping. While the undersized minor drainage system currently provides a net benefit for the EFCD and the downstream lands by reducing peak flows in the channel, it does so at the expense of "storing" runoff in the city that often is in the form of localized flooding and property damage surrounding those areas. As the City of Humboldt works to improve and upgrade the capacity of its minor stormwater piping, peak flows to the EFCD will inevitably increase. However, except for the 1 Avenue trunk outlet along the City's southern edge, nearly all minor system outfalls to the EFCD are between Tameling Drive and (into) Water Ridge Pond. This upper reach of the EFCD attenuates and stores runoff upstream of the 6 Avenue, the CN railway, and Tameling Drive culvert crossings.

Maintaining and maximizing the amount of runoff stored and attenuated within the Water Ridge Pond and upper reaches of the EFCD north of Tameling Drive will be essential for accomodating the increased flows from the minor system outfalls as future improvements occur without upgrading the EFCD. Drainage upgrades that result or require increasing the flow capacity of the EFCD should only take place once all practical means of attenuating runoff within the Water Ridge Pond and the upper reaches of the channel are developed and exhausted. The 1D-2D model developed for this SMA will allow the designers of future minor and major drainage improvements projects to have the effects on the EFCD known and measures for accomodating them included.

As these findings and recommendations are based on the LiDAR topography and project records from the 1995 flood control ditch drawings, it may be beneficial to conduct an enhanced field investigation, survey, and capacity assessment of the EFCD. This study ideally would see:

- Surveying the locations, conditions, and elevations of the EFCD culverts.

- Surveying the full length of the existing channel with cross-sections made every 50 m (or tighter) to confirm that the design grades and profiles are still intact and document areas where deviations or undocumented alterations have been made (i.e. farm crossings).
- Updating the 1D-2D model with the gathered EFCD field data to improve its overall accuracy and reliability.

Should increasing the flow capacity of the EFCD become necessary, some methods that could be used to do so are:

- Widening the ditch bottom section.
- Flattening the side slope (widening the top of the channel).
- Adding and upsizing the culverts at embankment crossings.
- Lowering the ditch bottom.
- Raising and levelling off the top of the channel to have constant and adequate channel height; although, raising the channel height using embankments could prevent runoff from the adjacent lands from draining into the channel and cause ponding outside/adjacent to it.

8.0 Stormwater Master Plan for Future Growth

Humboldt is expected to see its population and developed area substantially grow over the next 20 years and beyond. This growth is largely expected to occur as outward growth onto surrounding lands. Figure 2.5 shows Humboldt's OCP plans for future and potential growth areas. Conceptual reviews and recommendations for stormwater management for accomodating growth within this SMA were limited to the areas identified as "Future" use. The concepts and recommendations made to accommodate the stormwater servicing need of "Future" growth areas could largely be applied to the "Potential" areas should earlier development of those areas be required.

Figure 8.1 shows nine (9) future development areas (FDA) within and immediately adjacent to Humboldt's developed area that will accommodate the City's immediate foreseeable growth needs. These growth areas total 370 ha. Once the FDAs are constructed, Humboldt's developed/urban area will increase from its current 580 ha to 950 ha (including road and rail ROWs), a more than 65% increase.

Table 8.1: Future Development Areas

FDA ID	Total Area	Land Use
	ha	
1	130	Residential, Light Commercial, Municipal Reserve, Institution
2	14	Residential
3	50	Residential, Highway Commercial, Municipal Reserve
4	8	Residential
5	8	Residential
6	10	Highway Commercial
7	60	Residential, Highway Commercial, Municipal Reserve
8	70	Residential, Light Commercial, Municipal Reserve, Institution
9	20	Highway Commercial, Industrial

It is noted that FDAs 6 and 7 in the city's northwest corner are already partially developed and are serviced by stormwater detention ponds. This SMA assumes that these ponds are sized and operated to meet the stormwater servicing requirements of their FDAs and do not require reviews and recommendations.

8.1 Future Development Areas Servicing

This SMA and previous stormwater studies of Humboldt's stormwater management infrastructure have detailed how and why Humboldt's minor and major stormwater management systems cannot accommodate this growth through simple extensions and direct connections to the existing network. Given their distances from and already limited capacity of the EFCD, directly discharging more area to the EFCD would require installing several kilometres of expensive, large diameter sewers and major improvements to the channel.

The key to providing adequate stormwater service to these future growth areas without worsening existing flooding and overwhelming the EFCD will be the use of stormwater detention facilities (SWDF). Depending on the size, phasing and layouts of the future growth developments, one or multiple SWDFs should be constructed within each FDA. Figure 8.1 includes potential locations for SWDFs within future growth areas based on preliminary reviews of the topography within each site and available outlet/drainage connections. The sizes, locations, and configurations of all future SWDFs will need to be confirmed and optimized based on the requirements, phasing, and criteria developed within those areas' preliminary and detailed design engineering work.

A summary of the SWDFs requirements and conceptual costs of construction of the future SWDFs shown in Figure 8.1 as dry and wet pond configurations are presented in Tables 8.2 and 8.3. Cost estimates for wet ponds that would have a normal water level (NWL) less than 2.0 ha were not included as the 2015 Saskatchewan Water Security Agency A Stormwater Guidelines recommend a minimum NWL size of 2.0 ha for wet pond facilities. Detailed breakdowns of the data, assumptions and cost breakdowns used to generate Tables 8.2 and 8.3 can be found in Appendix D.

Table 8.2: FDA SWDF's General Details and Conceptual Cost Estimates – Dry Ponds

FDA/ SWDF ID	Active Storage Volume	Bottom Area	Top/ Daylight Area	Construction Sub-Total (Rounded)	Contingency (Rounded)	Engineering Fees (Rounded)	Total Cost (Rounded)
	m^3	m^2	m^2		30%	10%	
1a	61,000	27,107	39,857	$1,676,000	$503,000	$218,000	**$2,395,000**
1b	12,000	4,551	10,498	$498,000	$149,000	$65,000	**$710,000**
2	8,000	2,835	7,787	$321,000	$96,000	$42,000	**$460,000**
3a	44,000	20,534	31,790	Included in Major Drainage Concept No. 6 - South			
3b	13,000	4,988	11,156	$447,000	$134,000	$58,000	**$640,000**
4	4,000	1,206	4,861	$217,000	$65,000	$28,000	**$310,000**
5	4,000	1,206	4,861	$217,000	$65,000	$28,000	**$310,000**
8	77,000	34,676	48,936	Included in Major Drainage Concept No. 2 - 16 Street Pond			
9	17,000	6,756	13,735	$622,000	$187,000	$81,000	**$890,000**

Table 8.3: FDA SWDF's General Details and Conceptual Cost Estimates – Wet Ponds

FDA/ SWDF ID	Active Storage Volume	NWL Area	HWL Area	Daylight/ Top Area	Sub-Total (Rounded)	Contingency (Rounded)	Engineering Fees (Rounded)	Total Cost (Rounded)
	m^3	m^2	m^2	m^2		30%	10%	
1a	61,000	30,300	37,700	43,700	$2,555,000	$767,000	$332,000	**$3,655,000**
1b	12,000	5,200	8,400	11,400	Too Small for Wet Pond Configuration			
2	8,000	3,200	5,800	8,300	Too Small for Wet Pond Configuration			
3a	44,000	21,400	27,600	32,800	$1,868,000	$560,000	$243,000	**$2,670,000**
3b	13,000	5,600	9,000	12,100	Too Small for Wet Pond Configuration			
4	4,000	1,400	3,200	5,200	Too Small for Wet Pond Configuration			
5	4,000	1,400	3,200	5,200	Too Small for Wet Pond Configuration			
8	77,000	38,800	47,000	53,800	$3,206,000	$962,000	$417,000	**$4,585,000**
9	17,000	7,600	11,400	14,900	Too Small for Wet Pond Configuration			

Minor and major runoff generated within each FDA would be directed and conveyed into SWDFs. Each SWDF would be sized to provide safe runoff storage from a 1:100 year, 24-hour major rainfall. The SWDFs will attenuate and keep runoff from their service/catchment areas from directly flowing into and overwhelming the existing stormwater systems of existing adjacent and downstream areas. Controlled and relatively lower-cost piped outlets from each SWDF would connect and drain them using the existing stormwater infrastructure. Outlet control structures and facilities will need to be implemented to ensure that SWDF drainage only occurs when the existing downstream areas have been adequately drained and can accommodate the SWDF outlet flows.

8.1.1 Future Development Area No. 1 – South West

This 130 ha FDA is located south of 3 Avenue between Peck Road to the west and 14 Street to the east. This area is currently undeveloped and is planned for a combination of Parks, Recreation and Open Space; Community Service; and Residential development. Due to its large size, it will likely be beneficial to provide minor and major stormwater drainage in this FDA utilizing multiple SWDFs. Two storage pond locations have been assumed in this SMA and are shown in Figure 8.1. SWDFs for FDA No.1 would be drained via piped connections to the existing 1 Avenue S and 14 Street minor stormwater trunks. A total runoff storage volume of approximately 73,000 m^3 will be required to store and attenuate runoff from the 1:100 year, 24-hour major event (92mm total rainfall, Runoff C=0.60).

8.1.2 Future Development Area No. 2 – 1 Avenue

This 14 ha FDA is located between 1 Avenue and 1 Avenue S and the east rear lots of properties along 14 Street and the west lots along Highway 20/Main Street to the east. This FDA is planned for residential development. Runoff could be managed by a single SWDF situated in either the northwest corner or along the south end of the area, as shown in Figure 8.1. The SWDF would be drained via a piped connection tied into the existing 1 Avenue S and 14 Street minor stormwater trunk. A total runoff storage volume of approximately 8,000 m^3 will be required to store and attenuate runoff from the 1:100 year, 24-hour major event (92 mm total rainfall, Runoff C=0.60).

8.1.3 Future Development Area No. 3 – Southeast

This 50 ha FDA consists of the area between 1 Avenue and Saskatchewan Avenue between Main Street and 14 Street and along 1 Avenue and north of 1 Avenue S on the east side of Main Street. Figure 8.1 illustrates how the northern portions (3a) would utilize the SWDF as proposed in Major Drainage Concept No.5 (Section 7.2.5), while a second SWDF would be constructed to serve the southern half of the FDA (3b). The 3b SWDF would be discharged to the south outlet ditch along 1 Avenue S.

The 3a SMWF would store 44,000 m^3 of runoff generated from approximately 55 ha of the existing city and the 25 ha FDA 3a. The 3b SWDF would provide the remaining 13,000 m^3 of runoff storage from a 25 ha FDA. These volumes for the proposed (3a) and future (3b) SWDFs are those required to store and attenuate runoff from the 1:100 year, 24-hour major event (92 mm total rainfall, Runoff C=0.60).

8.1.4 Future Development Areas No. 4 and No. 5 – Central

These two (2) 9 ha FDAs would see further residential development occur in the areas south of 6 Avenue, east of 5 Street, north of 2 Avenue and west of 101/102 Street. While two separate SWDFs are shown for FDA 4 and 5 in Figure 8.1, stormwater servicing for these adjacent growth areas could alternatively be serviced by one SWDF if an adequate major and minor flow route under the CN railway can be established. Runoff from these areas could also be directed and stored/attenuated in the low-lying and wetlands areas along the east flood control ditch so long as adequate studies and improvements are made to ensure no significant increases in peak flows to the flood control ditch, or unsafe attenuation depths would result.

This conceptual SMA assumes using the more conservative approach of separate SWDFs for each FDA connected and drained to nearby minor drainage piping. Each SWDF for FDAs 4 and 5 needs to provide 4,000 m^3 of active storage volume to hold and attenuate runoff from the 1:100 year, 24-hour major event (92 mm total rainfall, Runoff C=0.60).

8.1.5 Future Development Areas No. 6 and No. 7 – Northwest

These two FDAs straddle and are separated by Highway 5 on the west end. More than 70 ha of combined future growth will be accommodated within these FDAs. These areas are already partially developed and serviced by evaporative and irrigation SWDFs. Their elevations are too low to be drained by gravity storm sewers of the existing city east of them. These SWDF areas are also not permitted to outlet any additional runoff to their natural outlet direction to the northwest due to the drainage moratorium for the downstream Waldsea, Houghton, and Deadmoose Lakes Drainage Basins that have been in place since 2008. This SMA assumes that the SWDFs that already exist and are servcing FDA’s 4 and 5 have been properly sized and engineered for their operation to meet the drainage requirements of their respective service areas.

8.1.6 Future Development Area No. 8 – North

This 70 ha FDA is north of the existing city between Peck Road and Highway 20. Figure 8.1 illustrates how the SWDF as proposed in Major Drainage Concept No.2 (Section 7.2.2). The proposed north SWDF would be discharged/drained by the 11 Avenue trunk through a new large diameter trunk sewer along 16 Street.

Implementation of the proposed SWDF at the north end of 16 Street and connecting it to the existing 11 Avenue and 16 Street is recommended as the new storage area can be used to provide major drainage improvements to the city's existing drainage system (as outlined in Drainage Improvement Concept Section 7.2.2 - 16 Street Trunk Twinning and North Stormwater Storage).

The FDA 8/North SWDF would store 77,000 m^3 of runoff generated from approximately 70 ha of the existing city and 70 ha of future development area. This volume is required to store and attenuate runoff from the 1:100 year, 24-hour major event (92 mm total rainfall, Runoff C=0.60).

Alternatively, historical concept plans for developments in the City's north have been proposed using SWDFs that discharge to a new stormwater sewer line routed along a future western extension of 14 Avenue. This new storm sewer would drain east into the golf club drainage channel and onward to Water Ridge Pond. While this stormwater servicing concept is likely feasible and could be modelled in future detailed servicing studies for north-end developments, it will likely have higher cost implications due to:

- the longer distances between the developments and the golf course,
- drainage improvements required within the golf course,
- Several hundred meters of new storm sewer to be installed within an existing roadway along the existing 14 Avenue roadway from east of Highway 20, and the
- Crossing Highway 20.

This servicing concept does not provide drainage improvement capacity within the existing city area compared to the 16 Street north pond and major piping connection. For these reasons, ISL recommends utilizing a centralized SWDF near the north end of the existing 16 Street proposed in this study. However, other drainage servicing methods, such as the 14 Street storm sewer upgrades and extensions, maybe further explored if other factors such as development timing, sizes, location, and budgets require.

8.1.7 Future Development Area No. 9 – East Commercial/Industrial

A 20 ha FDA in Humboldt's east end south of Highway 5 and east of Bruce Street is shown in Figure 8.1. This area will consist of highway commercial and light industrial landuse. Figure 8.1 illustrates where a SWDF located in the southeast corner of FDA 9 would be located. A natural connected tributary system of sloughs, ponds, and streams located 350 m east of the FDA could receive and convey the attenuated runoff volumes from FDA 9 to Humboldt Lake. A drainage assessment of this receiving system will be required to ensure no significant impacts from the additional runoff within the natural tributary system. The east flood control ditch could also receive the attenuated runoff for the FDA 9 SWDF if discharging to the east is not feasible.

FDA 9 requires 17,000 m^3 of runoff storage to accommodate the runoff from the 1:100 year, 24-hour major event (92 mm total rainfall, Runoff C=0.90).

8.2 Future Stormwater Conveyance

A runoff release rate is required to establish an allowable release runoff rate for new development and thus properly size any future stormwater management facilities (SWDF) in the City. Doing so helps minimize the impact of increased runoff due to future developments by controlling flows through stormwater ponds.

As there is no existing Stormwater Master Plan or Master Drainage Plan for the area specifying an allowable release rate from future development, a pre-development runoff rate was estimated. This release rate is estimated using two methods:

- Release rate required to drain SWDFs from their 1:100 year HWL to normal/empty levels within 48 hours (as per City of Saskatoon wet pond design guidelines)
- The predevelopment release rate for the area drainage basin

8.2.1 SWDF 48-Hour Drawdown Release Rate

The 2021 City of Saskatoon Design and Development Standards Manual recommends that SWDFs have adequate drainage outlets so that water levels return to their NWL within 48 hours after a rainfall event has ended. When these criteria are applied to the various SWDFs discussed within this SMA and their respective storage volume requirements, an average release rate of 3.0 L/s/ha of service/catchment area will be suitable for draining them within 48 hours. This is only a conceptual estimate of the 48-hour drawdown release rate. Preliminary and detailed designs of individual SWDFs would require design and modelling to meet the specific conditions of each outlet.

If a 3.0 L/s/ha release rate were achieved/applied for the entire City of Humboldt through the use of extensive SWDF storage and attenuation, the 950 ha of existing and the future urban area would see a peak flow release rate to the EFCD of 2.90 m^3/s. This peak flow rate can already be accommodated reasonably well by the EFCD (as discussed in Section 7.4). Servicing Humboldt with and expanding stormwater management designs to the entire city that incorporate SWDFs, storage, attenuation, and controlled release rates significantly reduces the need for upgrades to the EFCD and greatly extends its useful service life.

8.2.2 Drainage Basin Predevelopment Release Rate

A second, more conservative estimate for a release rate for stormwater management designs and planning is presented below. An estimate of the pre-development release rate of the catchment area was determined using the Comparative Basin Formula. This release rate is often applied to communities and drainage areas with limited drainage outlets and runoff discharge points.

Available stations in the Water Survey of Canada were compared based on years of available data and proximity and relevance to the study area. Statistical analysis of the selected historical station data was then performed using HydroStat. The average of the passing distributions was used, and the rate for the study area was then correlated using the Comparative Basin Formula:

Historical hydrometric information was obtained through the Water Survey of Canada for the five selected gauging stations surrounding the City shown in Figure 8.2. The following sites were selected based on the number of years of available data as well as proximity and relevance to the study area:

- Ranch Creek Above Ranch Lake
- Lanigan Creek Above Boulder Lake
- Romance Creek Near Watson
- Ironspring Creek Near Watson
- Carrot River Near Kinistino

The annual peak discharge rates from each site were obtained from the Water Survey of Canada historical records. A statistical analysis of this data was then undertaken using the program Hydrostat to determine which statistical distribution best fit the data. This analysis can be viewed in Appendix F. With this information, the 1:100 year flow rates were recorded. The following formula is recommended by the Water Survey of Canada and was used to convert rates for the effective drainage area for each watershed upstream of the gauging station to a per hectare rate applicable to DMF:

$$Q_{proj} = Q_{peak}\left(\frac{A_{proj}}{A_{watershed}}\right)^{k}$$

Where, *k* is an exponent equal to:

1.0 for a uniform application over the watershed
0.8 for an area-based distribution over the watershed (recommended)

Assuming the City is approximately 1,400 ha (representing the City Limits), the calculated pre-development rate ranges are shown in Table 8.4. using an exponent of 0.8 and 1.0:

Table 8.4: Pre-Development Runoff Rates for Proximal Hydrometric Stations

Station No.	Reach	Location	Period of Record	Record Length[1]	Gross Area	$Q_{watershed}$	$Q_{projected}$	
							k = 0.8	k = 1.0
					km^2	m^3/s	L/s/ha	
05MA025	Ranch Creek	Above Ranch Lake	1986-2021	34	170	34.51	3.34	3.34
05JJ003	Lanigan Creek	Above Boulder Lake	1958-2021	49	2,280	212.57	2.58	2.58
05MA016	Romance Creek	Near Watson	1966-2021	51	506	53.05	2.15	2.15
05MA012	Ironspring River	Near Watson	1926-2021	57	588	59.15	2.12	2.12
05KA001	Carrot River	Near Kinistino	1919-2021	52	1,170	69.54	1.44	1.44

[1] Record length refers to the number of years that data was successfully recorded within the period of record. It should be noted that the number of records used in the statistical analysis may be less than this number to eliminate major outliers in terms of recorded values or large timeline gaps between records.

Based on these estimates, a stormwater release rate of 2.1 L/s/ha from Humboldt's drainage infrastructure would be suitable to establish a runoff discharge from its urban area to pre-development conditions. Implementing this drainage management criterion would offer benefits to the downstream watersheds. Applying and meeting this more stringent release rate would require constructing larger SWDFs that can accommodate runoff from consecutive rainfalls events that might occur before NWLs are reached and through the use of runoff reduction practices (discussed in Section 8.4)

It should be noted that similarly to the other sites, the Log-Pearson Type III distribution best fit the Carrot River station's data based on the 10% significance level of the Hydrostat analysis. This distribution best fits the station data graphically; however, due to a small number of outlying data points for the Carrot River station, the chi-squared goodness-of-fit test failed for this distribution. The analysis of each distribution and the graphical results are provided in Appendix F. It should be noted that lakes or other stormwater storage and stormwater drainage infrastructure located upstream of the data station can skew the collected data.

8.3 Future System Recommendations

Upgrades to the stormwater network for future development are generally limited to the construction of new SWDFs, outlet control structures, and connections to the existing system and/or overland outfalls. Preliminary considerations for stormwater conveyance and connections and discharge rates from future development areas are outlined in Sections 8.1 and 8.2 above. Detailed landuse and densities have not yet been determined for the FDAs. Therefore, high-level SWDF sizing was prepared based on the future land uses provided in the City's OCP (Humboldt, 2016) to provide the City with guidelines for strategies to implement throughout the development as the land use in the area evolves.

8.3.1 Recommended Design Guidelines for Future SWDFs

There are several hydraulic design criteria necessary to conceptualize future SWDFs. The following criteria were utilized to conceptually size SWDFs for each future land use type. Unless otherwise noted, these criteria are based on Saskatoon's Design and Development Standards Manual (Saskatoon, 2021).

- Allowable area release rate of approximately 3.0 L/s/ha applies to all future SWDFs, as discussed in Section 8.2. A more stringent release rate of 2.1 L/s/ha could also be adopted to reduce downstream stormwater impacts from the city.
- Minimum 80% removal of total suspended solids (TSS) for particle size distributions applied by the Canadian Environmental Technology Verification (CETV).
- New SWDFs are to be sized using a 1:100 year design storm with a maximum depth of 1.8 m and 2.0 m from the normal water level (NWL) to the high water level (HWL) for wet and dry ponds, respectively.
- New pipes are sized for 1:5 year design storm based on Saskatoon's IDF curve.
- A minimum permanent pool depth of 2.5 m is required for all wet ponds.
- Maximum interior side slopes of 3:1 to 7:1 (H:V) within the permanent pool, 7:1 between NWL and HWL, and 5:1 above HWL to freeboard level for wet ponds. It is noted that for this SMA, a 7:1 side slope was utilized throughout.
- A minimum side slope of 5:1 for all dry ponds.
- A minimum effective length to width ratio of 4:1 to 5:1 is required for all SWDFs.
- A minimum freeboard of 0.3 m above the HWL has been assumed for this SMA.

- Quality control is typically provided by an oil/grit separator, normally upstream of the SWDF.

The City of Humboldt will need to update, expand and further develop its existing set of Minimum Infrastructure Design Standards to address better and outline the standards that the City will require developers to meet. These standards will be needed to ensure that the recommendations and stormwater planning made and selected for adoption are clearly defined and implementable.

Regardless of this study's specific findings and recommendations, the City of Humboldt stormwater design standards should, as a minimum, adopt the requirements and recommendations within the latest version of the Water Security Agency's EPB 322 – Stormwater Guidelines document. Another set of design standards that ISL recommends the City of Humboldt could review and model future standards on is Part A4 – Storm Drainage System of the City of Swift Current Development Standards. The latest versions of the documents (as of the issuance of this report) are included in Appendix G.

8.3.2 Low Impact Development

Low Impact Development (LID) options may be integrated into Humboldt's stormwater design to reduce the overall runoff produced by developments. 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 overall developments improves the volumes and quality of water flowing to future SWDFs, resulting in a reduced required SWDF size as discussed above. In addition to this, LID implementation can reduce the total loadings to the receiving waters. As such, LID would support the development in adhering to the recommendation to reduce TSS as outlined in the Design and Development Standards Manual (City of Saskatoon, 2021).

8.3.3 Source Control Measures

Source control measures are becoming of increasing value in terms of stormwater management. A primary focus of these practices is sustainability in pollution prevention strategies. These strategies involve the reduction of runoff volume and rate of flow and the reduction of overall environmental impact in terms of water quality. Source control measures are physical measures located at the beginning of a drainage system and generally on private properties.

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
- Places of worship
- Schools
- Parks

It is recommended that the City employ a selection of technologies in conjunction with the SWDFs to achieve optimal stormwater runoff water quality and volume reduction. Source control options to be considered are summarized in Table 8.5.

Table 8.5: Source Control Practices

Source Control Practice	Description	Driving Forces
Evaporation Facilities	Large stormwater management facilities could be designed to promote evaporation. These could either be wet or dry ponds with designs governed by the continuous model simulation to ensure that adequate volumes can be evaporated annually. Near-zero outlet rates can often be achieved with emergency overflow provided for wet years.	• Relatively simple facilities to design • Eliminates up to 100% of runoff volume • Stormwater pollutants retained in the pond Highly applicable to residential, commercial or industrial areas
Stormwater Re-use/ Rainwater Harvesting	Stormwater could be captured in stormwater management facilities and used for non-potable uses. Stormwater could be used for irrigation. The larger the discharge area, the larger the volume reduction as evaporation could be considered over the net irrigated area, thus further enhancing the benefit of this stormwater volume reduction method.	• Irrigation water could be readily used with minimal if any, treatment • Potentially significant use of stormwater runoff • Stormwater pollutants retained by storage ponds • Highly applicable to both residential and commercial areas
Bioretention Areas	Stormwater is diverted into holding areas that allow for infiltration. Significant vegetation is planted in the area to provide additional quality treatment. Evaporation also contributes to volume reduction.	• Could work well upstream in subdivisions or low areas adjacent to the EFCD • Provides a high amount of volume/rate control • Provides a high amount of stormwater pollutant control by retaining pollutants within the bioretention area • Highly applicable to both residential and low-intensity 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. Ditch blocks are often installed to promote pollutant settling. Subdrains are often installed in soils with below 12.5 mm/hr infiltration rates.	• Provides a high amount of volume/rate control • Provides a high amount of stormwater pollutant control by retaining pollutants in the swales • Highly applicable to both residential, light commercial, and industrial areas
Adsorbent Landscapes	Stormwater runoff is reduced by promoting infiltration into the soil as runoff flows overland.	• Provides a high amount of volume/rate control

Source Control Practice	Description	Driving Forces
	This is often accomplished by designing for significant greenspace. Increased depth of topsoil and reduced soil compaction is also provided. This promoted infiltration can allow the soil to work like a sponge to absorb stormwater. However, the local geology may not be conducive to absorbent landscapes. A geotechnical report is required if this source control is to be implemented.	• Highly applicable for low-intensity commercial areas • Somewhat applicable for residential areas • Minimal maintenance required
Permeable Pavement	Stormwater runoff is reduced by promoting infiltration into pavements by providing a permeable surface. Stormwater is then infiltrated into the underlying soil or diverted to a storage tank for later use. However, the local geology may not be conducive to permeable pavement. A geotechnical report is required if this source control is to be implemented.	• Works well for parking lots in commercial and industrial areas and residential back lanes • Provides a high amount of volume/rate control • Reduces the size of stormwater management facilities downstream • Can be used as on-lot stormwater control for commercial and residential areas
Green Roofs	Stormwater runoff is reduced by using vegetated roofs. Stormwater is absorbed into a soil layer and then evaporated naturally or collected by a subdrain system.	• Works well for roofs of larger buildings (normally commercial and industrial) • Provides a high amount of volume/rate control, particularly for small events • Can be used as on-lot stormwater control for commercial/industrial areas

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. For vegetated practices, soil microbes decompose 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 8.6 summarizes the environmental performance of LID practices.

Table 8.6: 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]

Note: Adapted from Table I-3 - City of Calgary Source Control Practices Handbook (2007) and amended by TRCA/CVC (2010).

