Schedule ‘C’ Municipal Class Environmental Assessment for Merritt Road (Regional Road 37) and Rice Road (Regional Road 54) in the Town of Pelham, the City of Thorold and the City of Welland

APPENDIX

F

Stormwater Management and Hydraulic Assessment Report

If technical reports are required in an alternative format for accessibility needs, please contact:

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REGIONAL MUNICIPALITY OF NIAGARA

STORMWATER MANAGEMENT AND HYDRAULIC ASSESSMENT REPORT

MERRITT ROAD & RICE ROAD SCHEDULE 'C' MUNICIPAL CLASS ENVIRONMENTAL ASSESSMENT

FEBRUARY 2024

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STORMWATER MANAGEMENT & HYDRAULIC ASSESSMENT REPORT

MERRITT ROAD & RICE ROAD SCHEDULE ‘C’ MUNICIPAL CLASS ENVIRONMENTAL ASSESSMENT

REGIONAL MUNICIPALITY OF NIAGARA

PROJECT NO.: IM20103036
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1 INTRODUCTION

The Regional Municipality of Niagara (Niagara Region) has retained WSP E&I Canada Limited (WSP) (formerly Wood Environment & Infrastructure Solutions (Wood)) to undertake a Schedule ‘C’ Municipal Class Environmental Assessment (MCEA) Study for improvements to Regional Road 37 (Merritt Road) and Regional Road 54 (Rice Road), in the Town of Pelham, City of Thorold, and City of Welland, Ontario.

Through various plans and studies, the need for additional east/west transportation capacity has been identified. Merritt Road's extension between Rice Road and Cataract Road and improvements to Merritt Road between Cataract Road and Regional Road 50 (Merrittville Highway)/Niagara Street have been identified and recommended to address the need for additional east/west transportation capacity. The purpose of this MCEA was to address the need for additional east/west transportation capacity and connectivity of the active transportation network through the extension and improvement of Merritt Road and the improvement of Rice Road.

Building on the recommendations of the Niagara Region’s Transportation Master Plan, this study was conducted in accordance with the requirements of a MCEA Schedule ’C’ project (Phases 1 to 4) as outlined in the Municipal Class Environmental Assessment document (Municipal Engineers Association, 2023).

1.1 STUDY AREA

For the purposes of the current study, the Regional Road 37 (Merritt Road) and Regional Road 54 (Rice Road) corridors within the study area have been divided into the following four (4) road segments (ref. Figure 1-1):

- Segment 1 – Merritt Road from Rice Road to Cataract Road
- Segment 2 – Merritt Road from Cataract Road to Merrittville Highway / Niagara Street
- Segment 3 – Merritt Road from Merrittville Highway / Niagara Street to Highway 406
- Segment 4 – Rice Road from Merritt Road to Quaker Road