8.3.4 Typical Source Control Implementation Costs

Typical unit costs for BMPs are detailed in Table 8.7. Costs may vary depending on site-specific factors, including soil infiltration rates. 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 8.7: Typical Source Control Unit Costs

BMP Technique	Unit Construction Cost
Rainwater Harvesting (underground storage and irrigation)	\$310 to \$1,235 / m^3 stored
Green Roofs	\$150 to \$370 / m^2 roof area
Infiltration Trenches and Chambers	\$530 to \$680 / m^3 stored
Bioretention Facility	\$740 to \$930 / m^2 of facility (\$64,300 / imp. ha treated)
Bioretention Planters (contained within concrete curbing or urban container)	Bioretention Planter (small) \$1,235 to \$1,980 / m^3 treated Stormwater Tree Pits \$2,970 to \$4,200 / m^3 treated

8.4 Wetland Conservation and Protection

Generally, ISL recommends retaining reasonably permanent, large, and 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. These basins typically hold more water than other wetlands and significantly affect catchment hydrology. To infill them during development would displace this water and likely impact the overland flow dynamics, leading to flooding and 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, nutrient retention, and wildlife habitat. However, the impacts of their disturbance are anticipated to be less since there is a greater chance they were historically disturbed by cultivation. ISL recommends that during development, conservation of these wetlands be considered.

8.5 Erosion and Sediment Control

Water quality objectives have been established for Saskatchewan in the Surface Water Quality Objectives (Water Security Agency, 2015) document to minimize environmental impacts and support the health of the watersheds in the face of increasing development. During construction, the removal of topsoil and vegetation will expose subsoils that are more susceptible to erosion since they are not as compacted. Developments that increase runoff may also contribute to erosion if not properly managed.

Erosive agents, such as wind and water, can detach, entrain, and transport soil particles, thus causing erosion. This process is dependent on the cohesion and texture of soils and 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 erosion and sediment control (ESC) practices are not implemented, sediment and contaminant transport will occur, thus polluting downstream water bodies and potentially causing the following negative impacts:

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

The most effective and economical method of controlling erosion is at the source. This includes implementing methods such as controlling stormwater runoff (generally accomplished by stipulating maximum allowable area release rates) or stabilizing exposed soils. Potential options to mitigate the negative impacts of erosion are summarized in Table 8.8.

Table 8.8: Erosion and Sediment Practices

ESC Practices	Description	Driving Forces
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 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.	• Maximum feasible slope for implementation of approximately 8% and a minimum slope of 1% to 2% • Provides flow velocity reduction to reduce erosion • Provides water quality improvement

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
	• Turf Reinforcement Mats
		• Most applicable where erosion is the primary risk rather than water quality implications
		• These offer a typical erosion reduction of 95% to 99%
		• Straw Blankets:
		  • Ideal for short-term erosion control
		• Turf Reinforcement Mats:
		  • Recommended for additional shear resistance
		  • Ideal for more long-term erosion control

Rip Rap Outlet Protection	Riprap outlet protection slows runoff velocity, providing erosion-resistant ground cover that protects the underlying soil from erosion and stabilizes channel slopes. The most common placements for riprap include drainage channel banks and inlet and outlet structures, such as pond outlets, culverts, etc. A geotextile fabric or gravel underlay is placed before the riprap to separate it from the soil, redistribute forces, and facilitate drainage.	• Effective energy dissipator by reducing runoff velocity • Commonly included on drainage channel banks and at inlet and outlet structures, such as pond outlets, culverts, etc.

Note that the information found in this section has been taken from the Guidelines for Erosion and Sediment Control (City of Calgary, 2017).

9.0 Conclusions and Recommendations

The City retained ISL to complete a City-Wide Heavy Rainfall SMA. This SMA includes an assessment of the City's current stormwater infrastructure capacity and the City'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 for existing system upgrades and future system upgrades or expansions to accommodate future growth. This project intends to provide a road map to the City for assessing the needs of and options for existing system upgrades as well as the capability of the infrastructure to accommodate new development.

The objectives of completing the SMA include:

- Assessing existing drainage conditions and determining design criteria for the stormwater drainage system, including runoff rates.
- Providing an inventory of and analyzing existing natural drainage conveyance.
- Determining if any upgrades are required to the existing system to meet the municipality's needs and allow future growth properly.
- Developing stormwater infrastructure plans to manage increased runoff resulting from future development.
- Producing a stormwater management assessment that uses best management practices to minimize the effect on the natural hydrological and hydro-geological regimes and ensure the planned stormwater management system meets regulatory authority requirements.
- Providing a framework for future development and a quality control benchmark for future system design and Stormwater Management Reports (SWMRs).
- Providing cost estimates related to required infrastructure upgrades.

9.1.1 Existing System

Typically, the minor (piped) system is sized based on the 1:5 year event; however, a substantial portion of the system is considered under capacity during this event, with surcharging to the surface highlighted at many locations throughout the City. Similarly, many of the City's main trunk sewers are under capacity during the 1:2 year event, with various locations showing surcharging to the surface. Most notably, stretches of 2 Avenue, 3 Avenue, 5 Avenue, 6 Avenue, and 17 Street experience surface surcharging based on the model results and localized areas throughout the City.

These results highlight several areas of concern that have been observed by the City, including the area around Carl Schenn Recreational Park, the intersection of 6 Avenue and 2 Street, and the intersection of 5 Avenue and 11 Street. Continuing to improve the previously identified minor system piping network and outfalls, such as the efforts already underway to the 11 Avenue stormwater trunk, are recommended to continue with roadway surface improvements and as budgets allow. General improvements of the existing minor drainage system could also be optimized and improved by implementing major drainage system improvements, such as those outlined within this study.

The major (overland) system was assessed using the 24-hour duration storms for the 1:5, 1:25 and 1:100 year rainfall events. This was done to highlight the changes in surface ponding within the City and identify building impacts under these event frequencies. These surface ponding areas largely correlate to the surcharging locations shown in the 1D model results. Additional ponding areas were highlighted where the catchbasin inlet capacity might limit flows to the minor system and low-lying areas where an inlet to the minor system may not exist.

9.1.2 Major Drainage Improvements for Existing City Areas

Five major drainage improvement concepts that could provide major drainage system improvements across the city were developed and presented within the findings of this study.

The proposed major drainage upgrades for flood-prone areas of the city are summarized as follows:

- Major Drainage Concept No. 1: Carl Shenn Park SWDF
  - This upgrade involves a dry pond and proposed sewer connections to the existing stormwater system on Barnes Crescent, Dust Crescent, and 12 Avenue. The estimated cost of this upgrade is $1.29 million.

- Major Drainage Concept No. 2: 16 Street North SWDF
  - This upgrade includes twinning, upsizing, redirecting, and extending the existing sewer along 16 Street and a proposed retention facility (dry pond) on the north end of 16 Street. This upgrade includes upgrading existing catchbasins along 16 Street and installing additional catchbasins at 9 Avenue and 16 Street. The estimated cost of this upgrade is $6.64 million.

- Major Drainage Concept No. 3: 5 Avenue SWDF
  - This upgrade includes the implementation of a dry pond between 5 Avenue and 6 Avenue and between 11 Street and 13 Street. The dry pond is connected to the 5 Avenue sewer at 11 Street. The estimated cost of this upgrade is $899,000.

- Major Drainage Concept No. 4: 6 Avenue
  - This upgrade involves a drainage ditch east of 1 Street from 6 Avenue to the existing south of 7 Avenue and improvements to the existing ditch east to the existing channel. The existing sewer along 6 Avenue would be upgraded and extended east to discharge to the proposed ditch. A new culvert is proposed to connect the improved ditch across 12 Street and replace the existing culvert. The estimated cost of this upgrade is $2.33 million.

- Major Drainage Concept No. 5: St. Dominic School
  - This upgrade includes a new sewer along 12 Street and 1 Avenue from 2 Avenue to 11 Street and 1 Avenue from 11 Street to a proposed dry pond south of St. Dominic School. The dry pond outlets via a pipe to the existing ditch along the City's south boundary west of the existing 1 Avenue S outfall (OF262). New connections at Main Street are proposed to connect the existing ditches to the proposed dry pond and a culvert to tie the west ditch along Main Street to the dry pond. Additionally, catchbasins are proposed at 1 Avenue and 11 Street. A new drainage ditch is proposed along 10 Street and Saskatchewan Avenue south of 1 Avenue with a tie-in to the proposed dry pond. The estimated cost of this upgrade is $5.42 million.

9.1.3 Stormwater Management for Future Growth

A pre-development runoff rate is required to establish an allowable release runoff rate for new development and thus properly size any future stormwater management facilities (SWDF) in the City. Doing so helps to minimize the impact of increased runoff from future developments on the downstream watershed and environment by controlling flows through stormwater ponds.

As there is no existing Stormwater Master Plan or Master Drainage Plan for the area specifying an allowable release rate from future development, a pre-development runoff rate was estimated. A maximum recommended SWDF release rate of 3.0 L/s/ha of service/catchment area to meet the 48-hour drawdown time requirements of the City of Saskatoon's Stormwater Design and Development Guidelines (City of Saskatoon, 2021).

The Comparative Basin Formula determined an alternate pre-development release rate for the City of Humboldt. A pre-development release rate of 2.0 L/s/ha was calculated and could be adopted to provide future downstream benefits and reduce the runoff conveyance capacity requirements for the city.

Conceptual-level designs for locations, sizes and connectivity of future SWDFs for storing, managing and attenuating runoff from nine (9) future development areas (FDA) totalling 370 ha of city growth were developed and presented in Figure 7.12. Cost estimates and basic design parameters for dry pond and wet pond (where suitable) SWDFs were also presented in Appendix D.

A conceptual review of the East Flood Control Ditch (EFCD) was conducted and found it to generally meet the existing peak runoff discharges expected from the city, though a degree of spillover and temporary flooding of adjacent, privately owned farm/agricultural land is expected when the channel drains runoff from major rainfall events. Significant increases in direct runoff discharge (non-controlled/attenuated) to the EFCD are not recommended unless attenuation in its upper reaches within the city limits is further increased or upgrades in the conveyance capacity of the channel are made between the city and Humboldt Lake.

10.0 References

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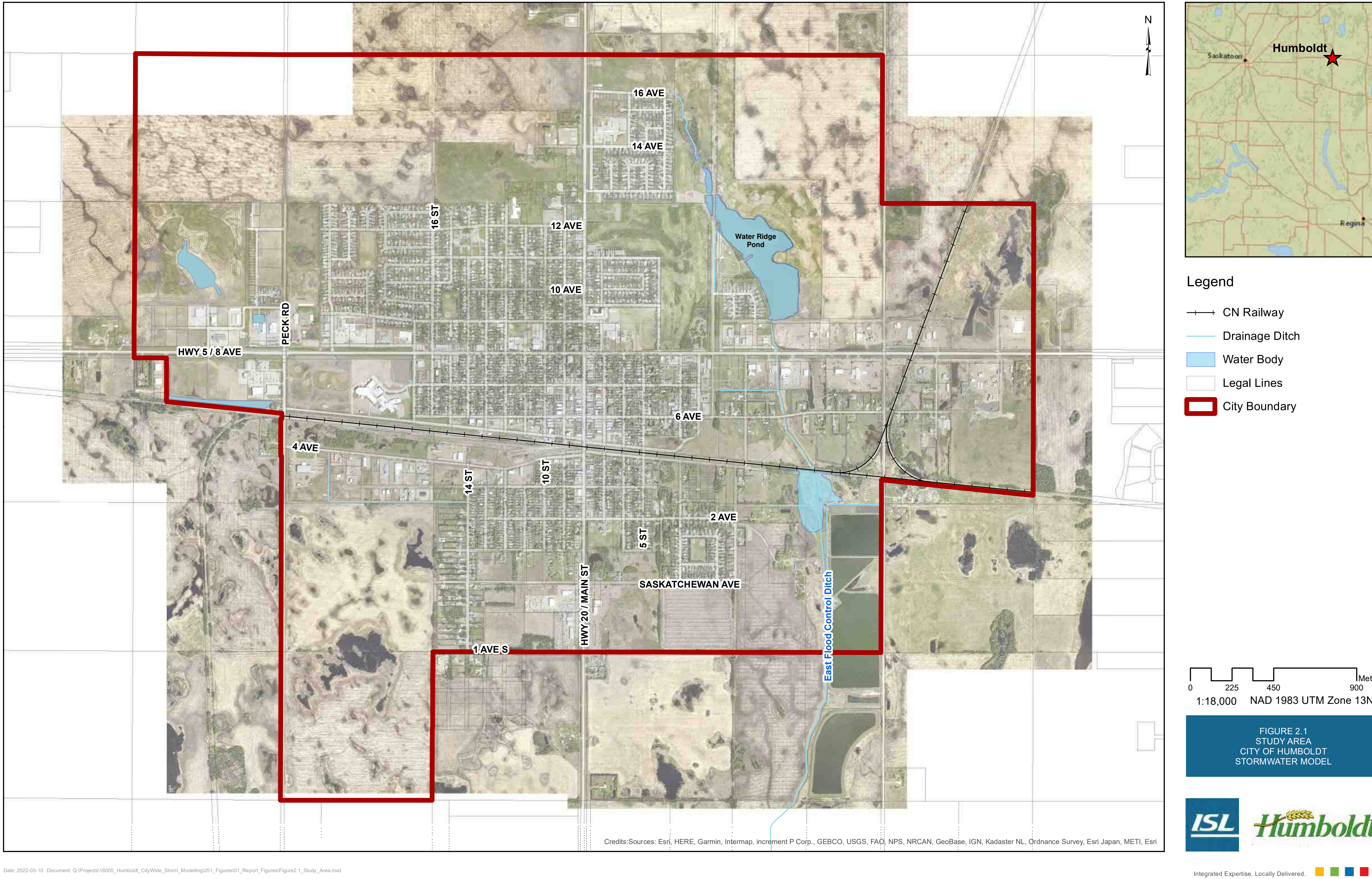

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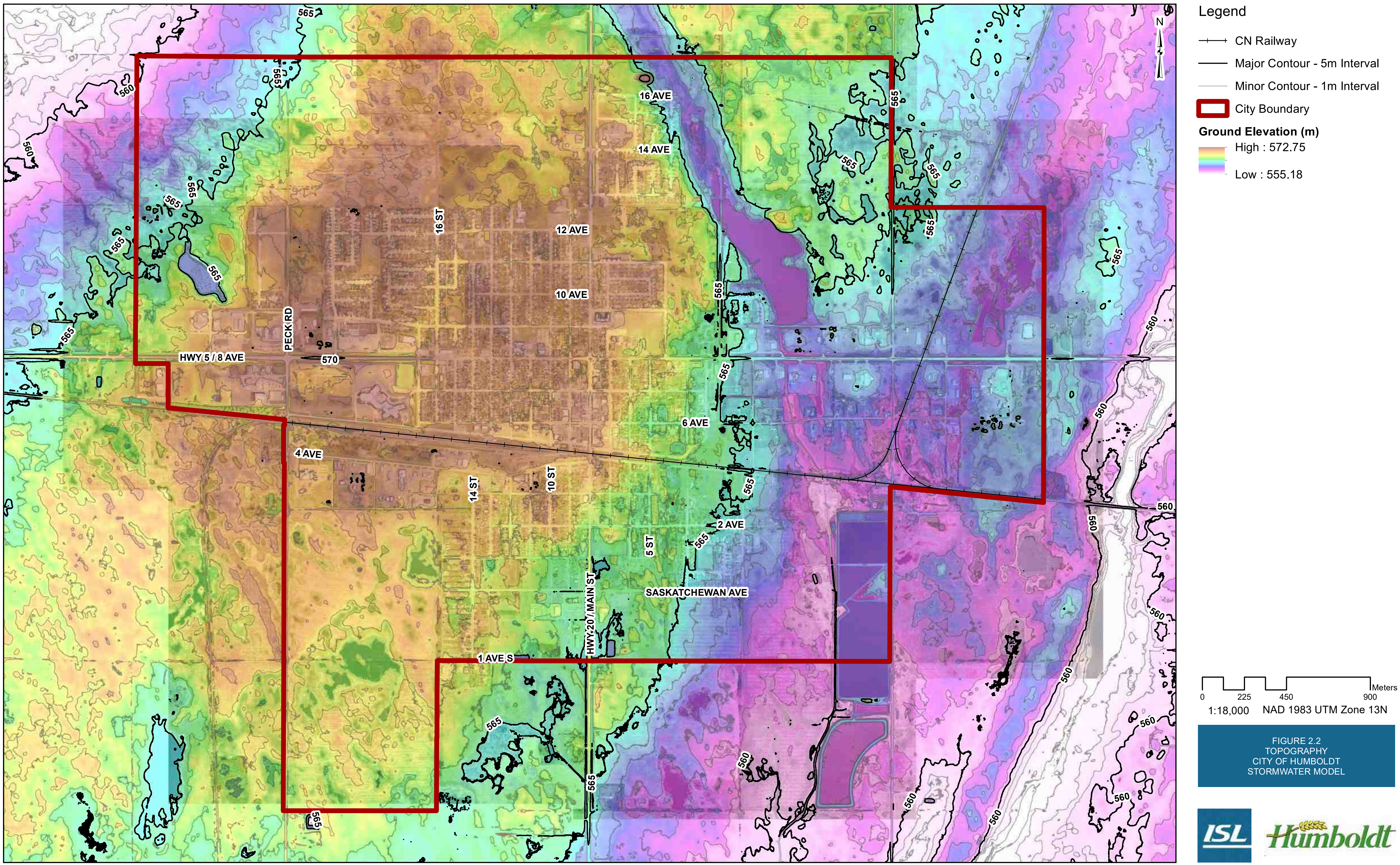
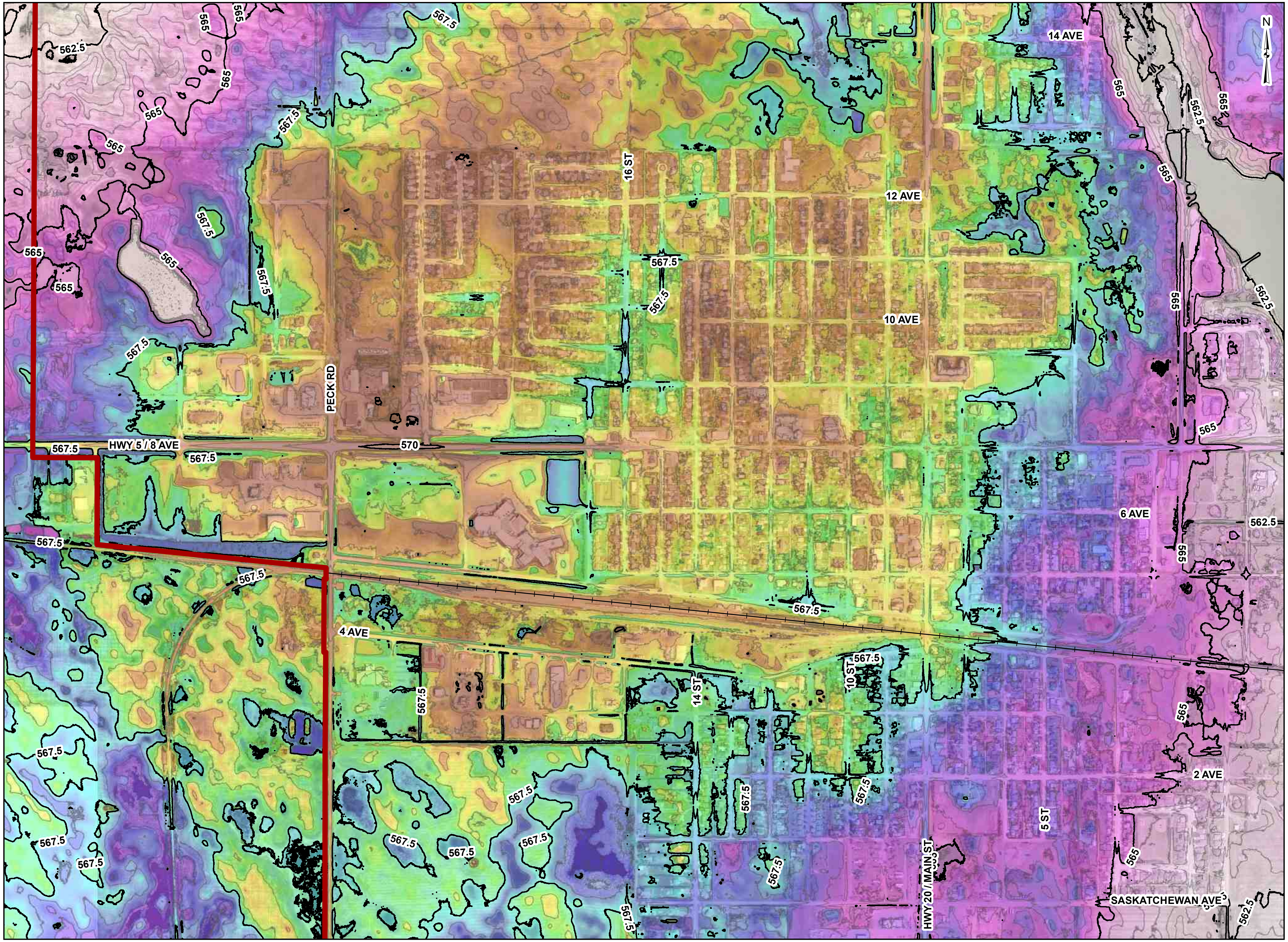


FIGURE 2.2
TOPOGRAPHY
CITY OF HUMBOLDT
STORMWATER MODEL

ISL

Humboldt



Legend

- CN Railway
- Major Contour - 2.5m Interval
- Minor Contour - 0.5m Interval
- City Boundary

Ground Elevation (m)

High : 572.1

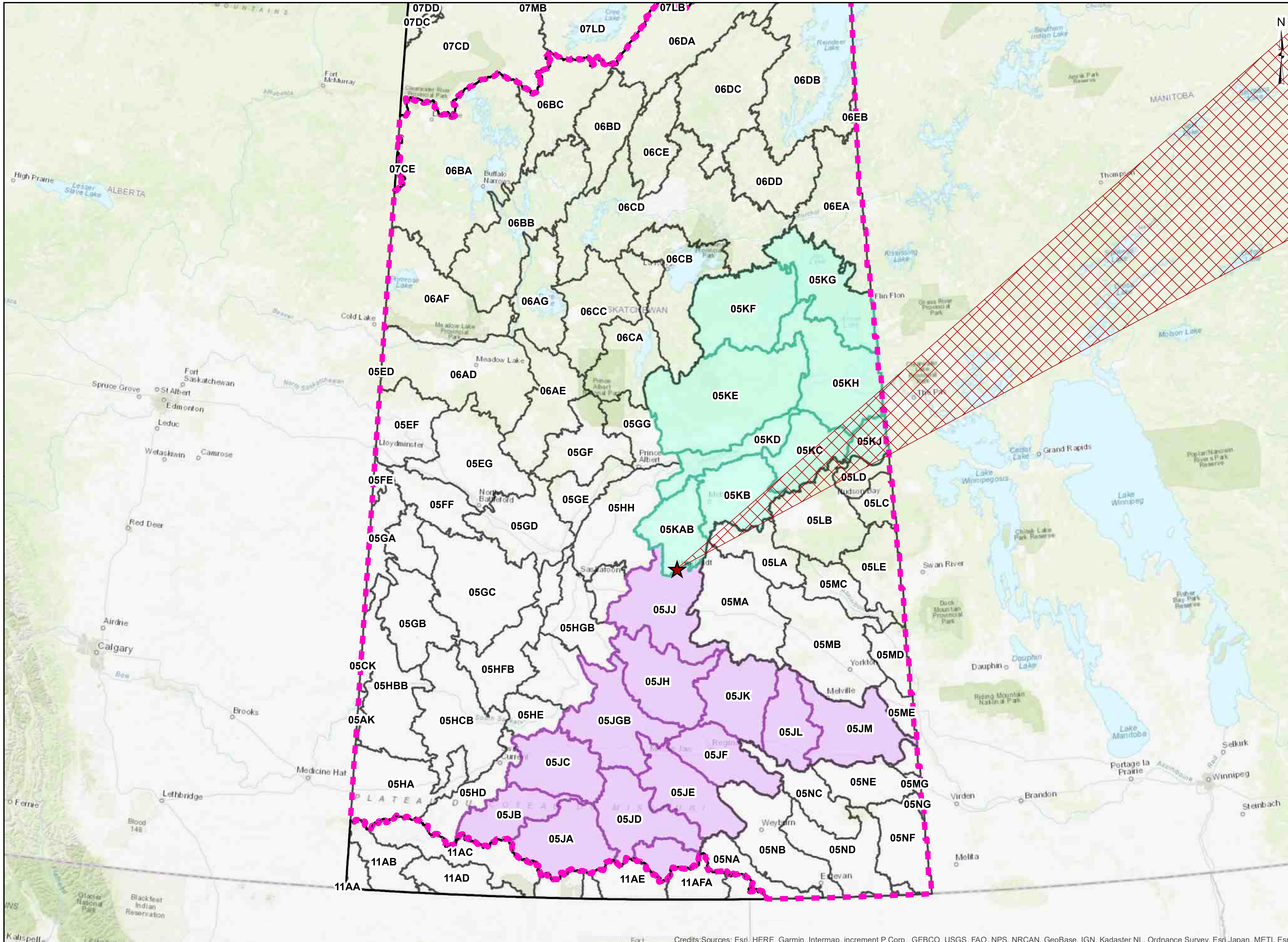
Low : 561.29

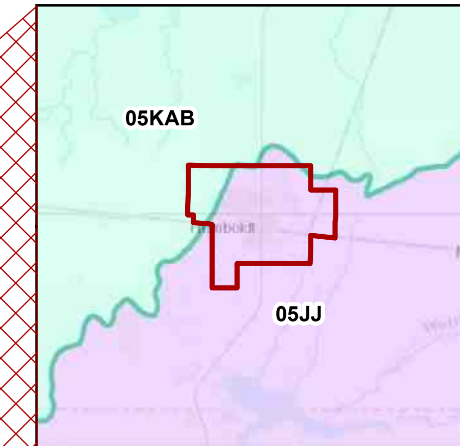
0 125 250 500 Meters

1:10,000 NAD 1983 UTM Zone 13N

FIGURE 2.3
TOPOGRAPHY - CITY CENTRE
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt





Legend

City Boundary

Watersheds

Qu'Appelle River

Saskatchewan River

Remaining Watershed Regions

Continental Drainage Basin

Nelson-Churchill (Hudson Bay)

Mackenzie (Arctic Ocean)

Mississippi (Gulf of Mexico)

0 50,000 100,000 200,000 Meters

1:4,000,000 NAD 1983 UTM Zone 13N

FIGURE 2.4
WATERSHED BOUNDARIES
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

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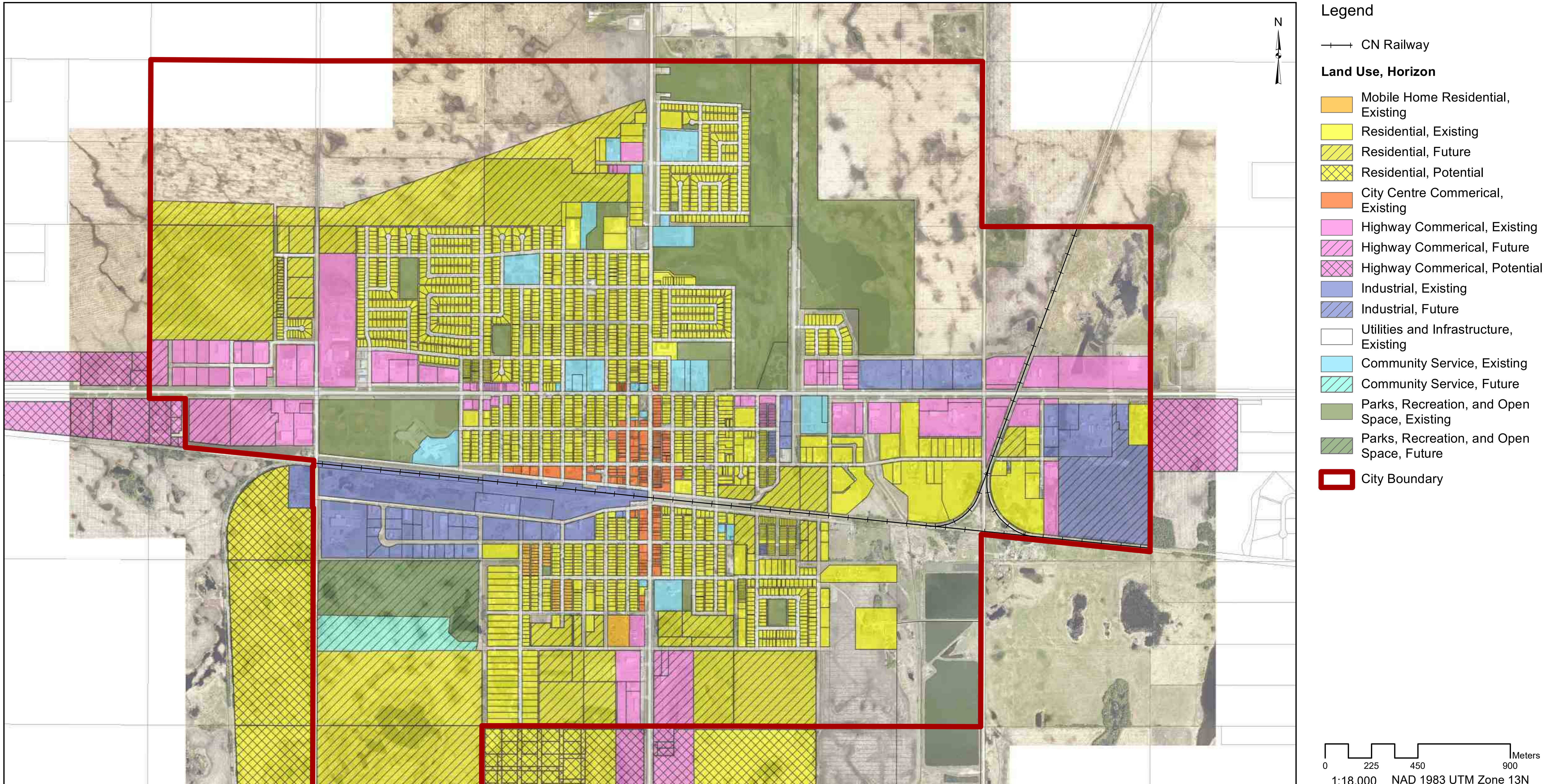

FIGURE 2.5
LAND USE
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

Date: 2022-03-04 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure2.5_Land_Use.mxd

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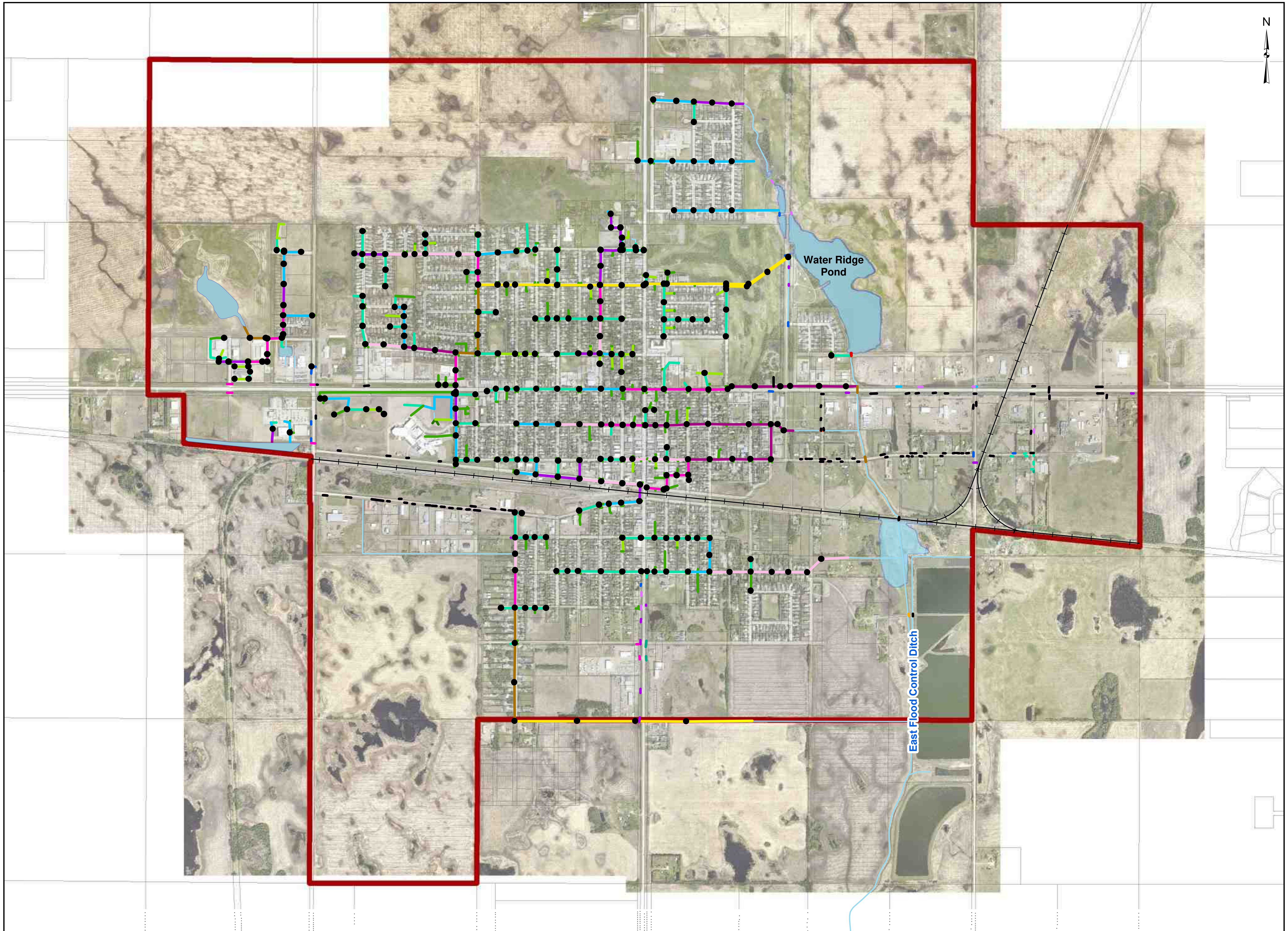

Legend

- Manhole
- CN Railway
- Drainage Ditch

Pipe Diameter (mm)

- 150
- 200
- 250
- 300
- 350
- 375
- 400
- 450
- 500
- 525
- 600
- 750
- 800
- 850
- 900
- 1000
- 1050
- 1200
- Unkown
- Water Body
- City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 3.1
EXISTING PIPE DIAMETER
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

Date: 2022-03-10 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure3.1_Ex_Pipe_Diameter.mxd

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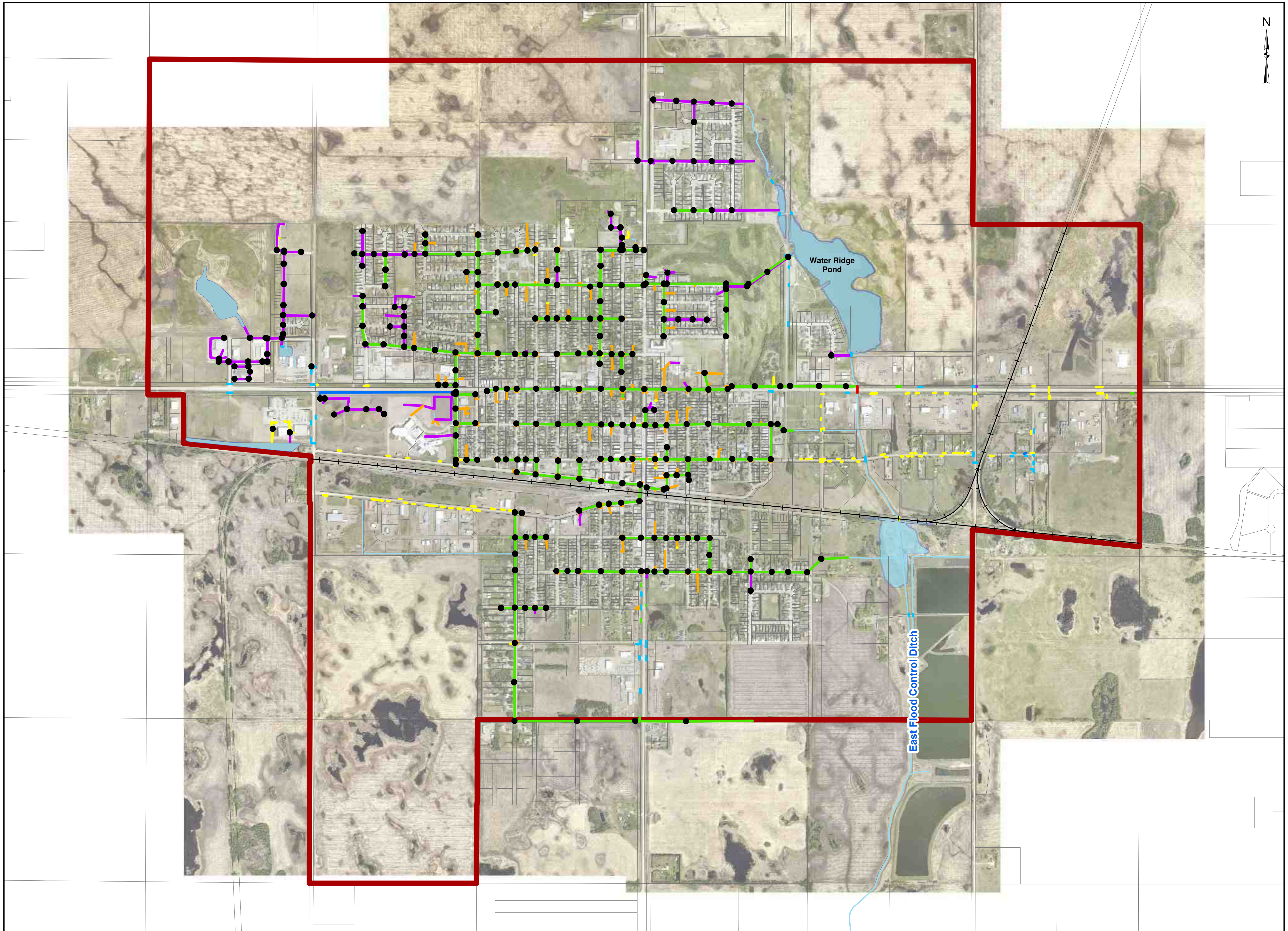


Legend

- Manhole
- CN Railway
- Drainage Ditch

Pipe Material

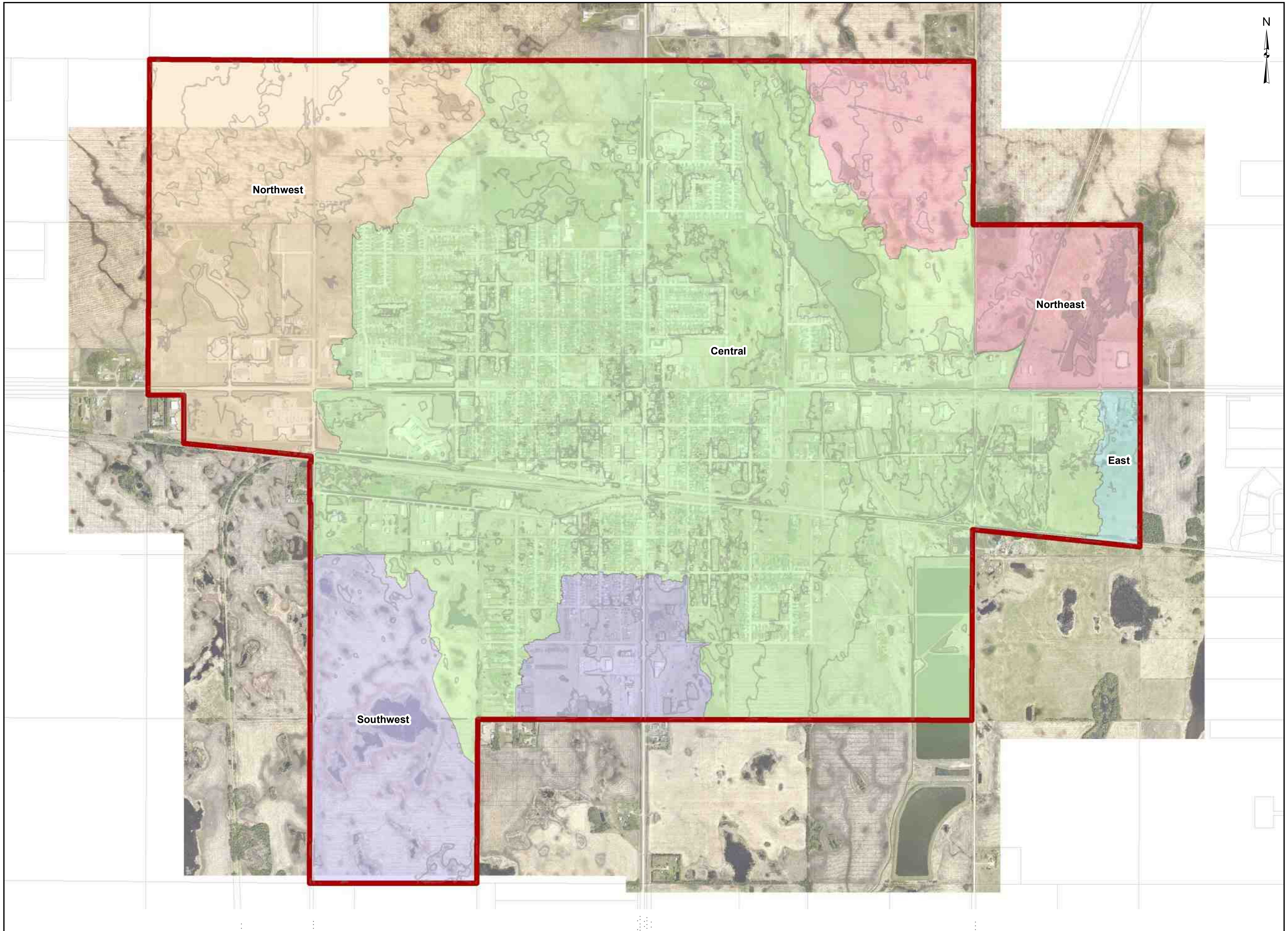
- Concrete (CONC)
- Corrugated Steel (CSP)
- High-Density Polyethylene (HDPE)
- Polyvinyl Chloride (PVC)
- Reinforced Concrete (RCP)
- Steel (STL)
- VCT
- Unknown
- Water Body
- City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 3.2
EXISTING PIPE MATERIAL
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt



Legend

Contour - 2m Interval

Drainage Basins

- East
- Northeast
- Northwest
- Central
- Southwest

City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 3.3
EXISTING SYSTEM
DRAINAGE PATTERNS
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

Date: 2022-03-14 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure3.3_Ex_Drainage_Patterns.mxd

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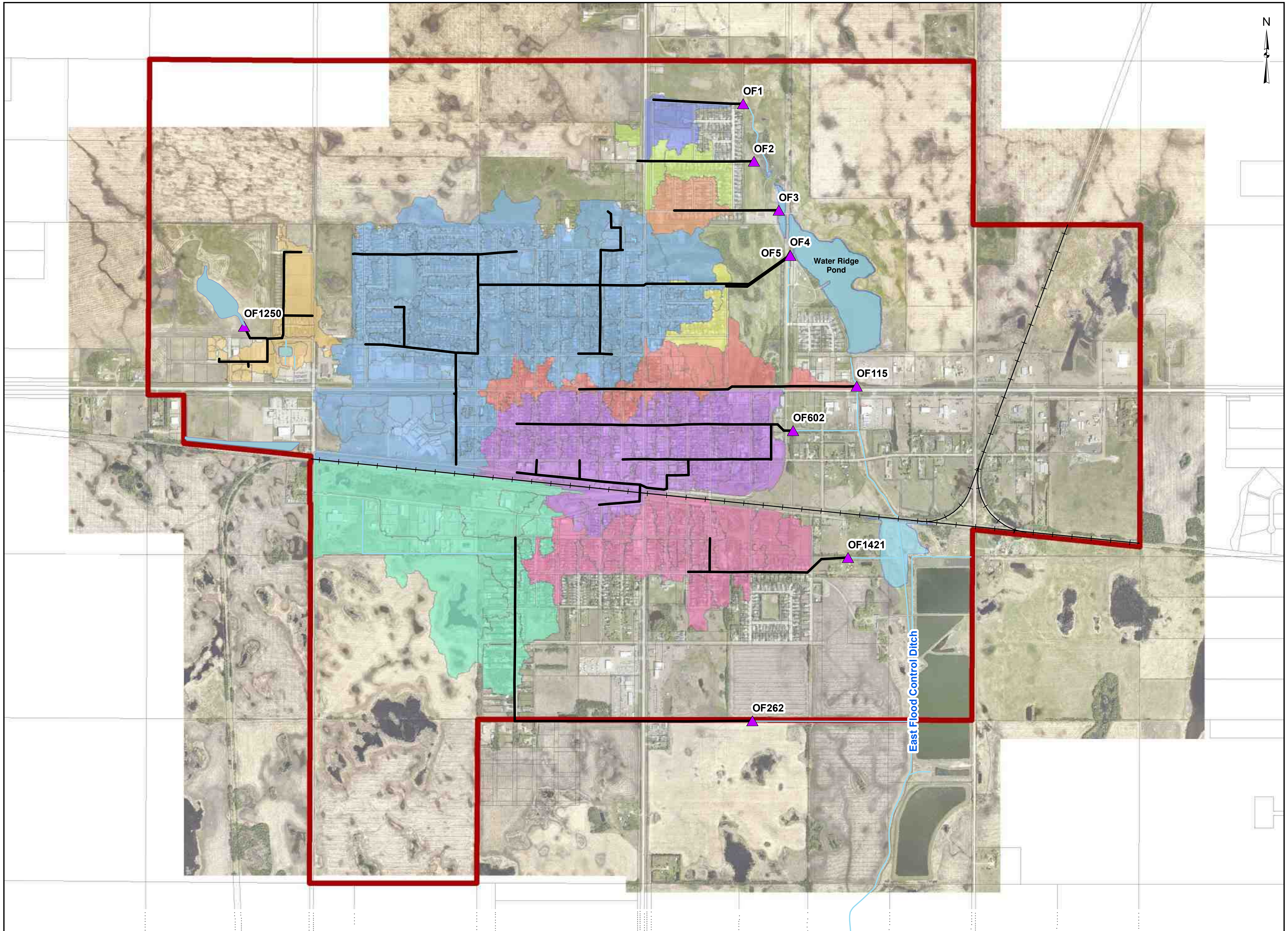

Legend

- Outfall
- Existing Pipe (Greater than 300mm Diameter)
- CN Railway
- Drainage Ditch
- Water Body

Outfall ID

- OF1
- OF2
- OF3
- OF4
- OF5
- OF115
- OF262
- OF602
- OF1421
- OF1250
- City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 3.4
EXISTING SYSTEM
SUBCATCHMENTS
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

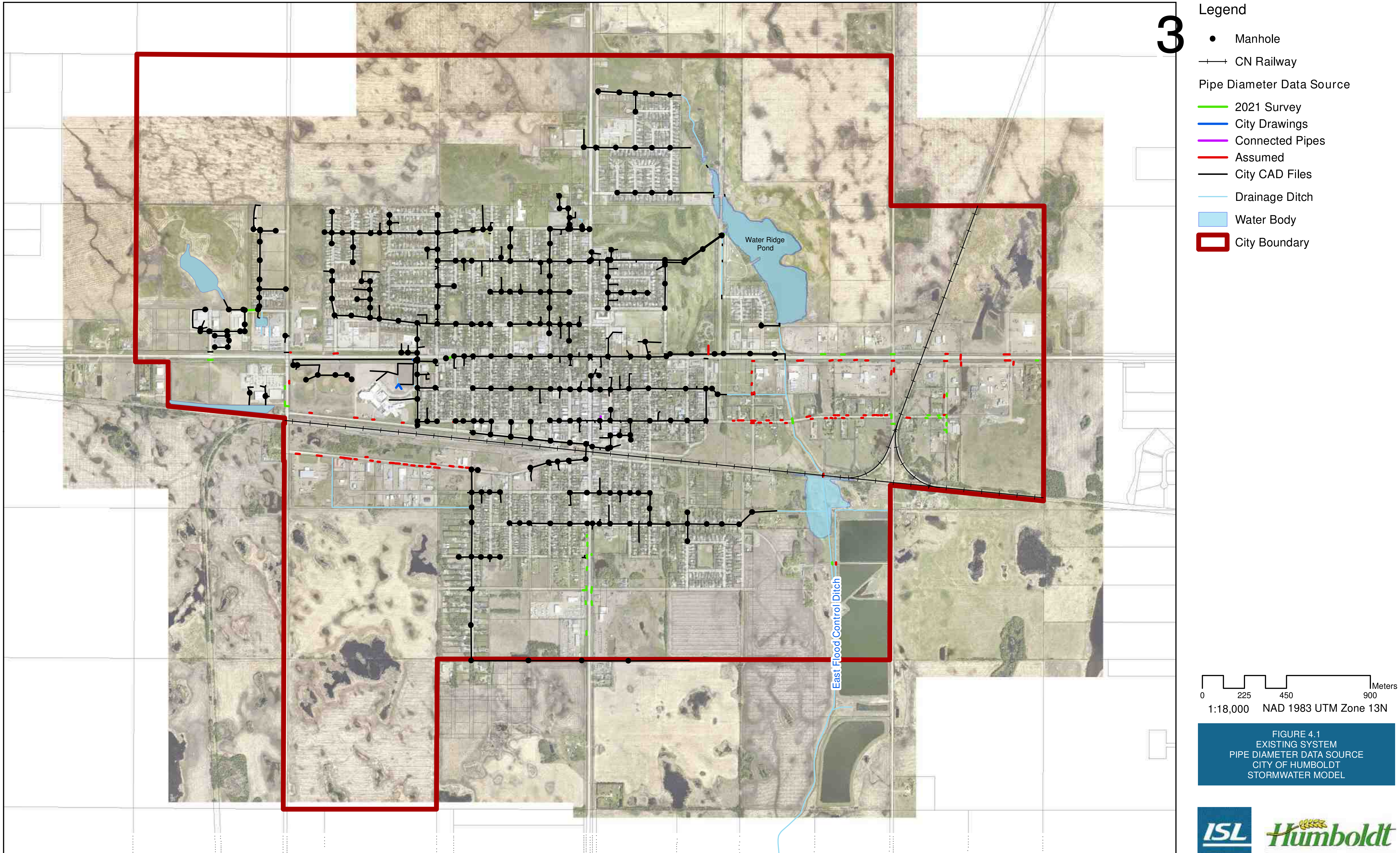

FIGURE 4.1
EXISTING SYSTEM
PIPE DIAMETER DATA SOURCE
CITY OF HUMBOLDT
STORMWATER MODEL

Date: 2022-03-10 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure4.1_Ex_Pipe_Diameter_Assumptions.mxd

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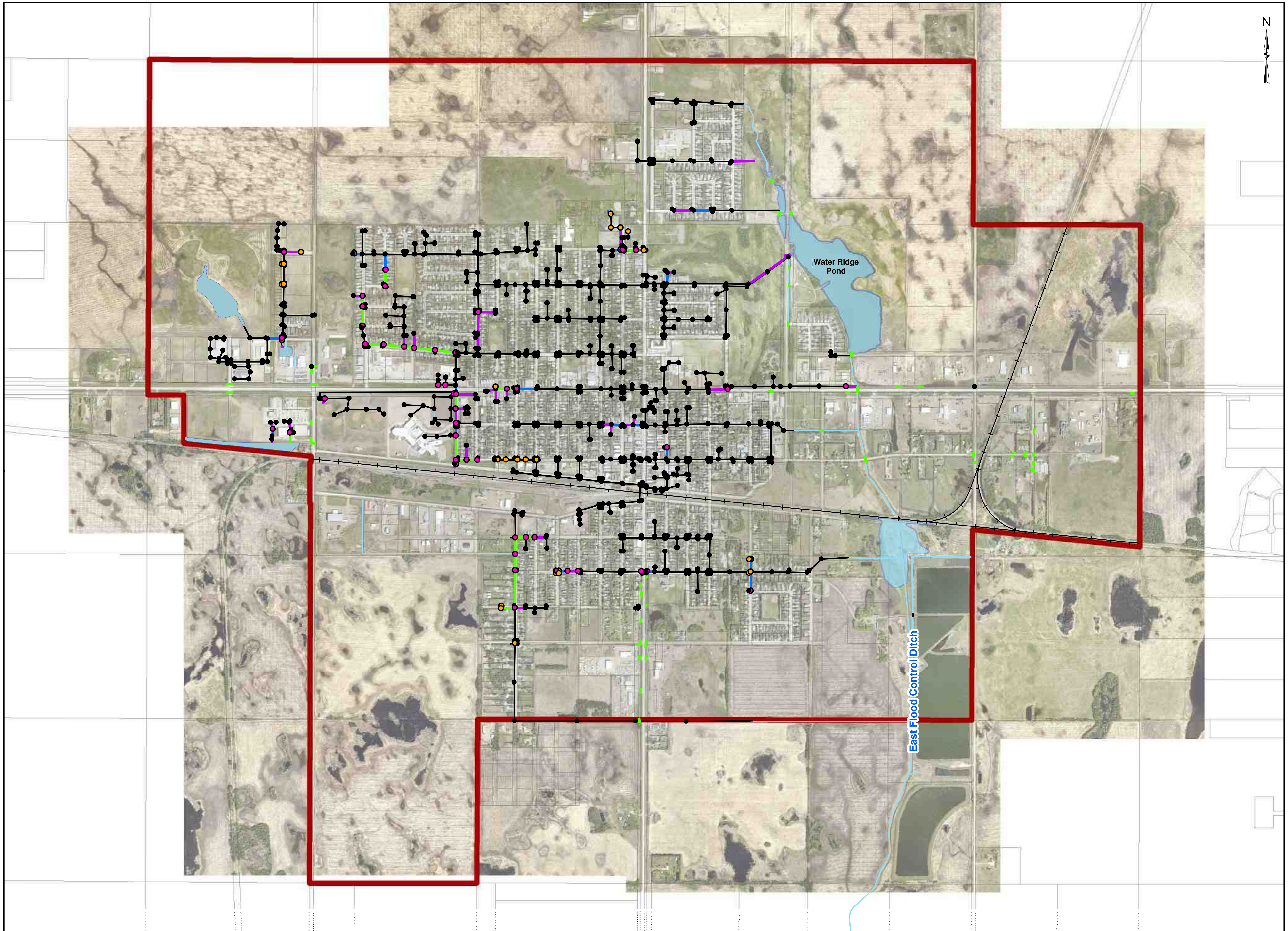