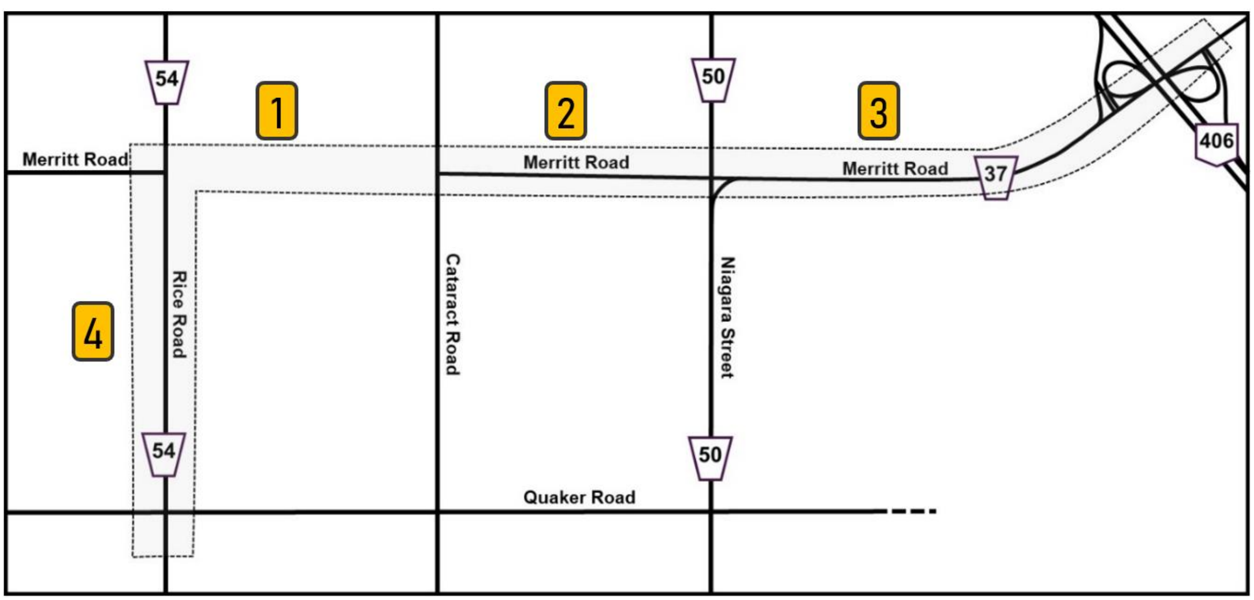


Figure 1-1: Study Area

The study area is located in a predominantly rural area that is rapidly developing due to the urbanization of portions of the Town of Pelham, Town of Thorold and City of Welland through a set of secondary plans. This project is to provide an opportunity to reimagine the two corridors such that the corridors will meet the future needs of the surrounding community from the perspective of all road users. The corridors pass through portions of three (3) different secondary plans: the East Fonthill Secondary Plan in the Town of Pelham, the West Port Robinson Secondary Plan in the City of Thorold, and the Northwest Welland Secondary Plan in the City of Welland. Further description regarding the active and planned Secondary Plans within this area can be found in the accompanying Environmental Study Report completed for this study (ref. WSP, 2023).

In terms of the local natural environment, the study area is located within the jurisdiction of the Niagara Peninsula Conservation Authority (NPCA). The study area contributes to two (2) subwatershed systems within NPCA's jurisdiction, including the Singer's Drain subwatershed, and the Towpath Drain subwatershed, both ultimately contributing to the Central Welland River. The majority of the study area is contributing to the Singer's Drain subwatershed, which has several tributaries crossing the subject road right-of-way (ROW) segments, feeding into Niagara Street Cataract Road Woodlot Wetland Complex, which is a Provincially Significant Wetland (PSW) regulated by the NPCA. These features and drainage conditions are important considerations as part of the infrastructure planning processes, as such NPCA has required an impact assessment to be conducted for the wetlands located adjacent to Segment 1.

1.2 STUDY OBJECTIVES

The purpose of this report is to characterize and outline the findings from the existing conditions drainage assessment of Merritt Road and Rice Road, and to establish preliminary stormwater management (SWM) alternatives to accommodate the proposed roadway designs. This report documents the following as guidance to be confirmed through subsequent detailed design phase:

- Existing & Proposed Hydrologic Conditions
- Preliminary Stormwater Management Strategies and Sizing
- Localized Floodplain Impact Assessment for Singer's Drain
- Preliminary Hydraulic Structure Sizing for Regulated Watercourses on Singer's Drain
- Wetland Impact Assessment for the PSW located along Segment 1

This work has been completed in support of the Schedule 'C' Municipal Class Environmental Assessment (MCEA), Detailed Transportation Assessment and Active Transportation Plan for both Merritt Road and Rice Road. The scope of Hydraulic Assessment and Wetland Impact Assessment presented in this report was determined with input from the Niagara Peninsula Conservation Authority (NPCA). This report should be read in conjunction with the associated Environmental Study Report, and the Environmental Impact Study, both produced in support of this study (ref. WSP, 2023). The following sections of this report outline the analysis and findings of the current study.

2 BACKGROUND REVIEW

2.1 BACKGROUND INFORMATION

In support of the current study, the following background information has been provided by the Niagara Region, NPCA, MTO, and/or sourced from open data sources for use in the current SWM assessment for Merritt Road and Rice Road as part of the MCEA.

MAPPING DATA:

- SWOOP 2015 LiDAR Data – 2 m Resolution Raster (LIO, 2015)
- NPCA Digital Elevation Model – 5 m Resolution Raster (NPCA, 2015)
- NPCA Digital Terrain Model – Polyline File (NPCA, 2020)
- Contemporary Watercourse Mapping (NPCA)
- Major Watercourse Mapping (Niagara Region)
- Cross Culvert Mapping (Niagara Region)
- Land Use Mapping (Niagara Region)
- Regulatory Floodplain Limits (NPCA)
- OMAFRA Soil Survey Complex (LIO, 2020)
- Wetland Mapping (NPCA)

REPORTS:

- Singer's Drain Floodplain Update Report (AMEC, June 2011)
  - HEC-RAS Model Version 4.1 & SWMHYMO Model
- Northwest Welland Stormwater Management Implementation Plan (Upper Canada Consultants, October 2022)
- Central Welland River Watershed Plan (Niagara Peninsula Conservation Authority, November 2010)
- Welland Northwest Area Secondary Plan, Stormwater Management Plan (Aquafor Beech Limited, 2020)
- Towpath Estates Functional Servicing Report (Upper Canada Planning and Engineering Ltd, August 2021)
- Port Robinson West Subwatershed Study (Totten Sims Hubicki Associates, April 1999)
- Port Robinson West Scoped Subwatershed Update (ref. Aquafor Beech, 2020)
- Beaverdams and Shriners Creek Watershed Plan (NPCA, June 2011)
- Plan & Profile Drawings for local Storm Sewer Systems (various)

This information has been used as key background resources to characterize and support the current assessment. Further details are provided in the subsequent sections to identify uses for the data as part of the current study.