Legend

Node Survey Status

- Surveyed
- Surveyed Rim and Location Only
- Not Surveyed

Link Survey Status

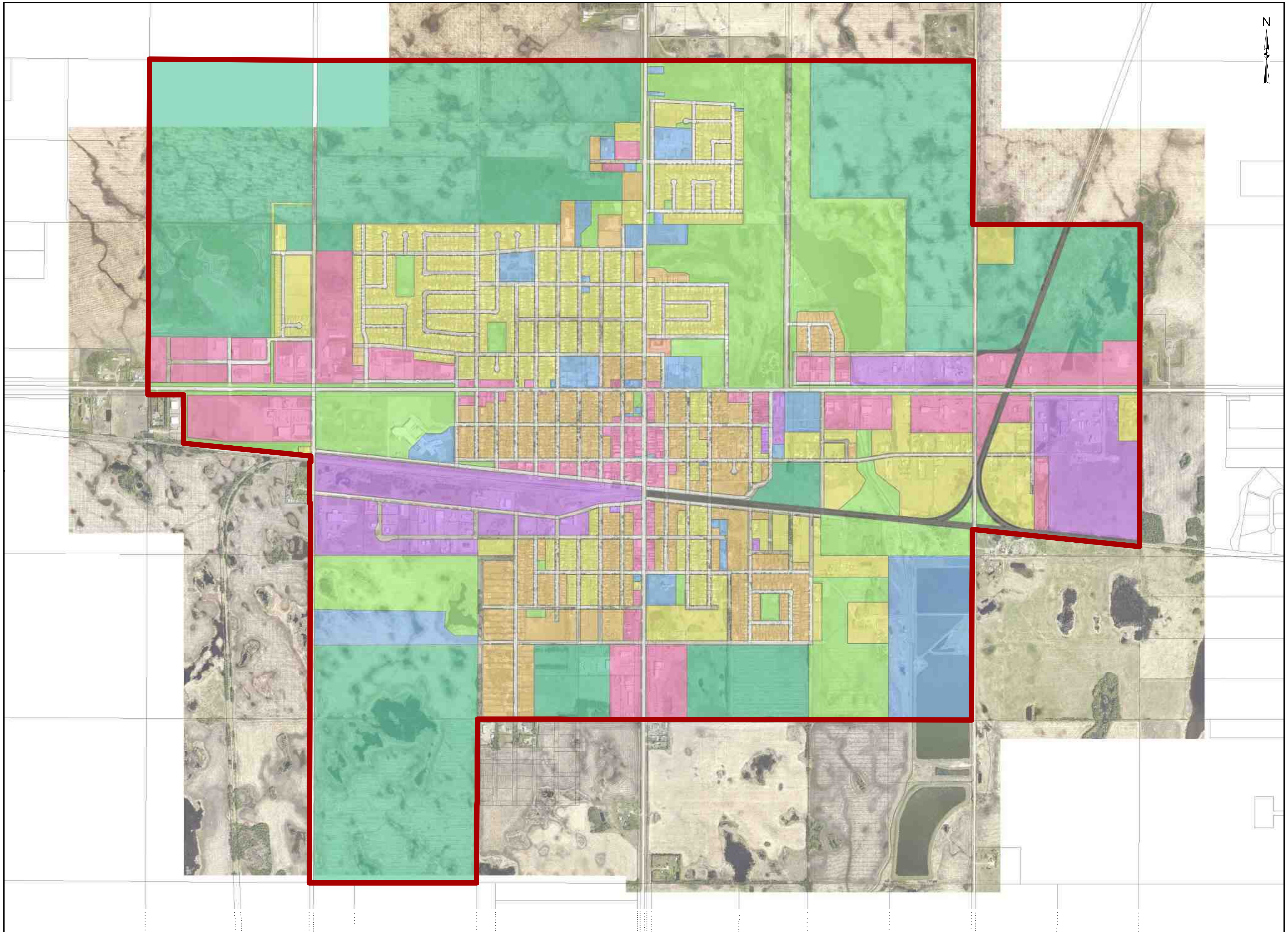
- Surveyed Upstream and Downstream Inverts
- Surveyed Upstream Invert
- Surveyed Downstream Invert
- Not Surveyed
- CN Railway
- Drainage Ditch
- Water Body
- City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 4.2
EXISTING SYSTEM
SURVEYED INFRASTRUCTURE
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt



Legend

Existing 2D Land Use

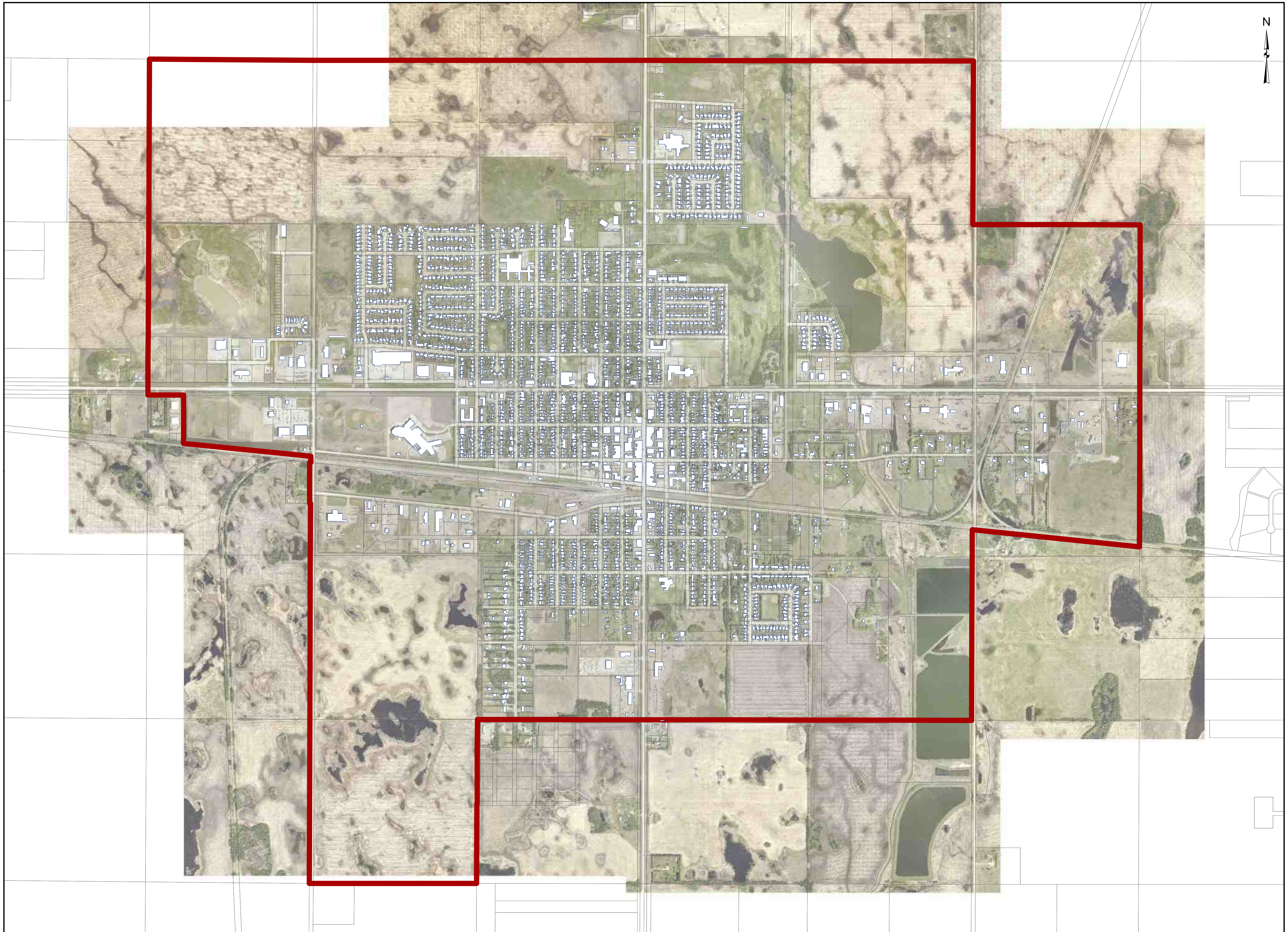
- Commercial
- Industrial
- Institutional
- Open Space
- Urban Holdings
- Low-Density Residential
- Medium-Density Residential
- High-Density Residential
- Railway
- City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 4.3
EXISTING SYSTEM
2D MODEL LAND USE
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt



Legend

Building Footprints

City Boundary

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 4.4
EXISTING SYSTEM
BUILDING FOOTPRINTS
CITY OF HUMBOLDT
STORMWATER MODEL

ISL

Humboldt

Date: 2021-11-03 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure4.4_Ex_Buildings.mxd

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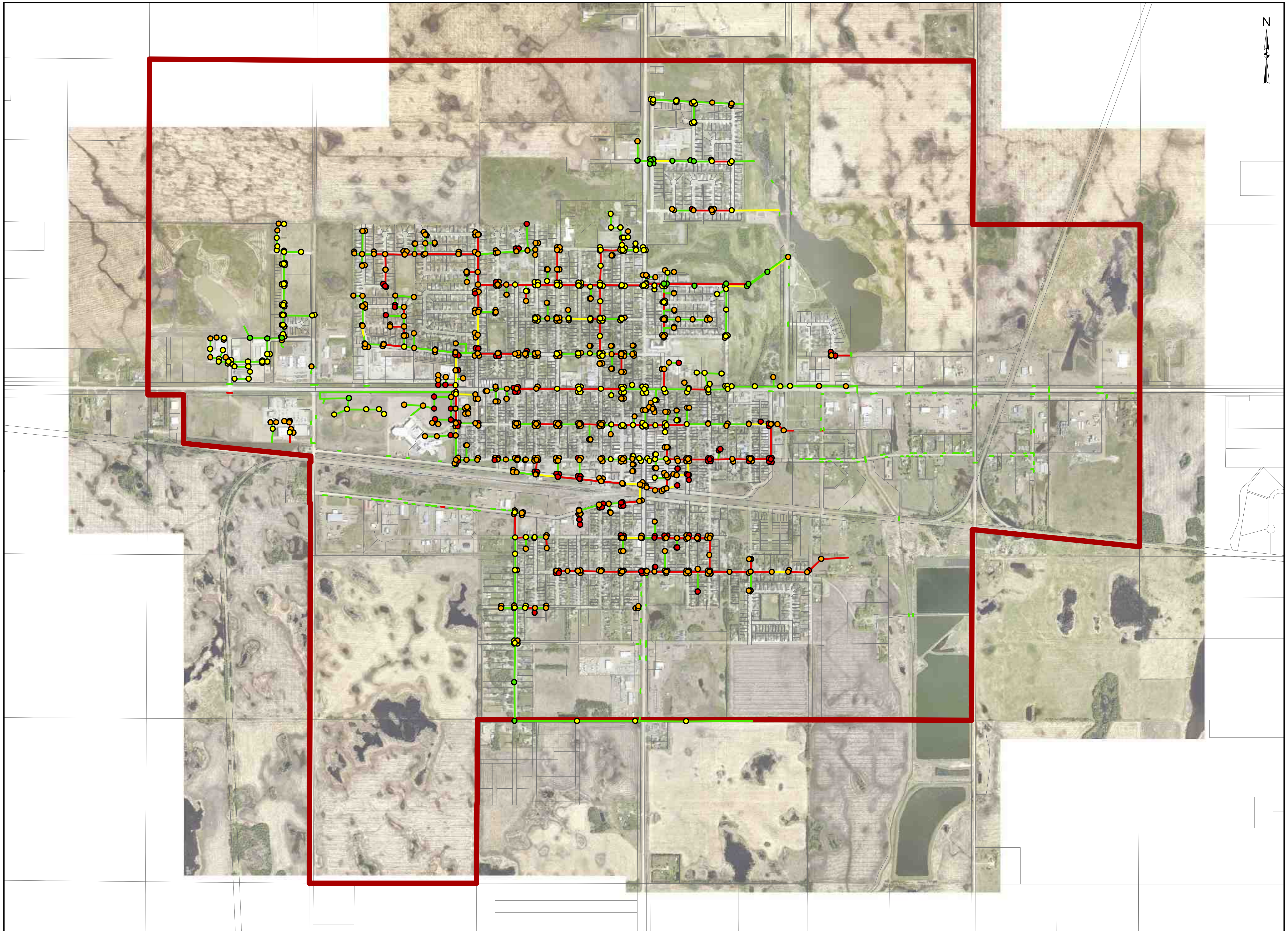
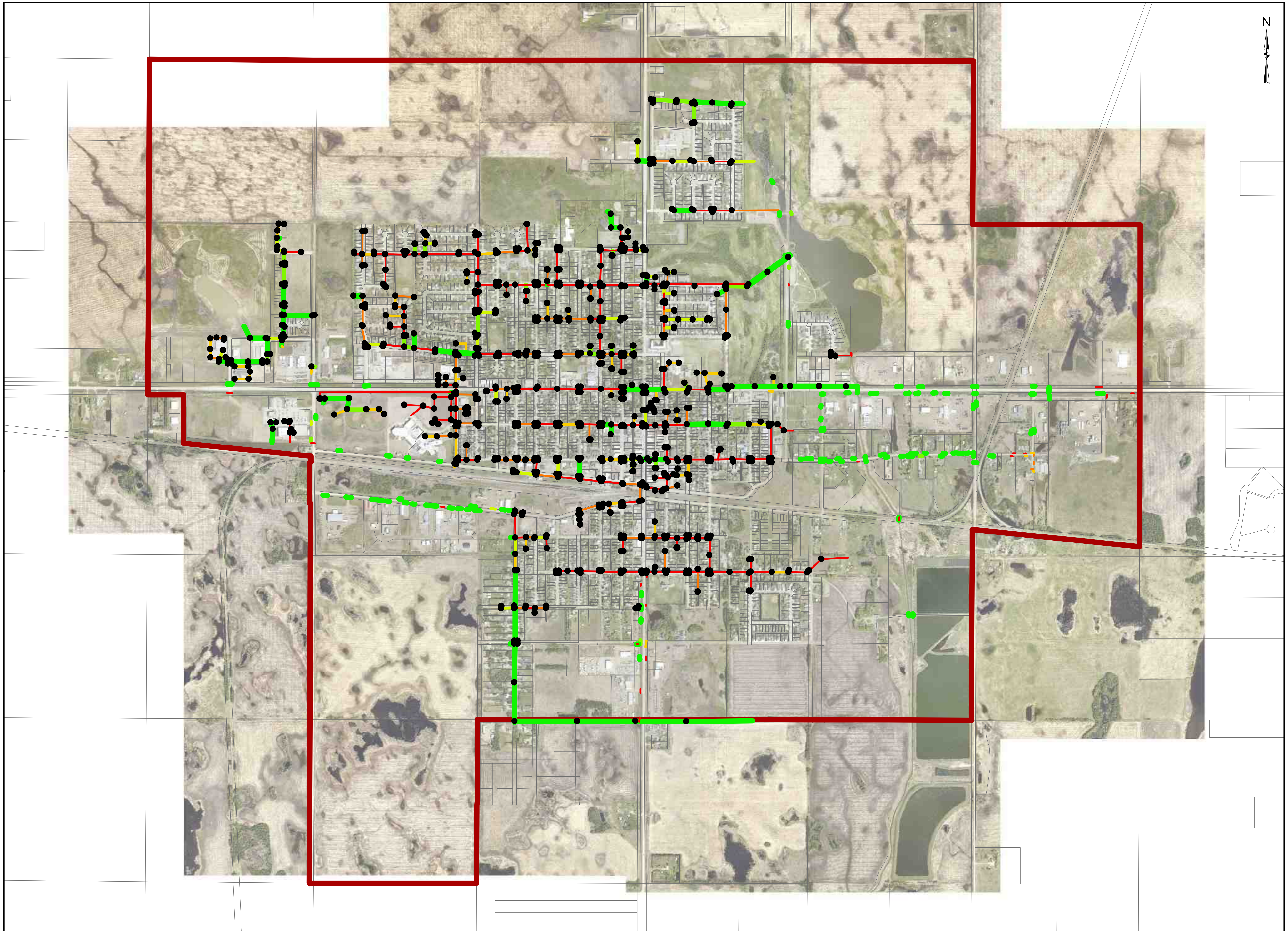


FIGURE 6.1
EXISTING MODEL RESULTS - 1D
2 YR 1 HR DESIGN STORM
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt



Legend

- Node

Spare Pipe Capacity

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

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 6.2
SPARE CAPACITY - 1D
2 YR 1 HR DESIGN STORM
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

Date: 2022-02-08 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure6.2_Ex_1D_Spare_Capacity_2yr_1hr.mxd

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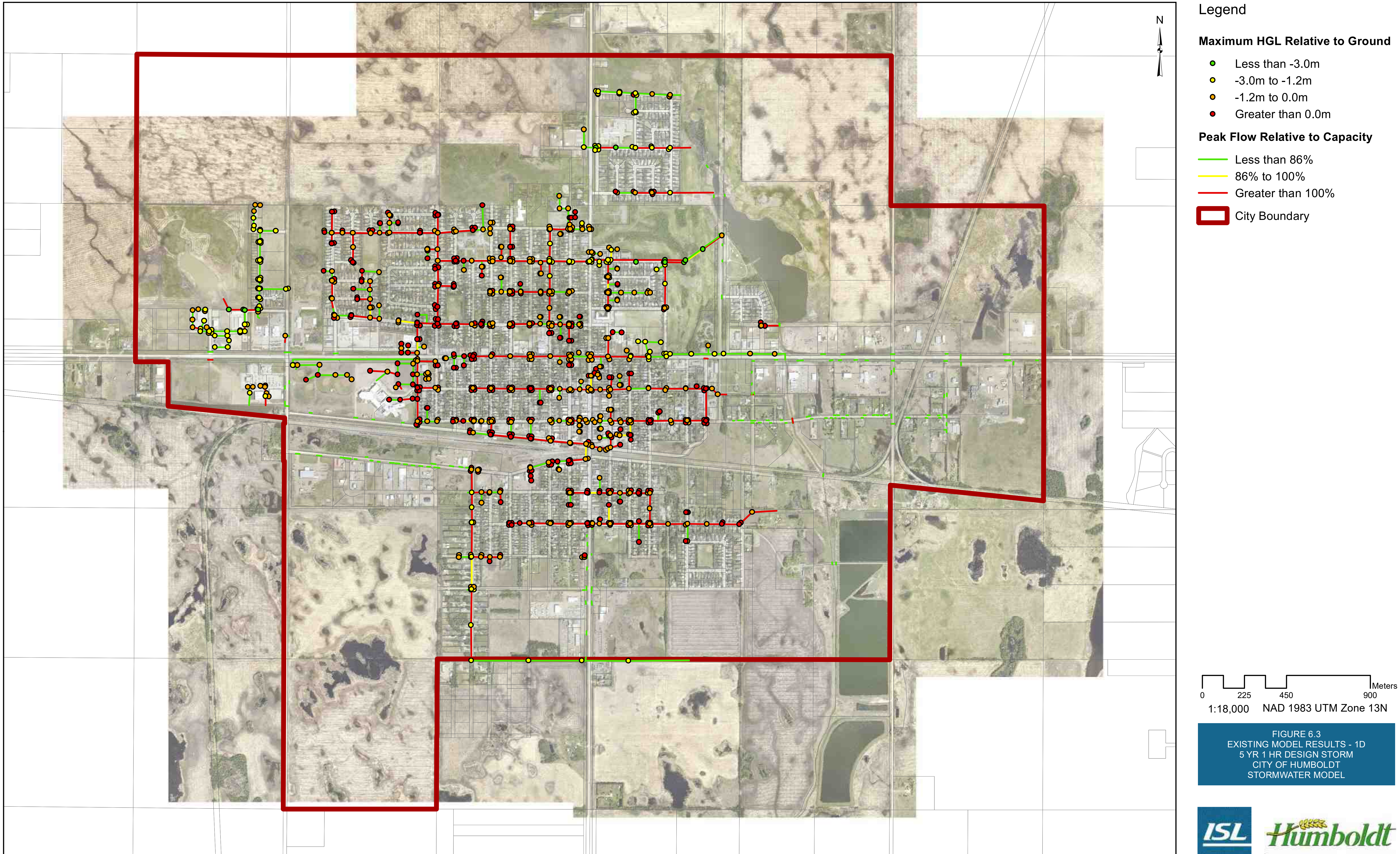

FIGURE 6.3
EXISTING MODEL RESULTS - 1D
5 YR 1 HR DESIGN STORM
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

Date: 2021-11-08 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure6.3_Ex_1D_Results_5yr_1hr.mxd

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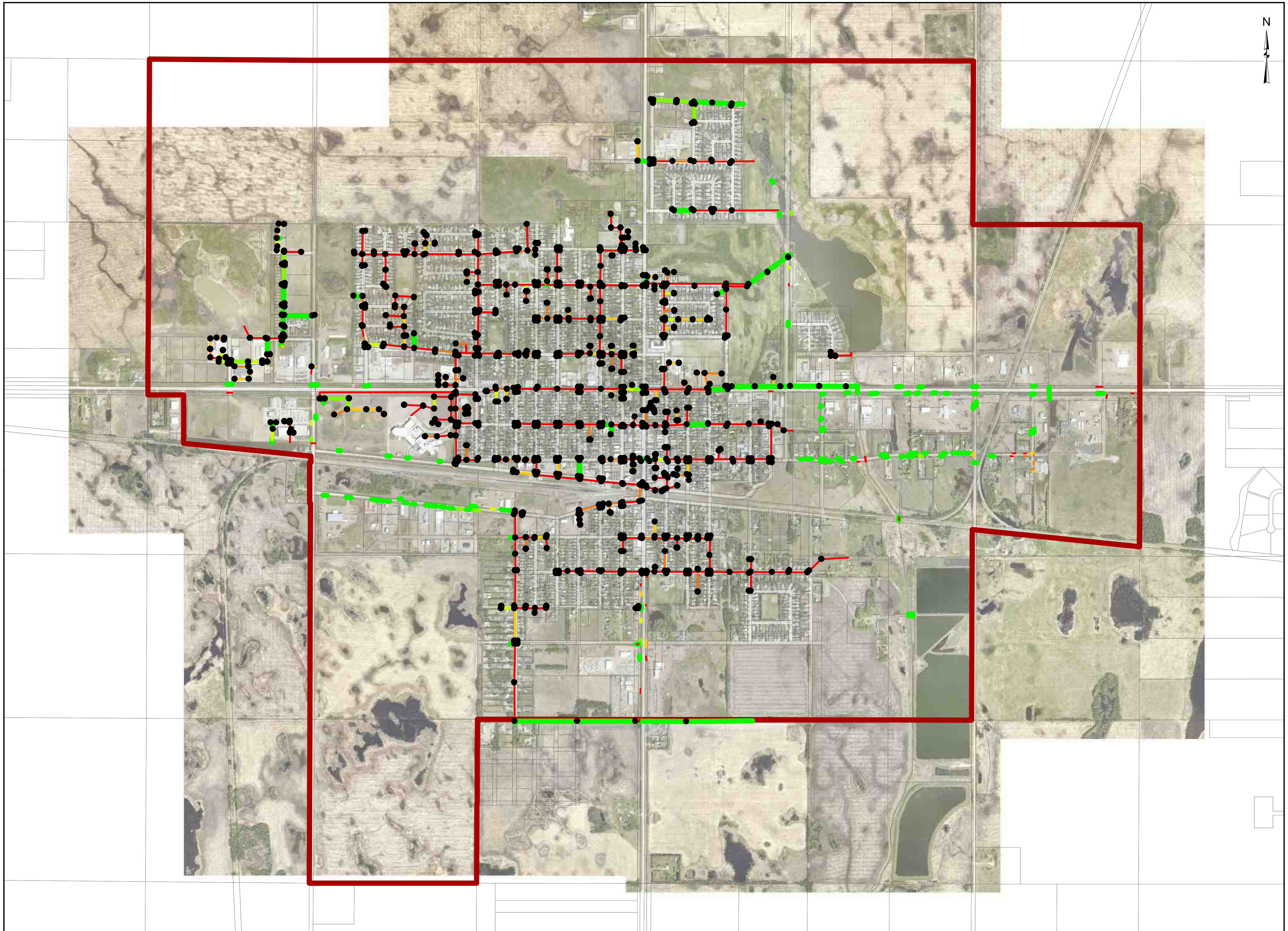
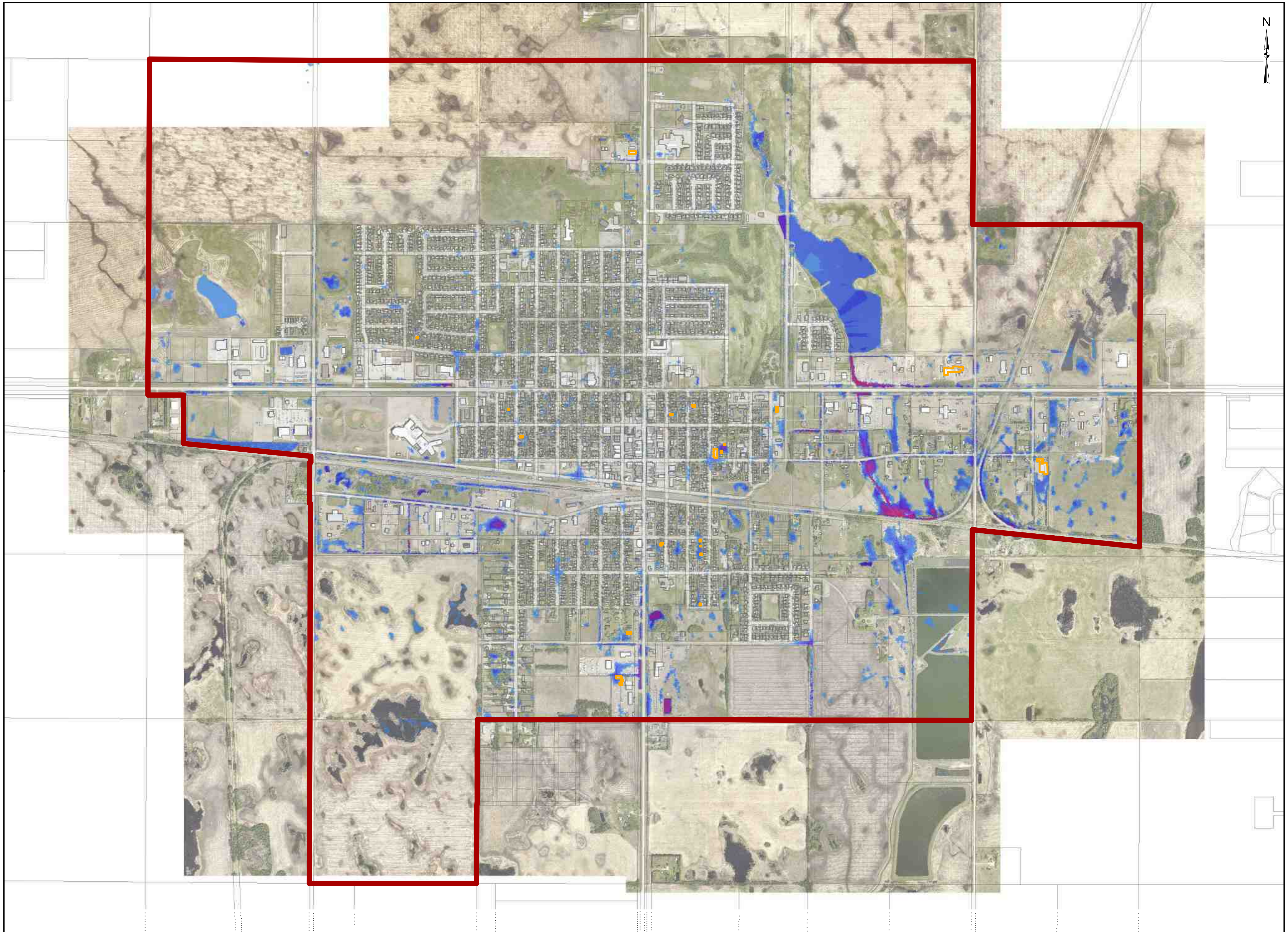


FIGURE 6.4
SPARE CAPACITY - 1D
5 YR 1 HR DESIGN STORM
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt



Legend

Maximum Depth (m)

Less than 0.101
0.101 - 0.100
0.101 - 0.200
0.201 - 0.300
0.301 - 0.400
0.401 - 0.500
0.501 - 0.750
0.751 - 1.000
1.001 - 1.500
Greater than 1.500

Impact Depth Greater than 200mm

Impacted Buildings (19)
Not Impacted Buildings

City Boundary

0 225 450 900 Meters

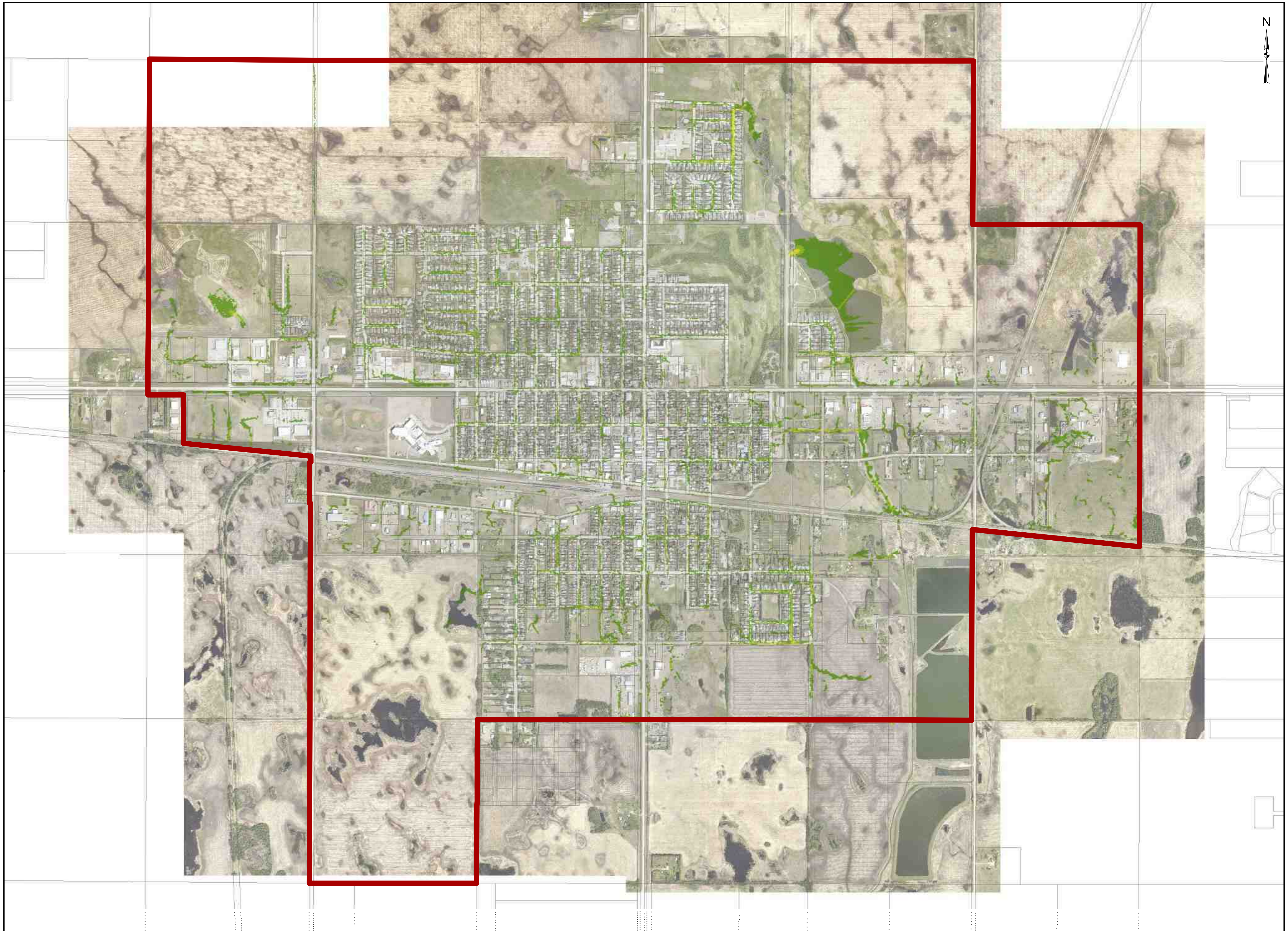
1:18,000 NAD 1983 UTM Zone 13N

FIGURE 6.5
EXISTING MODEL RESULTS - 2D
MAXIMUM WATER DEPTH
2 YR 24 HR DESIGN STORM
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

Date: 2022-03-16 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure6.5_Ex_2D_Depth_2yr_24hr.mxd

Integrated Expertise. Locally Delivered.



Legend

Flow Velocity (m/s)

- Less than 0.101
- 0.101 - 0.250
- 0.251 - 0.500
- 0.501 - 0.750
- 0.751 - 1.000
- 1.001 - 1.500
- 1.501 - 2.000
- Greater than 2.000
- City Boundary

0 225 450 900 Meters

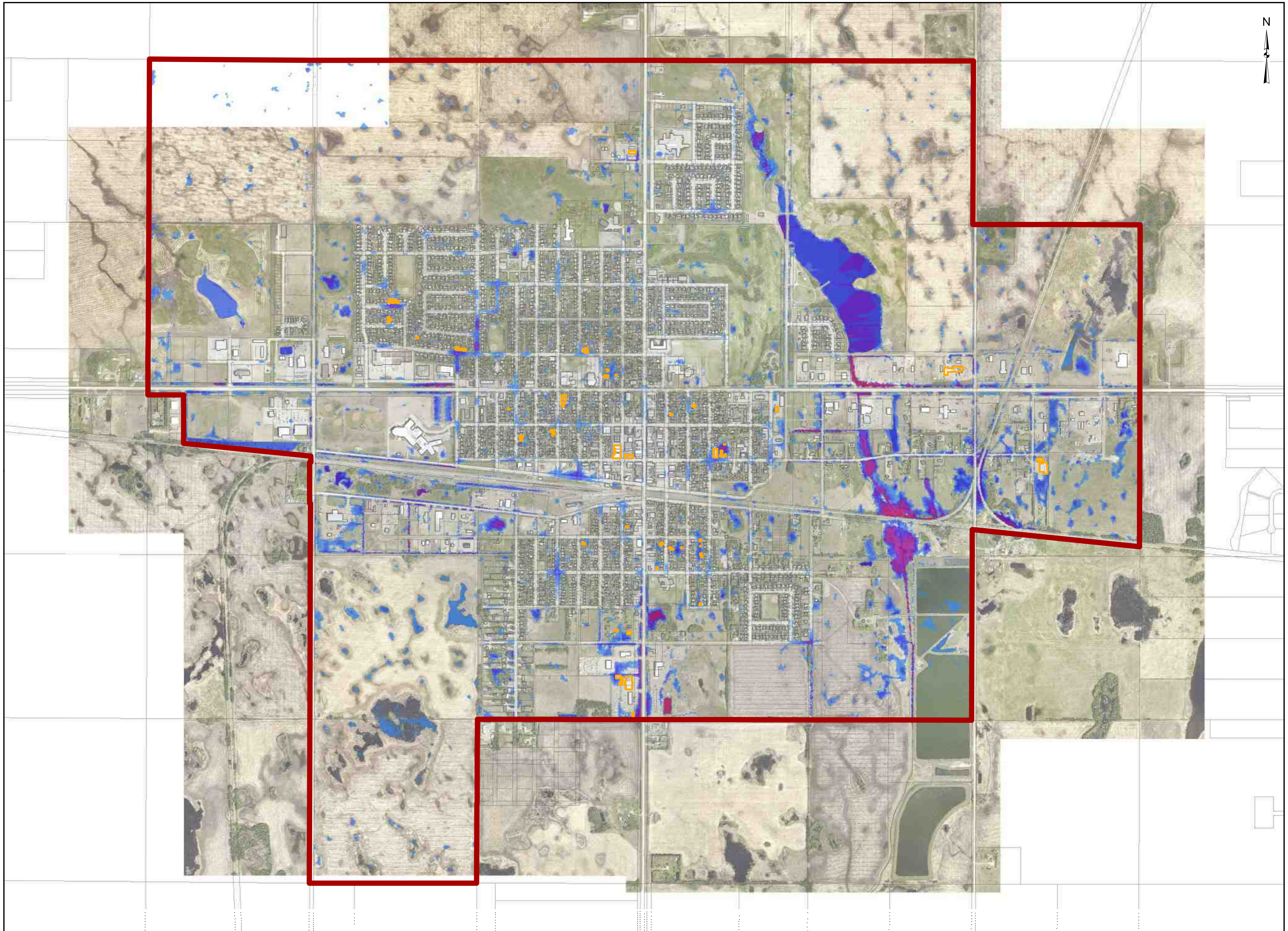
1:18,000 NAD 1983 UTM Zone 13N

FIGURE 6.6
EXISTING MODEL RESULTS - 2D
PEAK SURFACE FLOW VELOCITY
2 YR 24 HR DESIGN STORM
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

Date: 2021-11-07 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure6.6_Ex_2D_Velocity_2yr_24hr.mxd

Integrated Expertise. Locally Delivered.



Legend

Maximum Depth (m)

Less than 0.101
0.101 - 0.100
0.101 - 0.200
0.201 - 0.300
0.301 - 0.400
0.401 - 0.500
0.501 - 0.750
0.751 - 1.000
1.001 - 1.500
Greater than 1.500

Impact Depth Greater than 200mm

Impacted Buildings (47)
Not Impacted Buildings

City Boundary

0 225 450 900 Meters

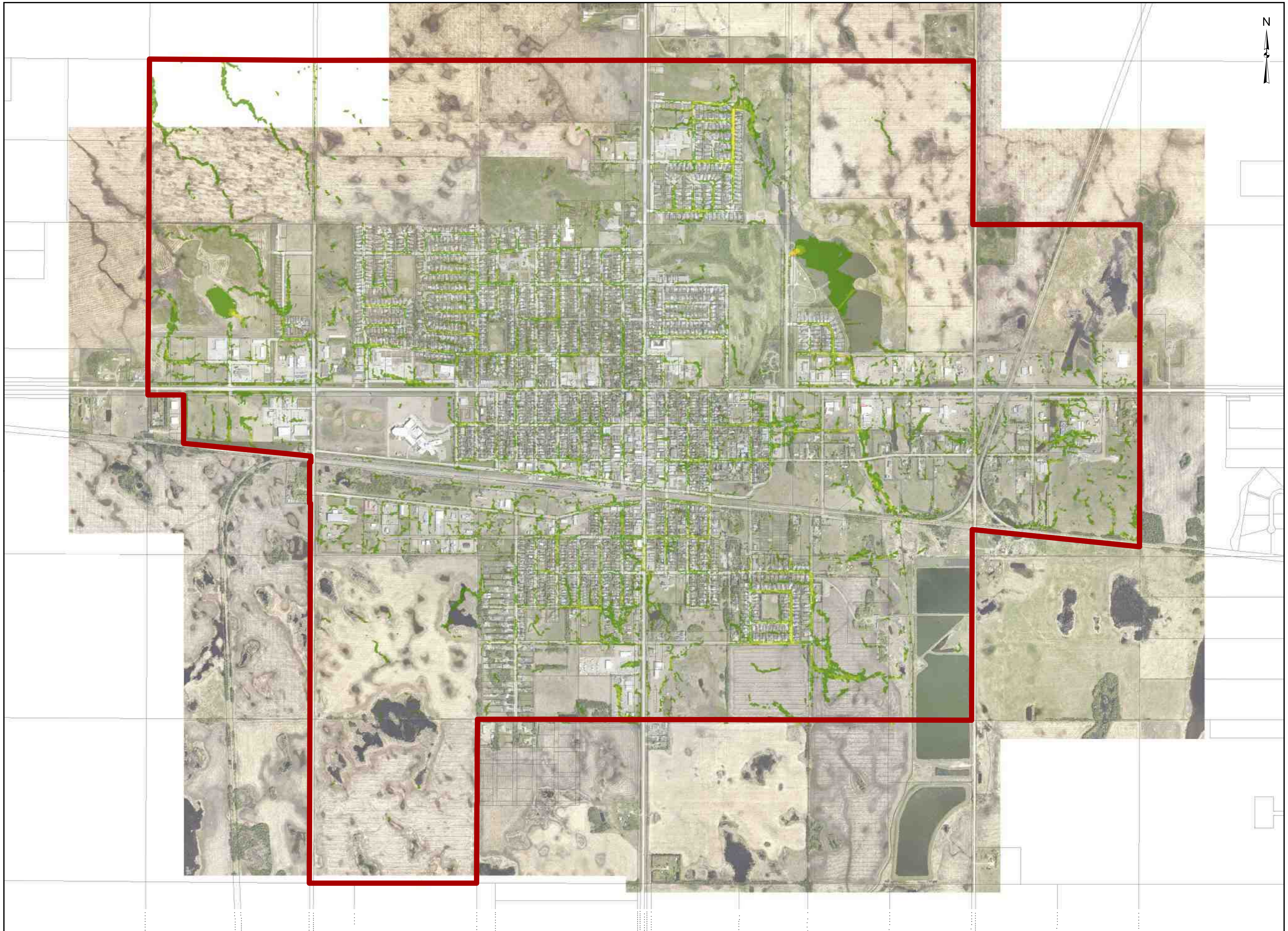
1:18,000 NAD 1983 UTM Zone 13N

FIGURE 6.7
EXISTING MODEL RESULTS - 2D
MAXIMUM WATER DEPTH
5 YR 24 HR DESIGN STORM
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

Date: 2022-03-16 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure6.7_Ex_2D_Depth_5yr_24hr.mxd

Integrated Expertise. Locally Delivered.



Legend

Flow Velocity (m/s)

Less than 0.101
0.101 - 0.250
0.251 - 0.500
0.501 - 0.750
0.751 - 1.000
1.001 - 1.500
1.501 - 2.000
Greater than 2.000

City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 6.8
EXISTING MODEL RESULTS - 2D
PEAK SURFACE FLOW VELOCITY
5 YR 24 HR DESIGN STORM
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

Date: 2021-11-08 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure6.8_Ex_2D_Velocity_5yr_24hr.mxd

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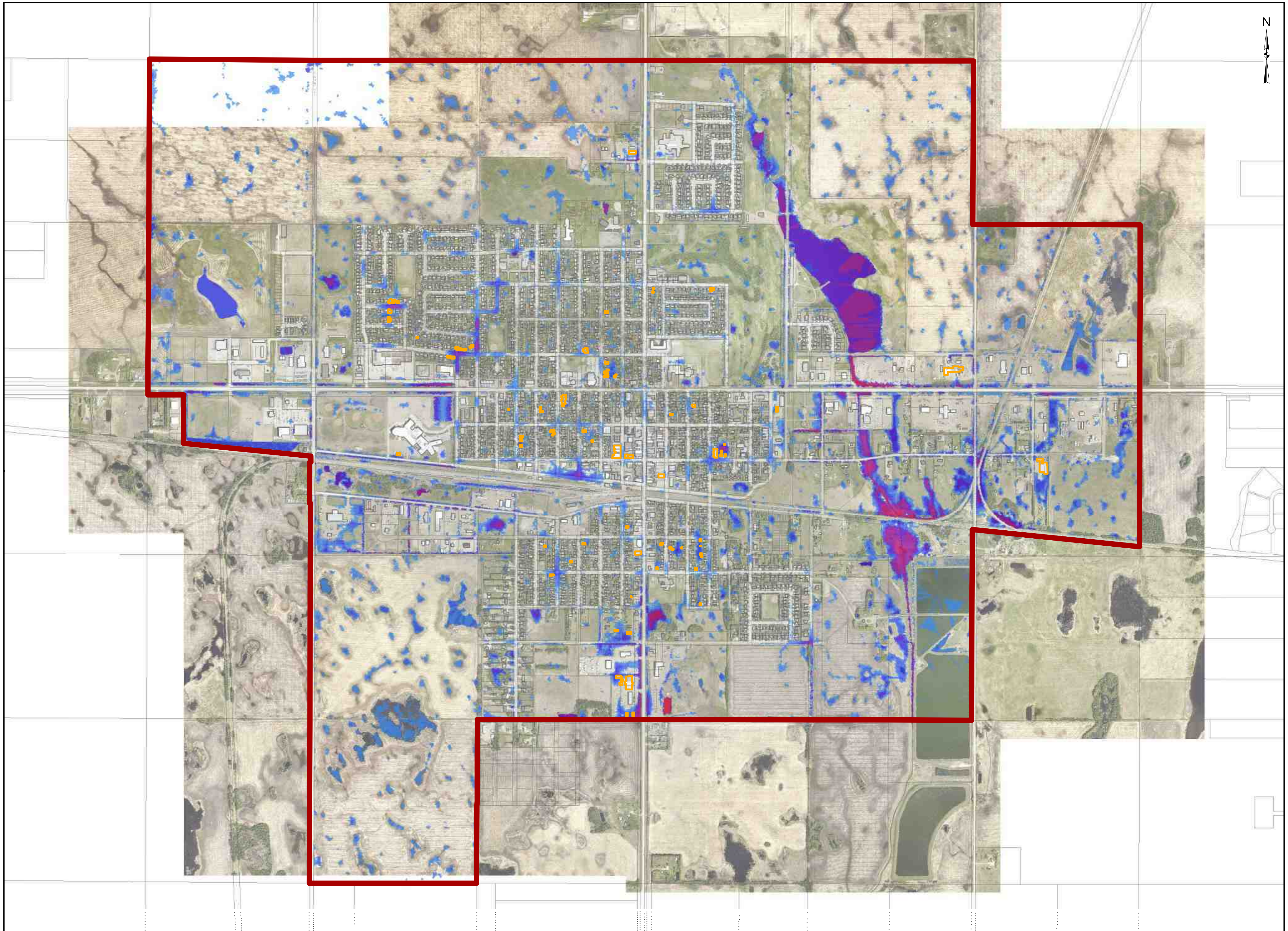

Legend

Maximum Depth (m)

- Less than 0.101
- 0.101 - 0.100
- 0.101 - 0.200
- 0.201 - 0.300
- 0.301 - 0.400
- 0.401 - 0.500
- 0.501 - 0.750
- 0.751 - 1.000
- 1.001 - 1.500
- Greater than 1.500

Impact Depth Greater than 200mm

- Impacted Buildings (71)
- Not Impacted Buildings
- City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 6.9
EXISTING MODEL RESULTS - 2D
MAXIMUM WATER DEPTH
10 YR 24 HR DESIGN STORM
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

Date: 2022-03-16 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure6.9_Ex_2D_Depth_10yr_24hr.mxd

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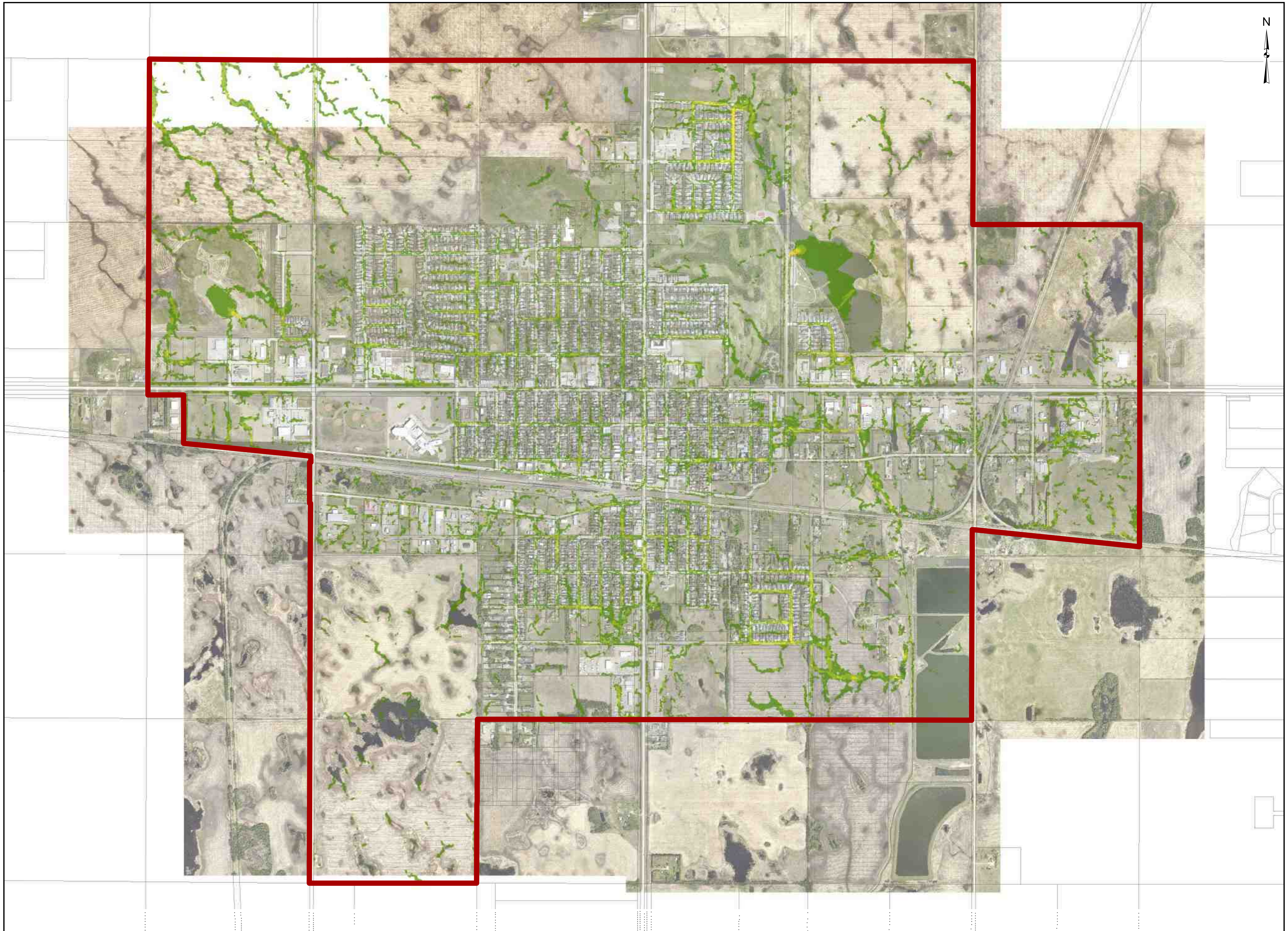


Legend

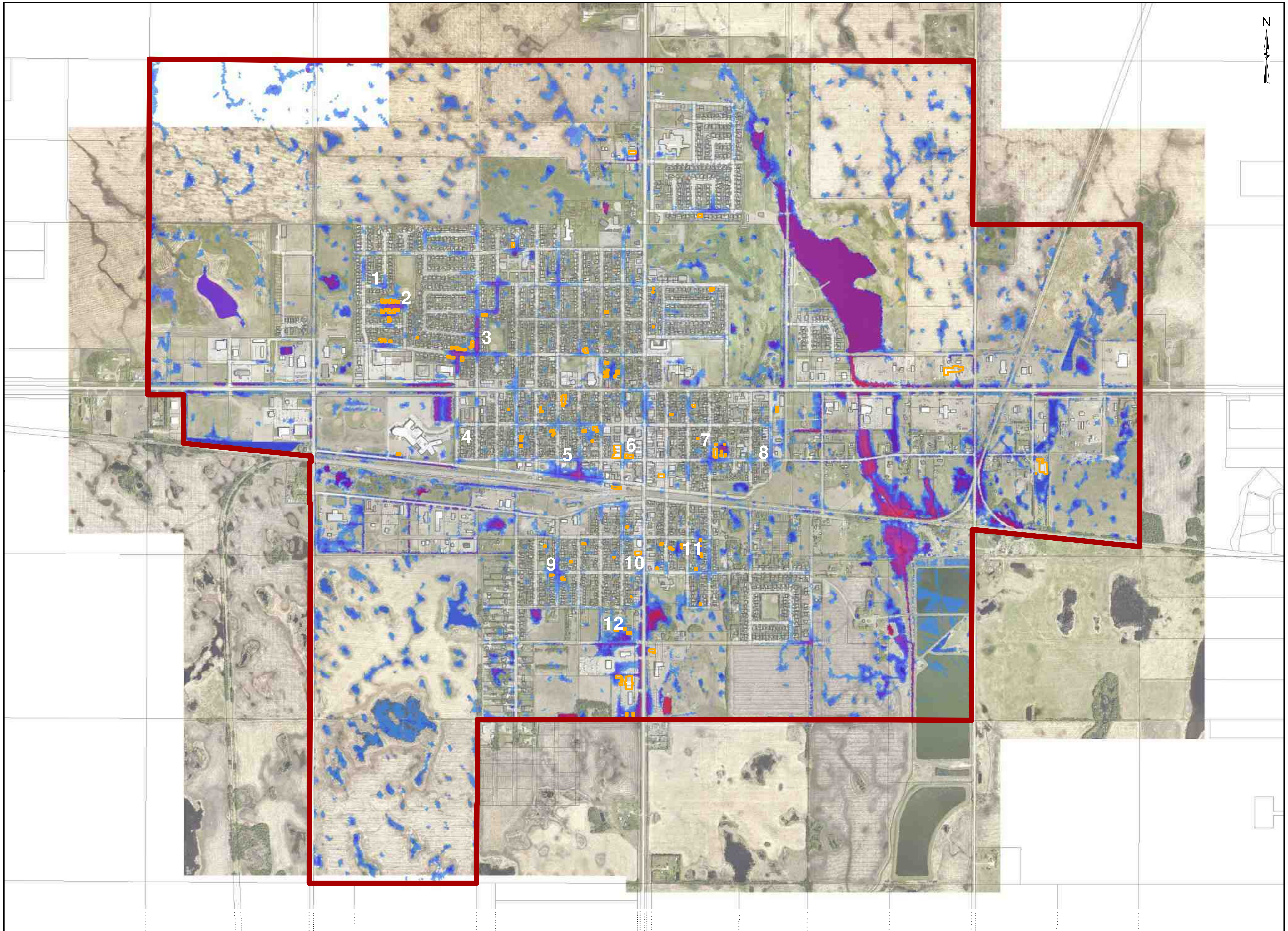
Flow Velocity (m/s)

- Less than 0.101
- 0.101 - 0.250
- 0.251 - 0.500
- 0.501 - 0.750
- 0.751 - 1.000
- 1.001 - 1.500
- 1.501 - 2.000
- Greater than 2.000
- City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 6.10
EXISTING MODEL RESULTS - 2D
PEAK SURFACE FLOW VELOCITY
10 YR 24 HR DESIGN STORM
CITY OF HUMBOLDT
STORMWATER MODEL



Legend

Maximum Depth (m)

Less than 0.101
0.101 - 0.100
0.101 - 0.200
0.201 - 0.300
0.301 - 0.400
0.401 - 0.500
0.501 - 0.750
0.751 - 1.000
1.001 - 1.500
Greater than 1.500

Impact Depth Greater than 200mm

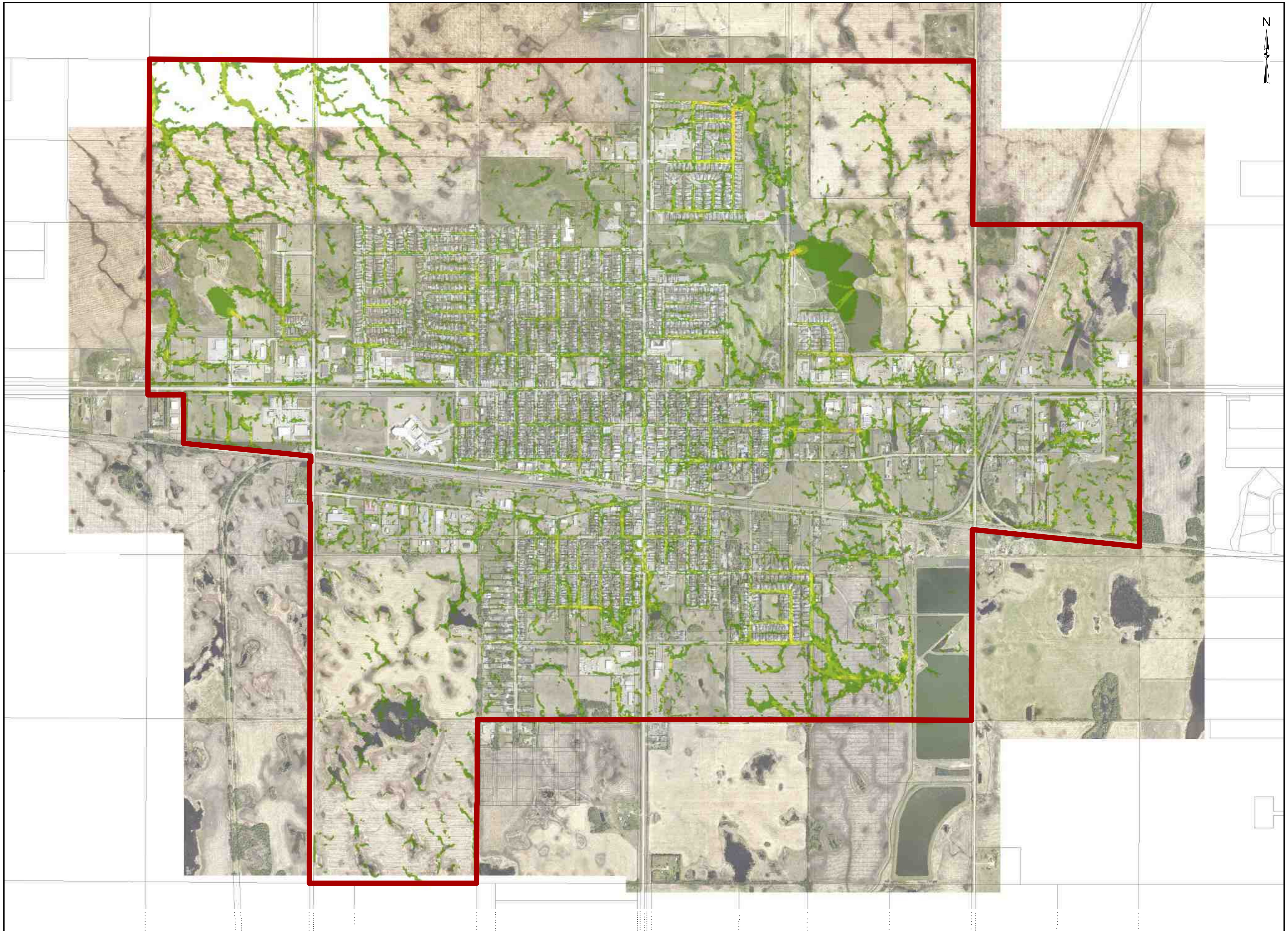
Impacted Buildings (100)
Not Impacted Buildings
City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 6.11
EXISTING MODEL RESULTS - 2D
MAXIMUM WATER DEPTH
25 YR 24 HR DESIGN STORM
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt



Legend

Flow Velocity (m/s)

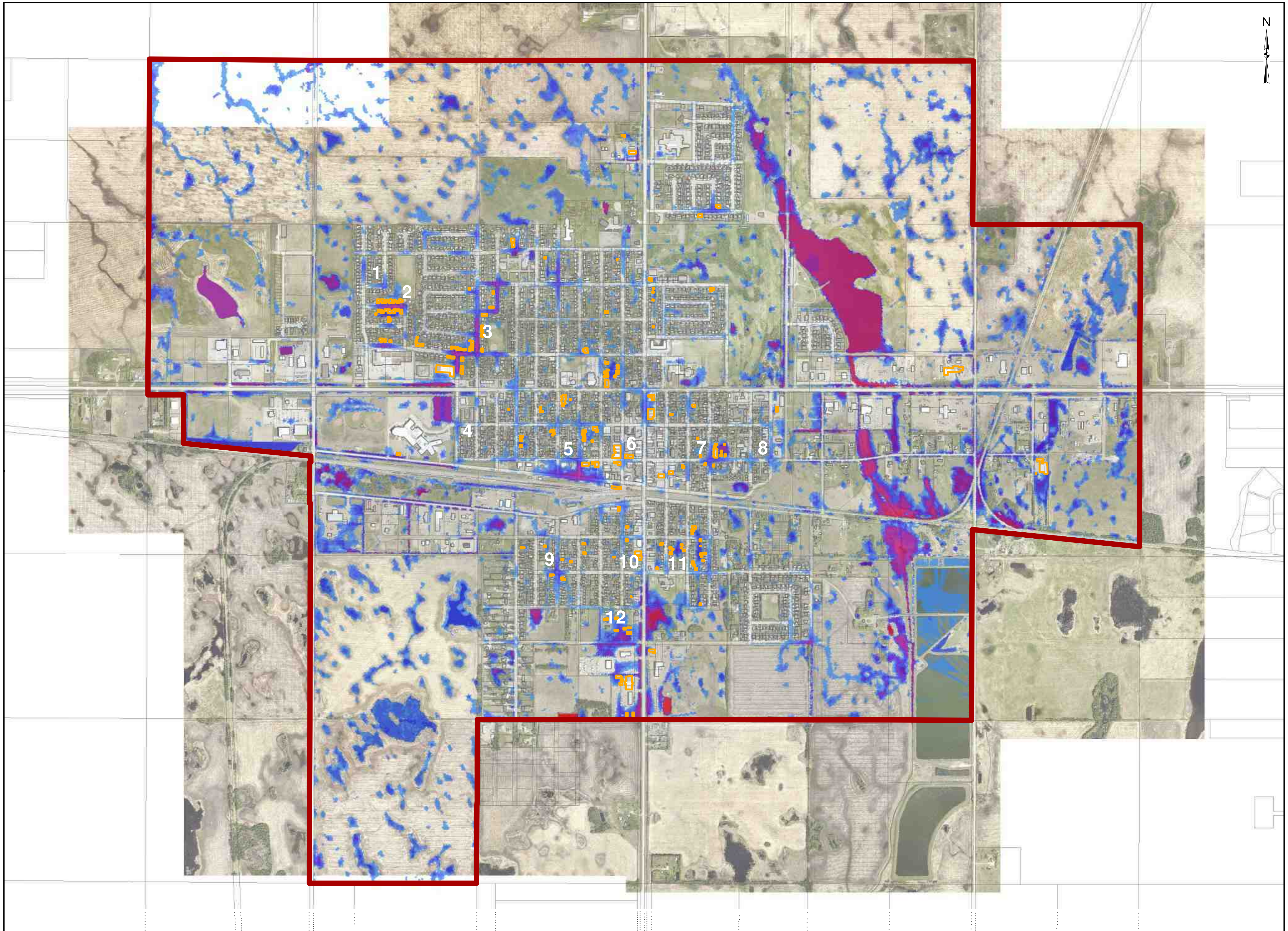
- Less than 0.101
- 0.101 - 0.250
- 0.251 - 0.500
- 0.501 - 0.750
- 0.751 - 1.000
- 1.001 - 1.500
- 1.501 - 2.000
- Greater than 2.000
- City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 6.12
EXISTING MODEL RESULTS - 2D
PEAK SURFACE FLOW VELOCITY
25 YR 24 HR DESIGN STORM
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt



Legend

Maximum Depth (m)

- Less than 0.101
- 0.101 - 0.100
- 0.101 - 0.200
- 0.201 - 0.300
- 0.301 - 0.400
- 0.401 - 0.500
- 0.501 - 0.750
- 0.751 - 1.000
- 1.001 - 1.500
- Greater than 1.500

Impact Depth Greater than 200mm

- Impacted Buildings (158)
- Not Impacted Buildings
- City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 6.13
EXISTING MODEL RESULTS - 2D
MAXIMUM WATER DEPTH
100 YR 24 HR DESIGN STORM
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

Date: 2022-03-16 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure6.13_Ex_2D_Depth_100yr_24hr.mxd

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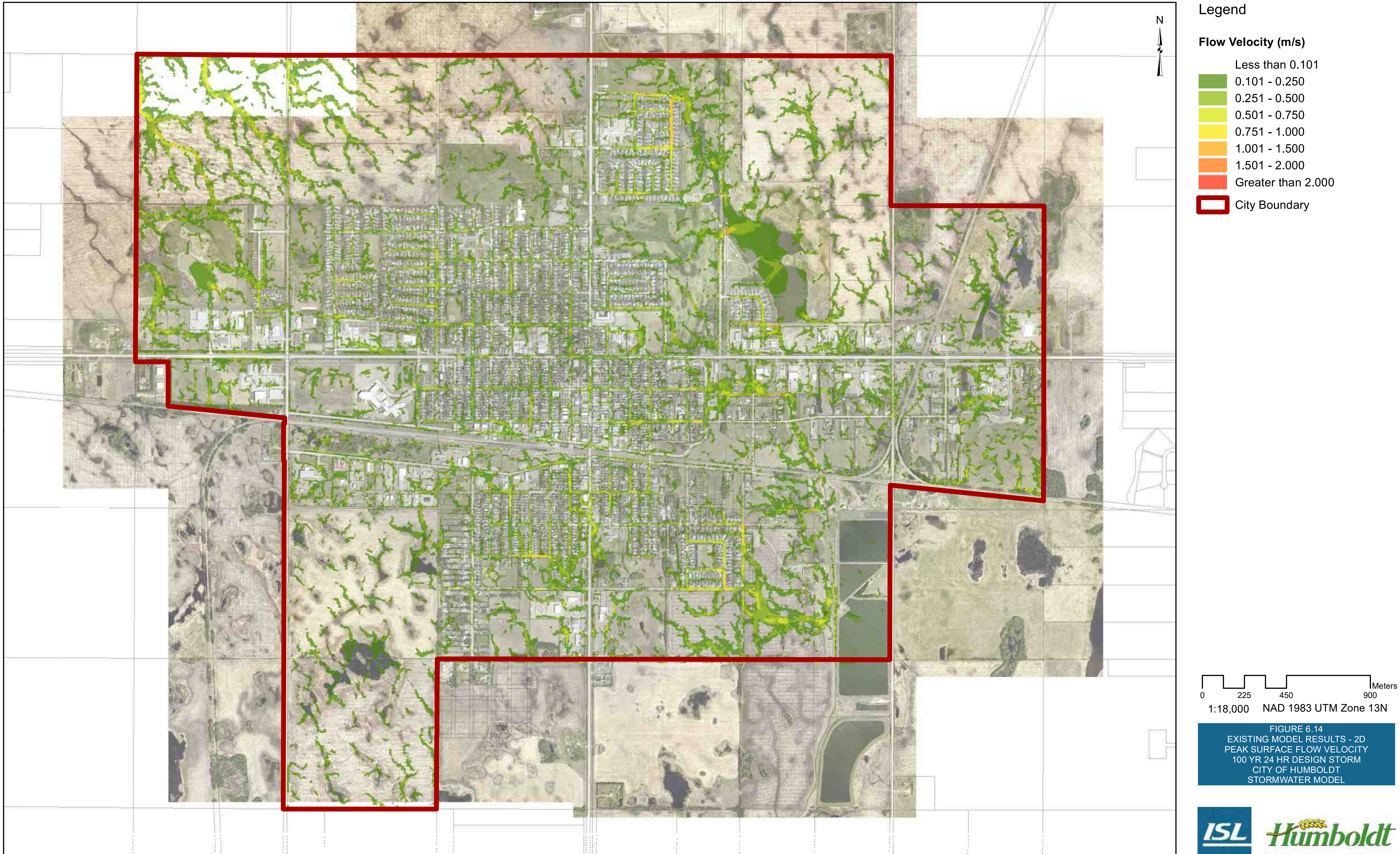
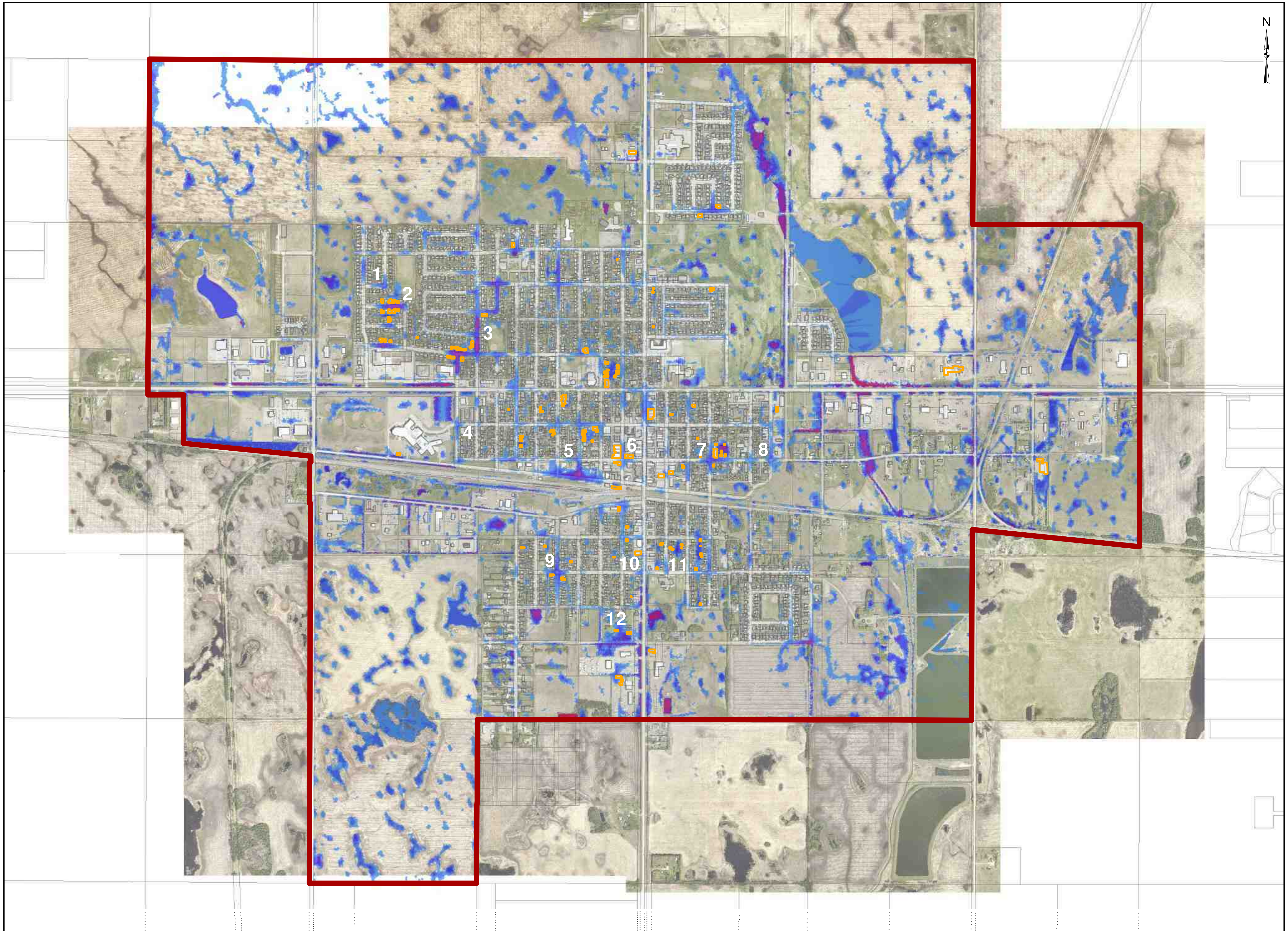


FIGURE 6.14
EXISTING MODEL RESULTS - 2D
PEAK SURFACE FLOW VELOCITY
100 YR 24 HR DESIGN STORM
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt



Legend

Maximum Depth (m)

Less than 0.101
0.101 - 0.100
0.101 - 0.200
0.201 - 0.300
0.301 - 0.400
0.401 - 0.500
0.501 - 0.750
0.751 - 1.000
1.001 - 1.500
Greater than 1.500

Impact Depth Greater than 200mm

Impacted Buildings (107)
Not Impacted Buildings
City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 6.15
EXISTING MODEL RESULTS - 2D
MAXIMUM WATER DEPTH
100 YR 1 HR DESIGN STORM - AES
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

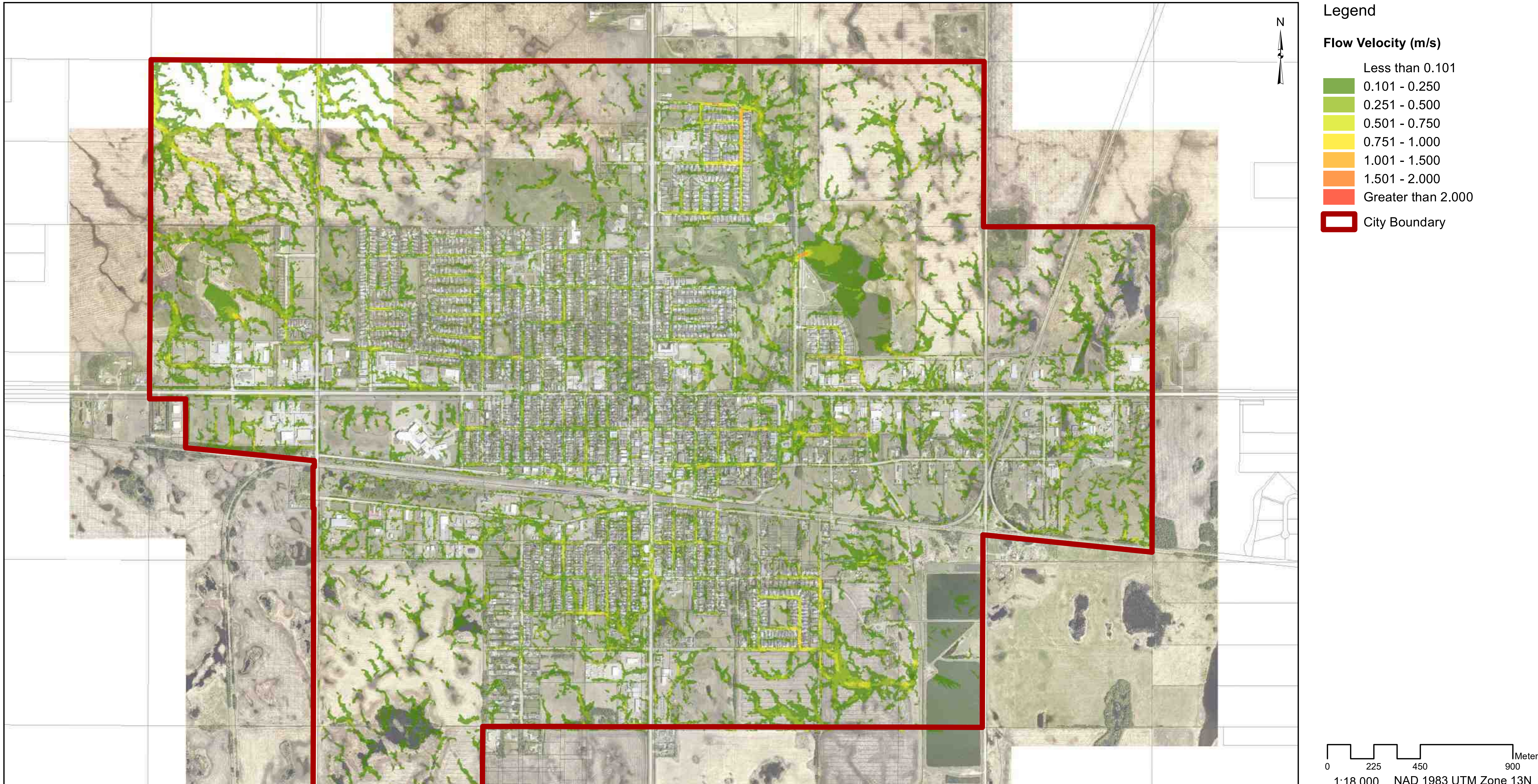
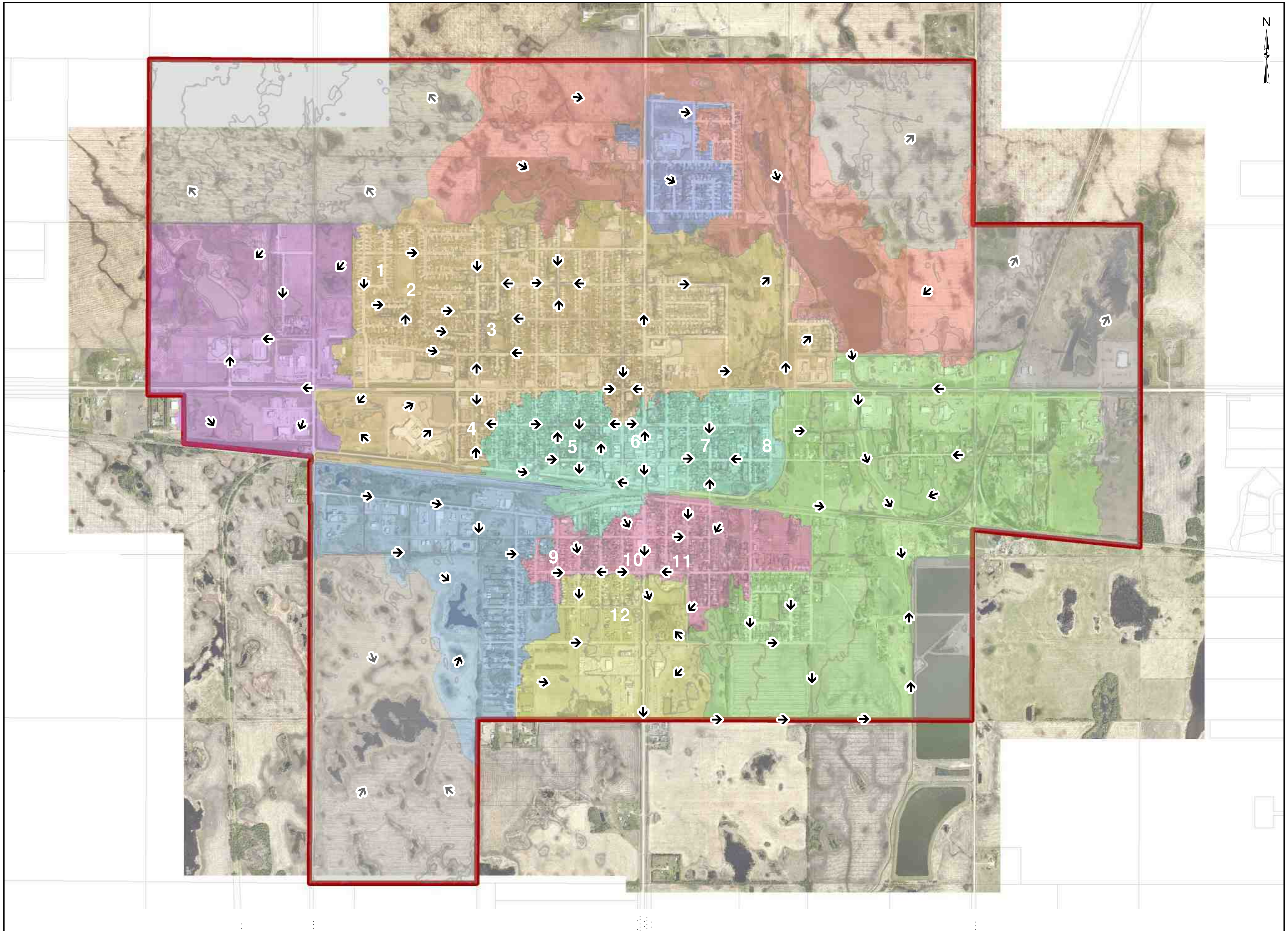


FIGURE 6.16
EXISTING MODEL RESULTS - 2D
PEAK SURFACE FLOW VELOCITY
100 YR 1 HR DESIGN STORM - AES
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt



Legend

Existing Flow Path

Off-Site Flow Path

Contour - 2m Interval

Major Drainage Areas

Drainage Area 1

Drainage Area 2

Drainage Area 3

Drainage Area 4

Drainage Area 5

Drainage Area 6

Drainage Area 7

Drainage Area 8

Mile Slough

Off-Site

City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 6.17
EXISTING SYSTEM
MAJOR DRAINAGE AREAS
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

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Date: 2022-03-14 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure6.17_Ex_Drainage_Areas.mxd

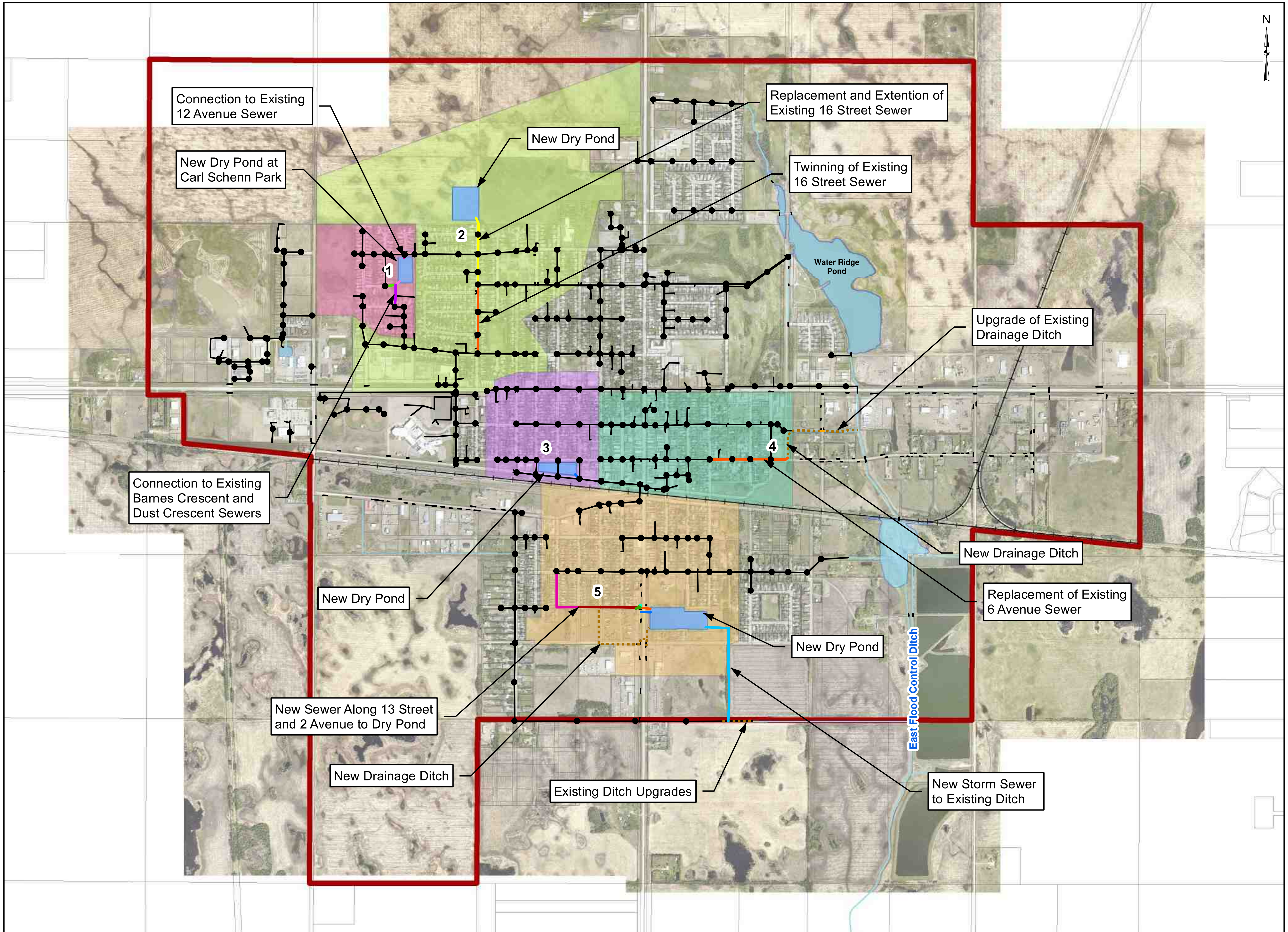
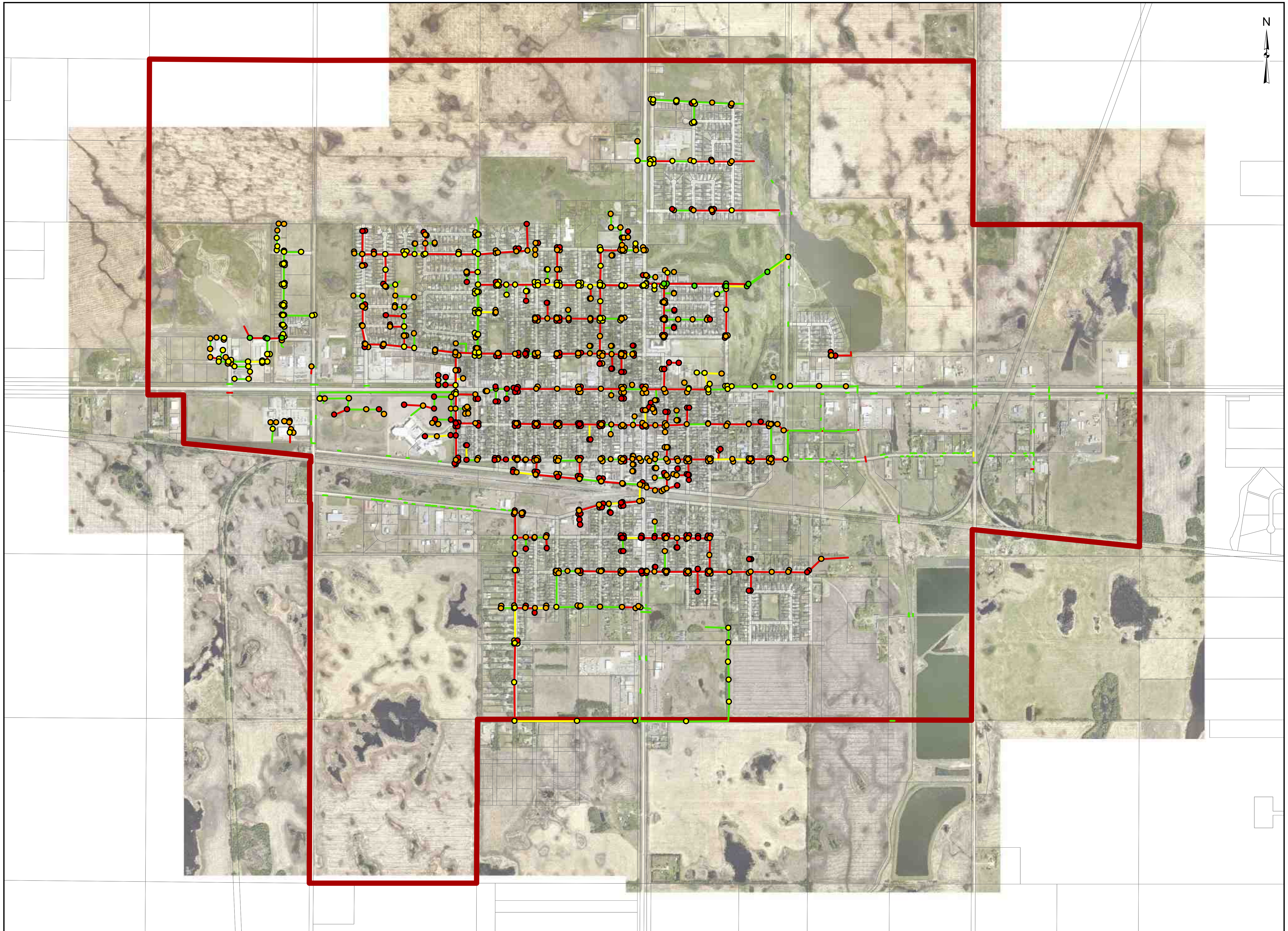


FIGURE 7.1
PROPOSED EXISTING SYSTEM UPGRADES
CITY OF HUMBOLDT
STORMWATER MODEL

ISL
Humboldt

Integrated Expertise. Locally Delivered.

Date: 2022-03-11 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure7.1_Ex_Proposed_Upgrades.mxd



Legend

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%
- City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 7.2
EXISTING UPGRADES MODEL RESULTS - 1D
5 YR 1 HR DESIGN STORM
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

Date: 2022-03-03 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure7.2_Pr_1D_Results_5yr_1hr.mxd

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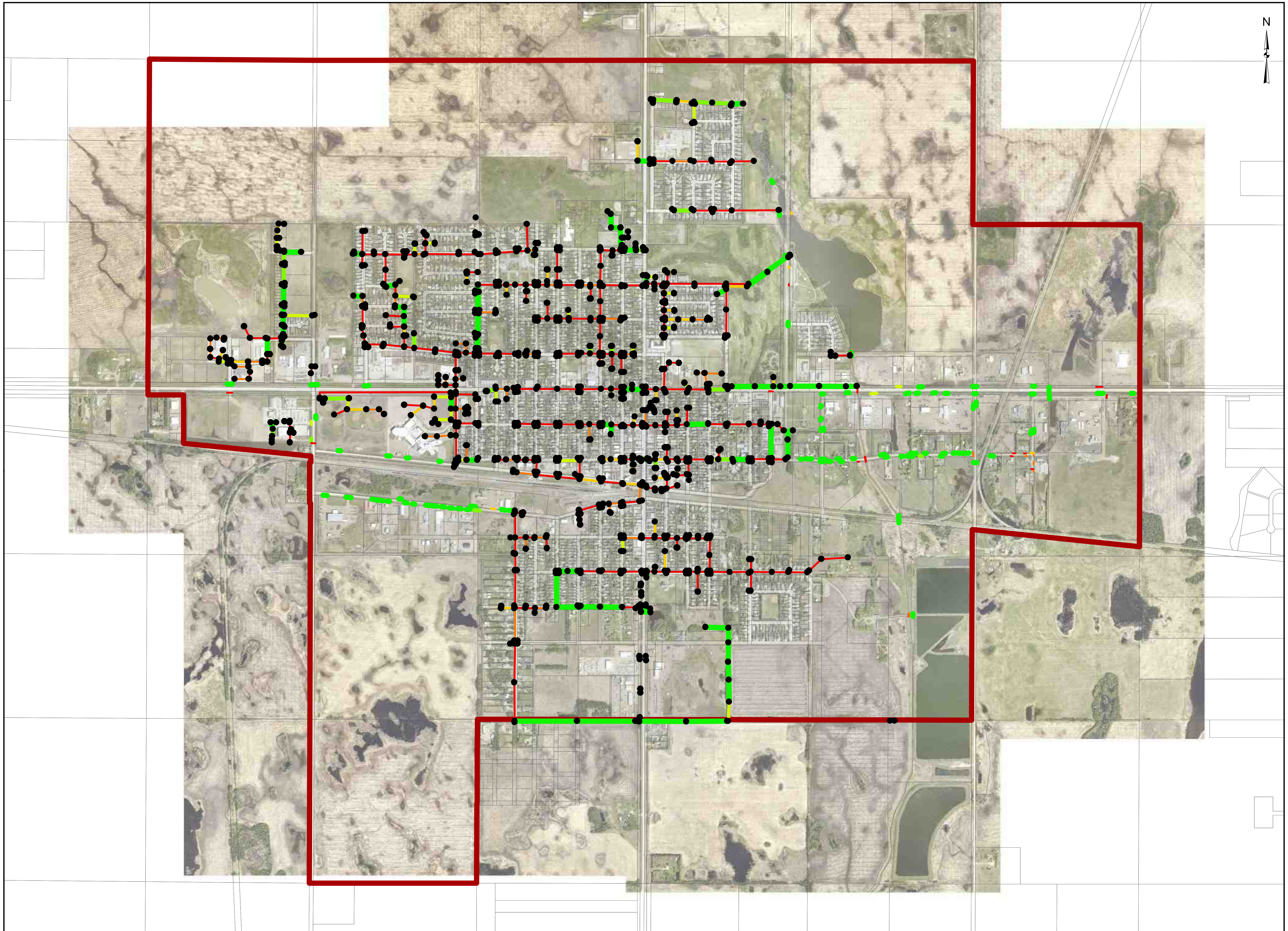

Legend

Node

Spare Pipe Capacity

Less than 0L/s

0 - 25L/s

25 - 50L/s

50 - 75L/s

75 - 100L/s

Greater than 100L/s

City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 7.3
EXISTING UPGRADES SPARE CAPACITY - 1D
5 YR 1 HR DESIGN STORM
CITY OF HUMBOLDT
STORMWATER MODEL

Date: 2022-03-03 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure7.3_Pr_1D_Spare_Capacity_5yr_1hr.mxd

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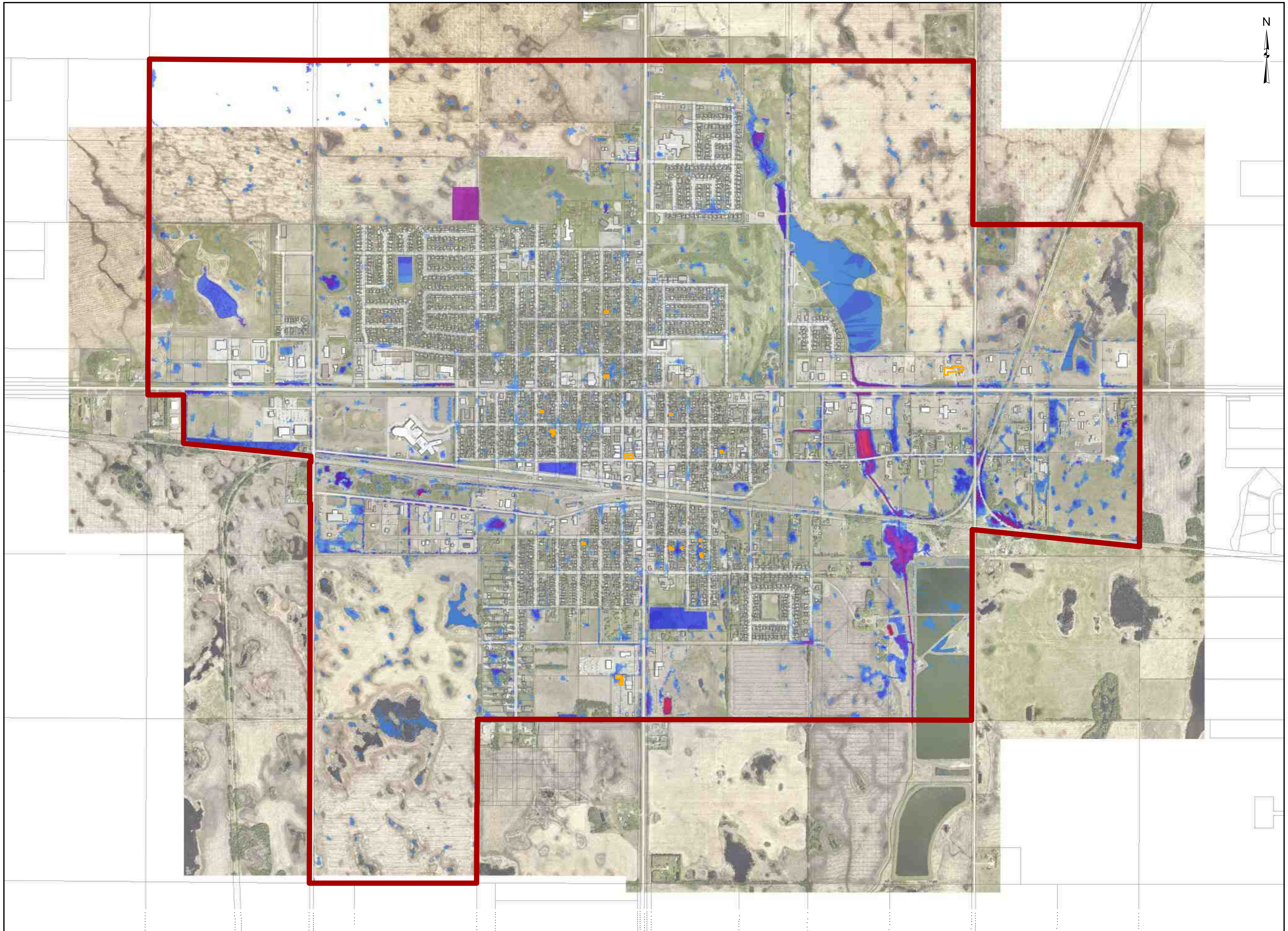

Legend

Maximum Depth (m)

- Less than 0.101
- 0.101 - 0.100
- 0.101 - 0.200
- 0.201 - 0.300
- 0.301 - 0.400
- 0.401 - 0.500
- 0.501 - 0.750
- 0.751 - 1.000
- 1.001 - 1.500
- Greater than 1.500

Impact Depth Greater than 200mm

- Impacted Buildings (17)
- Not Impacted Buildings
- City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 7.4
EXISTING UPGRADES MODEL RESULTS - 2D
MAXIMUM WATER DEPTH
5 YR 24 HR DESIGN STORM
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

Date: 2022-03-16 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure7.4_Pr_2D_Depth_5yr_24hr.mxd

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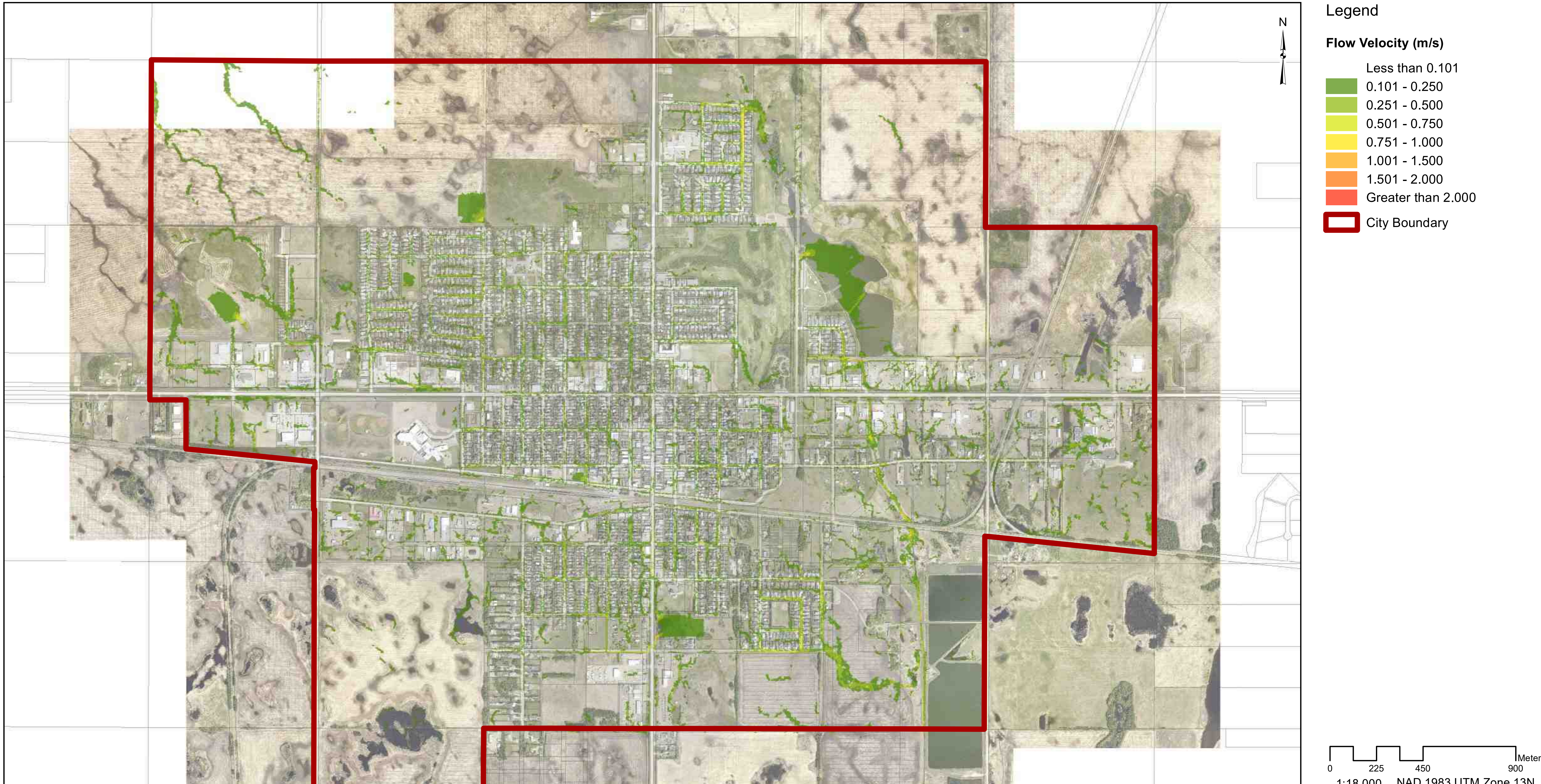

FIGURE 7.5
EXISTING UPGRADES MODEL RESULTS - 2D
PEAK SURFACE FLOW VELOCITY
5 YR 24 HR DESIGN STORM
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

Date: 2022-03-03 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure7.5_Pr_2D_Velocity_5yr_24hr.mxd

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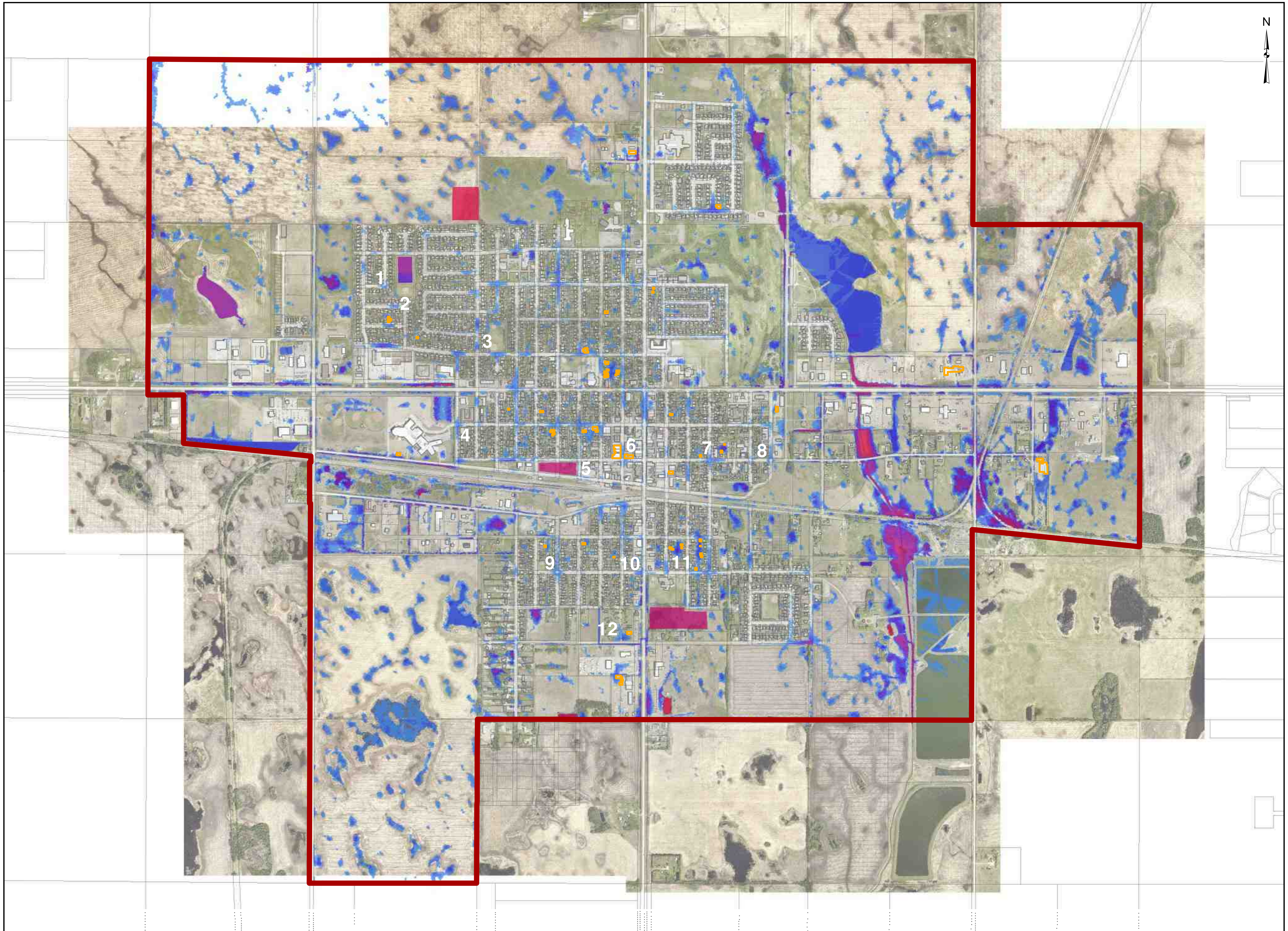

Legend

Maximum Depth (m)

Less than 0.101
0.101 - 0.100
0.101 - 0.200
0.201 - 0.300
0.301 - 0.400
0.401 - 0.500
0.501 - 0.750
0.751 - 1.000
1.001 - 1.500
Greater than 1.500

Impact Depth Greater than 200mm

Impacted Buildings (45)
Not Impacted Buildings
City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 7.6
EXISTING UPGRADES MODEL RESULTS - 2D
MAXIMUM WATER DEPTH
25 YR 24 HR DESIGN STORM
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

Date: 2022-03-16 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure7.6_Pr_2D_Depth_25yr_24hr.mxd

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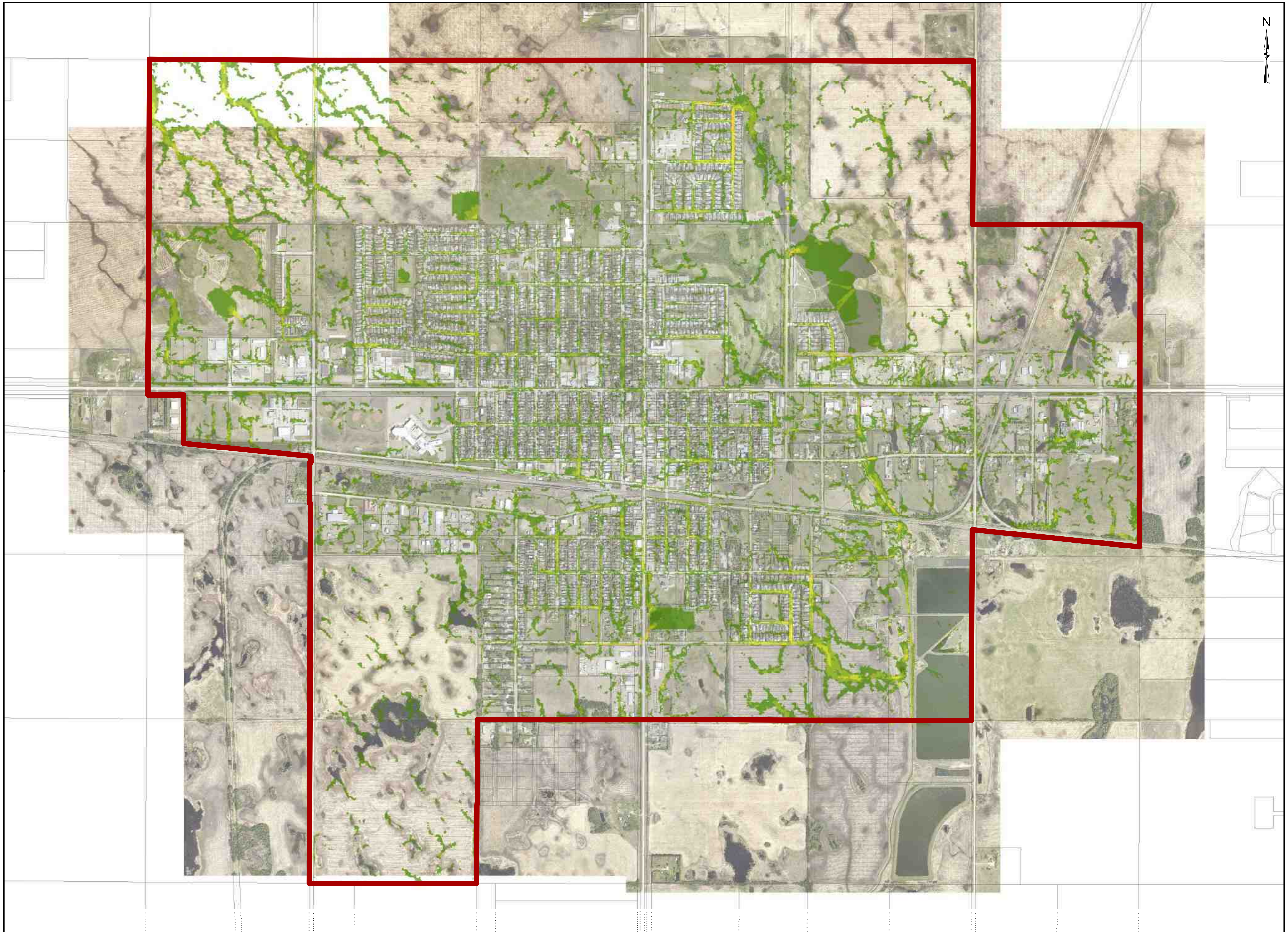

Legend

Flow Velocity (m/s)

- Less than 0.101
- 0.101 - 0.250
- 0.251 - 0.500
- 0.501 - 0.750
- 0.751 - 1.000
- 1.001 - 1.500
- 1.501 - 2.000
- Greater than 2.000
- City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 7.7
EXISTING UPGRADES MODEL RESULTS - 2D
PEAK SURFACE FLOW VELOCITY
25 YR 24 HR DESIGN STORM
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

Date: 2022-03-03 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure7.7_Pr_2D_Velocity_25yr_24hr.mxd

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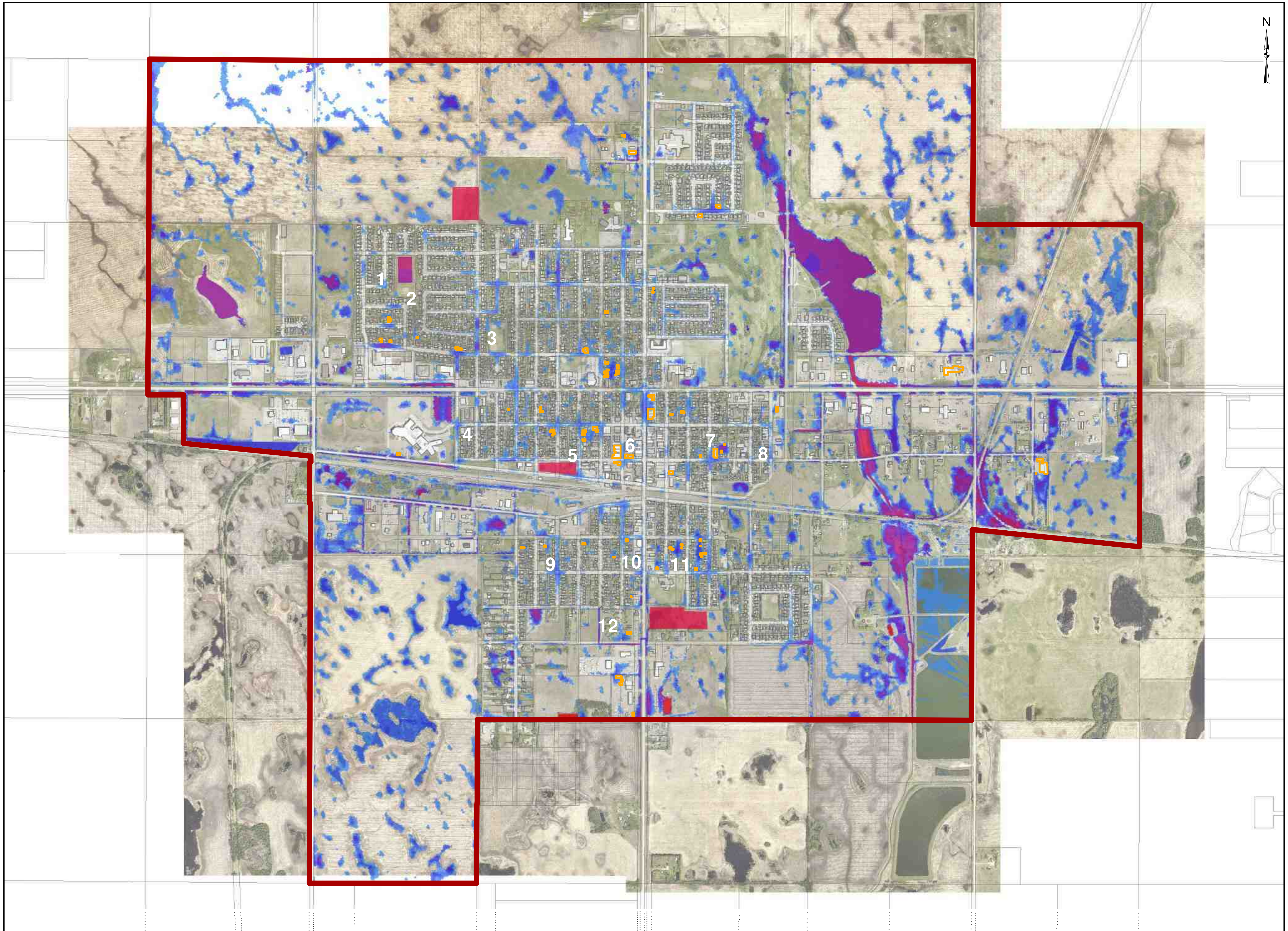

Legend

Maximum Depth (m)

- Less than 0.101
- 0.101 - 0.100
- 0.101 - 0.200
- 0.201 - 0.300
- 0.301 - 0.400
- 0.401 - 0.500
- 0.501 - 0.750
- 0.751 - 1.000
- 1.001 - 1.500
- Greater than 1.500

Impact Depth Greater than 200mm

- Impacted Buildings (66)
- Not Impacted Buildings
- City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 7.8
EXISTING UPGRADES MODEL RESULTS - 2D
MAXIMUM WATER DEPTH
100 YR 24 HR DESIGN STORM
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

Date: 2022-03-16 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure7.8_Pr_2D_Depth_100yr_24hr.mxd

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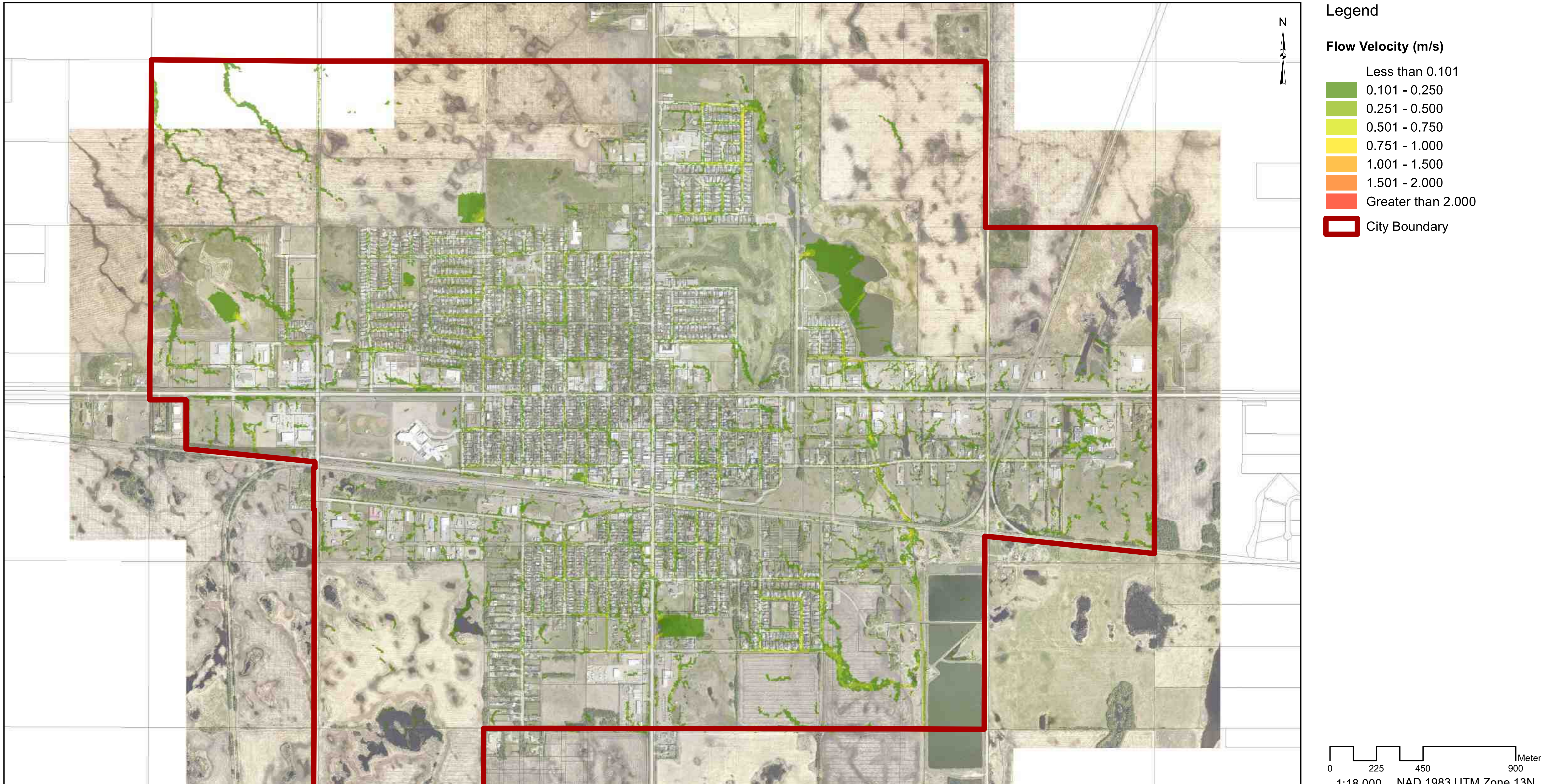

FIGURE 7.9
EXISTING UPGRADES MODEL RESULTS - 2D
PEAK SURFACE FLOW VELOCITY
100 YR 24 HR DESIGN STORM
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

Date: 2022-03-03 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure7.9_Pr_2D_Velocity_100yr_24hr.mxd

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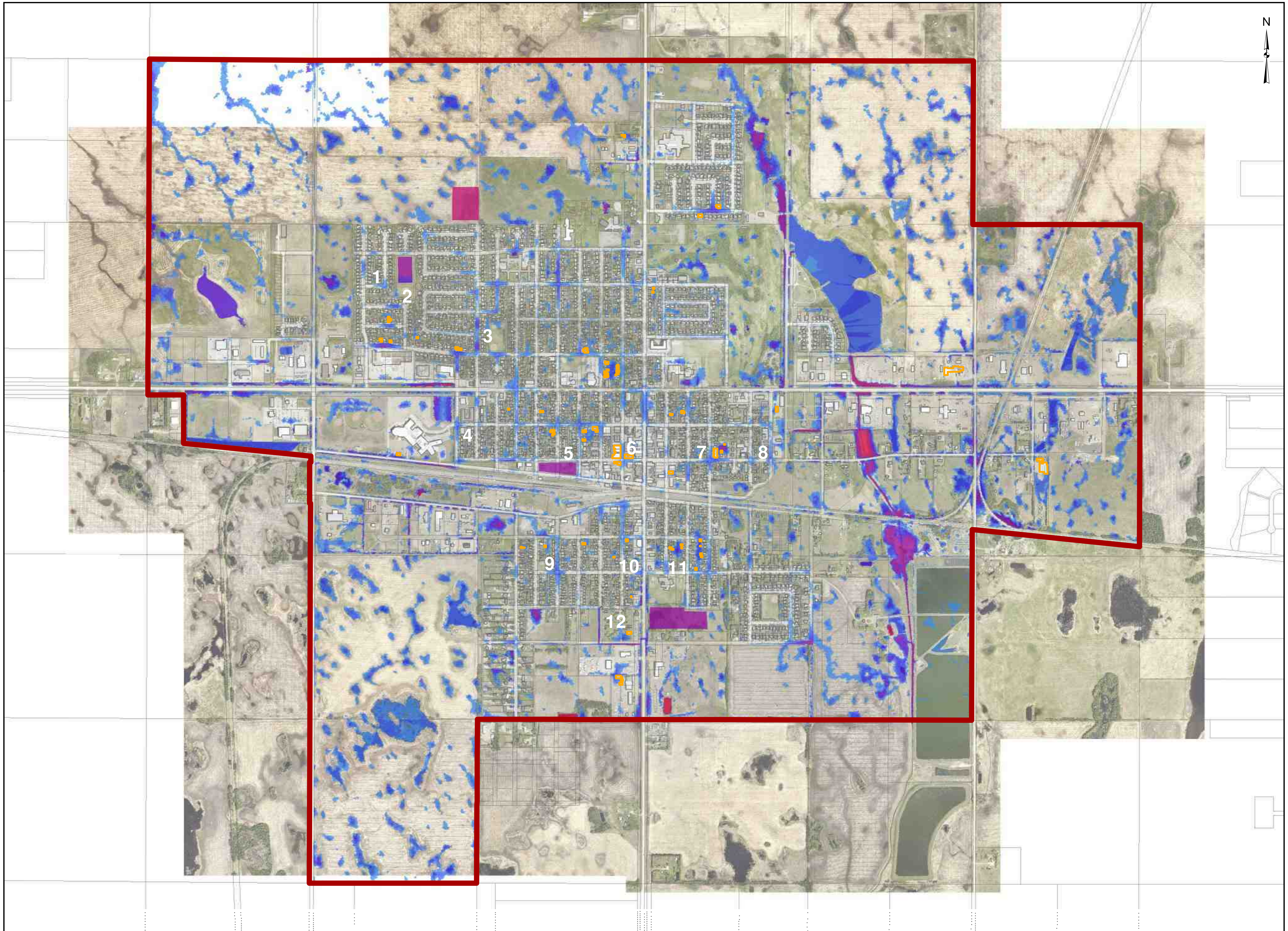

Legend

Maximum Depth (m)

- Less than 0.101
- 0.101 - 0.100
- 0.101 - 0.200
- 0.201 - 0.300
- 0.301 - 0.400
- 0.401 - 0.500
- 0.501 - 0.750
- 0.751 - 1.000
- 1.001 - 1.500
- Greater than 1.500

Impact Depth Greater than 200mm

- Impacted Buildings (56)
- Not Impacted Buildings
- City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 7.10
EXISTING UPGRADES MODEL RESULTS - 2D
MAXIMUM WATER DEPTH
100 YR 1 HR DESIGN STORM - AES
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

Date: 2022-03-16 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure7.10_Pr_2D_Depth_100yr_1hr_AES.mxd

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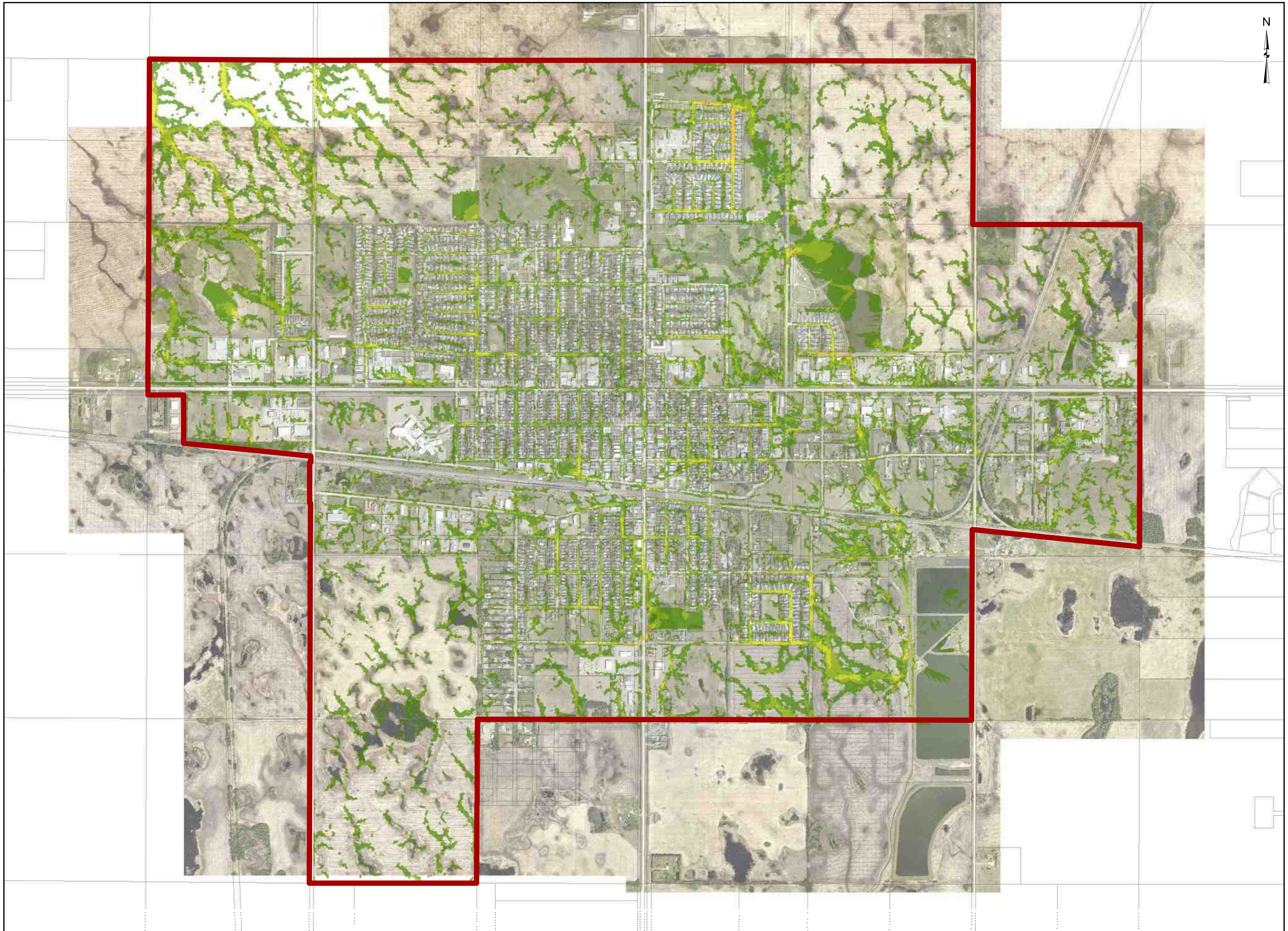


Legend

Flow Velocity (m/s)

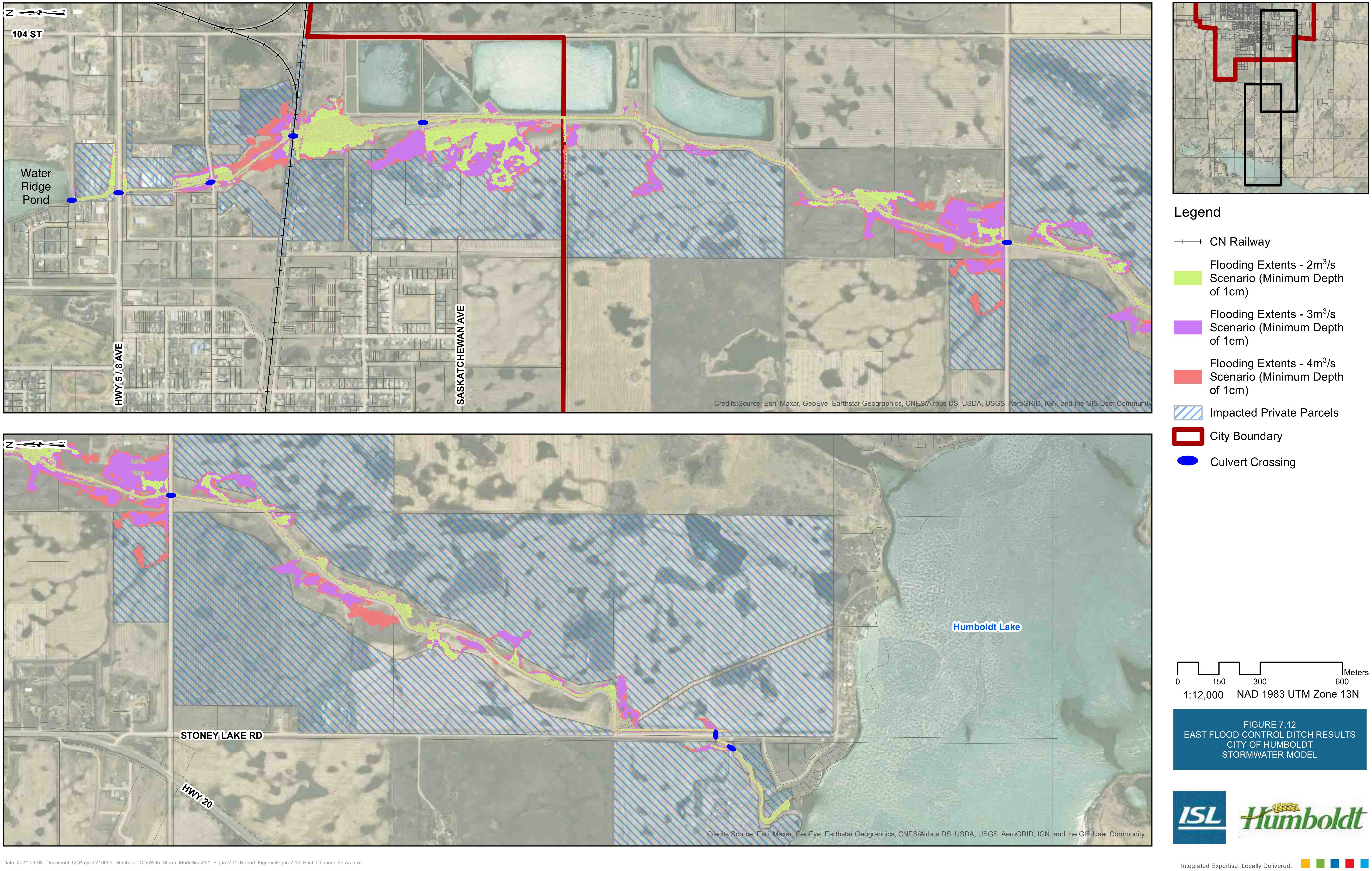
- Less than 0.101
- 0.101 - 0.250
- 0.251 - 0.500
- 0.501 - 0.750
- 0.751 - 1.000
- 1.001 - 1.500
- 1.501 - 2.000
- Greater than 2.000
- City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 7.11
EXISTING UPGRADES MODEL RESULTS - 2D
PEAK SURFACE FLOW VELOCITY
100 YR 1 HR DESIGN STORM - AES
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt


104 ST
Water Ridge Pond
HWY 5 / 8 AVE
SASKATCHEWAN AVE
Credits:Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
STONEY LAKE RD
HWY 20
Humboldt Lake
Legend
CN Railway
Flooding Extents - 2m3/s Scenario (Minimum Depth of 1cm)
Flooding Extents - 3m3/s Scenario (Minimum Depth of 1cm)
Flooding Extents - 4m3/s Scenario (Minimum Depth of 1cm)
Impacted Private Parcels
City Boundary
Culvert Crossing
0 150 300 600 Meters
1:12,000 NAD 1983 UTM Zone 13N
FIGURE 7.12
EAST FLOOD CONTROL DITCH RESULTS
CITY OF HUMBOLDT
STORMWATER MODEL
ISL
Humboldt
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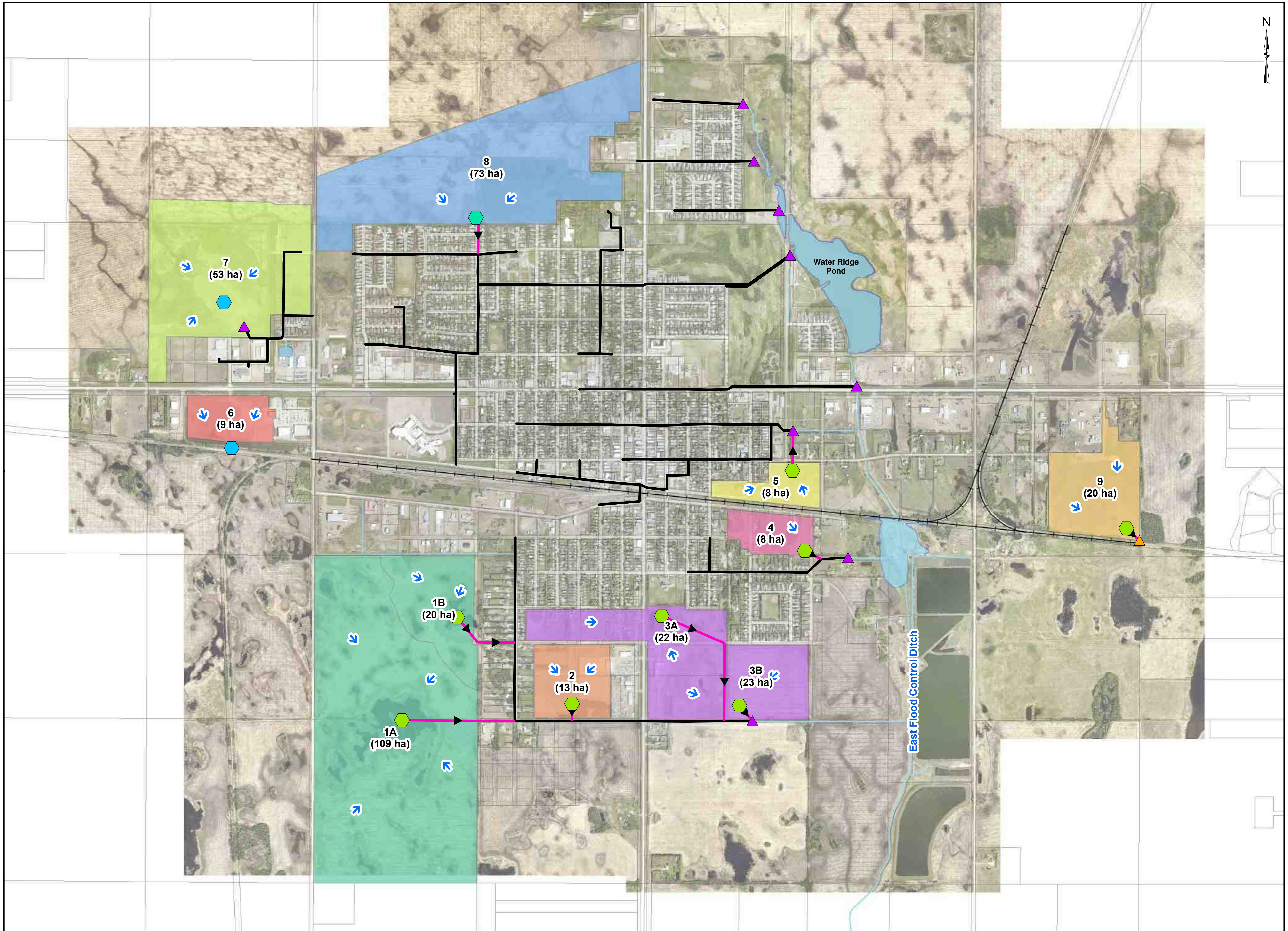

Legend

- Existing Outfall
- Future Outfall
- Existing SWMF
- Proposed SWMF
- Future SWMF
- Future Flow Path
- Existing Pipe (Greater than 300mm Diameter)
- CN Railway
- Drainage Ditch
- Future Storm Sewer

Future Drainage Areas

- Drainage Area 1
- Drainage Area 2
- Drainage Area 3
- Drainage Area 4
- Drainage Area 5
- Drainage Area 6
- Drainage Area 7
- Drainage Area 8
- Drainage Area 9
- Water Body
- City Boundary

0 225 450 900 Meters

1:18,000 NAD 1983 UTM Zone 13N

FIGURE 8.1
FUTURE DRAINAGE AREAS
CITY OF HUMBOLDT
STORMWATER MODEL

ISL Humboldt

Date: 2022-03-10 Document: Q:\Projects\16005_Humboldt_CityWide_Storm_Modelling\251_Figures\01_Report_Figures\Figure8.1_Fut_Drainage_Patterns.mxd

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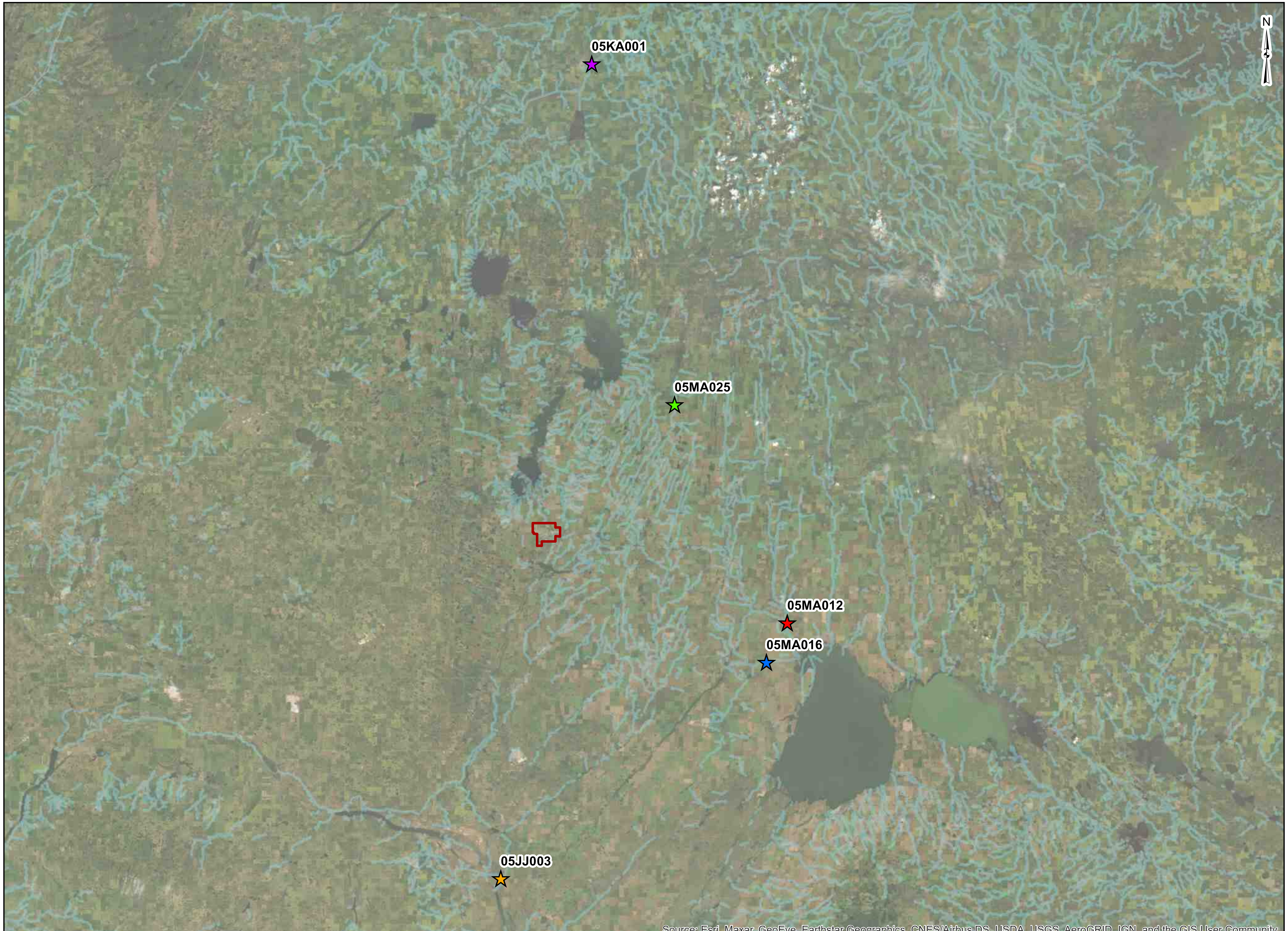

Legend

Hydrometric Station

- 05MA025: Ranch Creek Above Ranch Lake
- 05JJ003: Lanigan Creek Above Boulder Lake
- 05MA016: Romance Creek Near Watson
- 05MA012: Ironspring Creek Near Watson
- 05KA001: Carrot River Near Kinistino
- City Boundary

0 8,000 16,000 32,000 Meters

1:650,000 NAD 1983 UTM Zone 13N

FIGURE 8.2
PROXIMAL HYDROMETRIC STATIONS
CITY OF HUMBOLDT
STORMWATER MODEL

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