2.2 SUBWATERSHED SYSTEMS

As mentioned previously, the study area is located within the Central Welland River watershed, contributing to two (2) individual subwatershed systems, namely Singers Drain and Towpath Drain, both of which ultimately contribute to the Welland River (ref. Figure 2-1). These systems and the relation to the current study area are described further in the following sections.

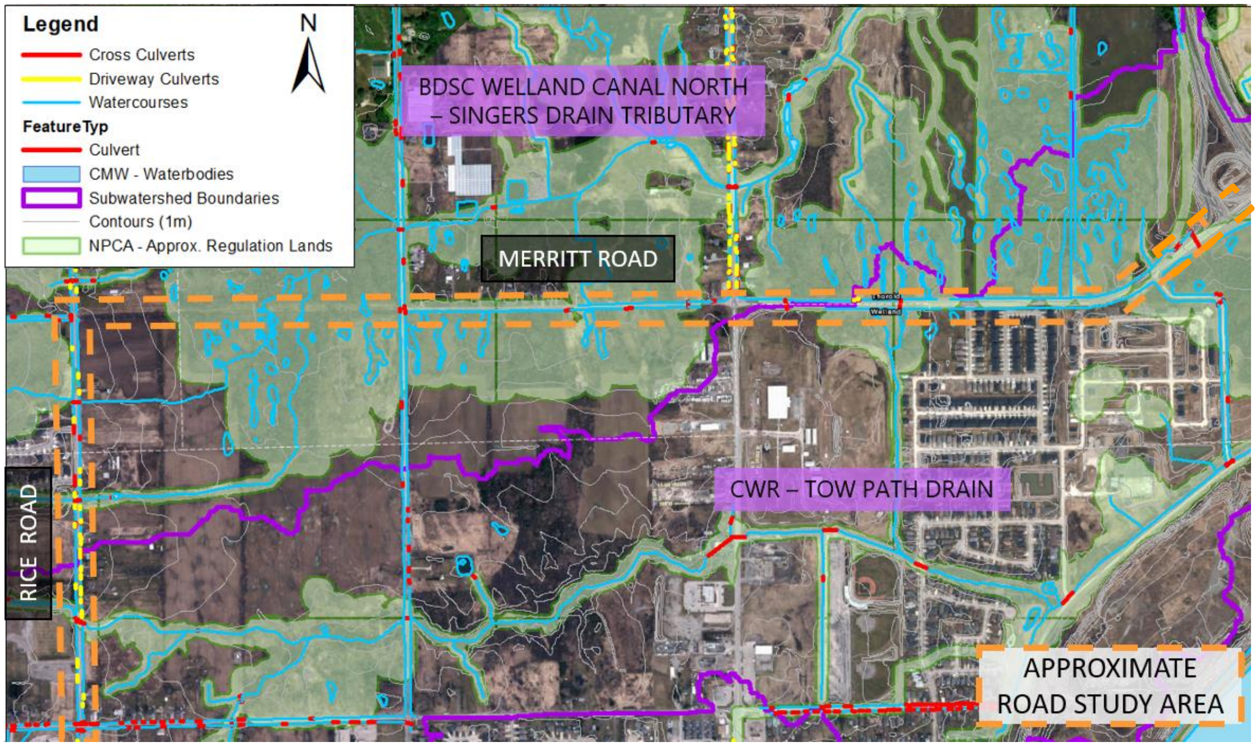


Figure 2-1: Merritt Road & Rice Road - Subwatershed Systems

2.2.1 SINGERS DRAIN

The Singers Drain is a watercourse located within the Beaver Dam Shriner's Creek (BDSC) subwatershed system, and ultimately contributes to the Welland Canal North system. The Singers Drain subwatershed has a drainage area of approximately 1570 hectares, and begins west of Pelham Street, south of Port Robinson Road, and continues to drain west to east, through the municipalities of the Town of Pelham, City of Thorold and City of Welland. The lands contributing to the Singers Drain are primarily rural / natural lands, as well as some areas of low density residential. The Singers Drain subwatershed has been assessed as part of several preceding studies, including but not limited to:

- Port Robinson West Subwatershed Study (Totten Sims Hubicki Associates, April 1999)
- Singers Drain Floodplain Update Report (AMEC, June 2011)
- Beaverdams and Shriners Creek Watershed Plan (NPCA, June 2011)
- Port Robinson West Scoped Subwatershed Update (ref. Aquafor Beech, 2020)

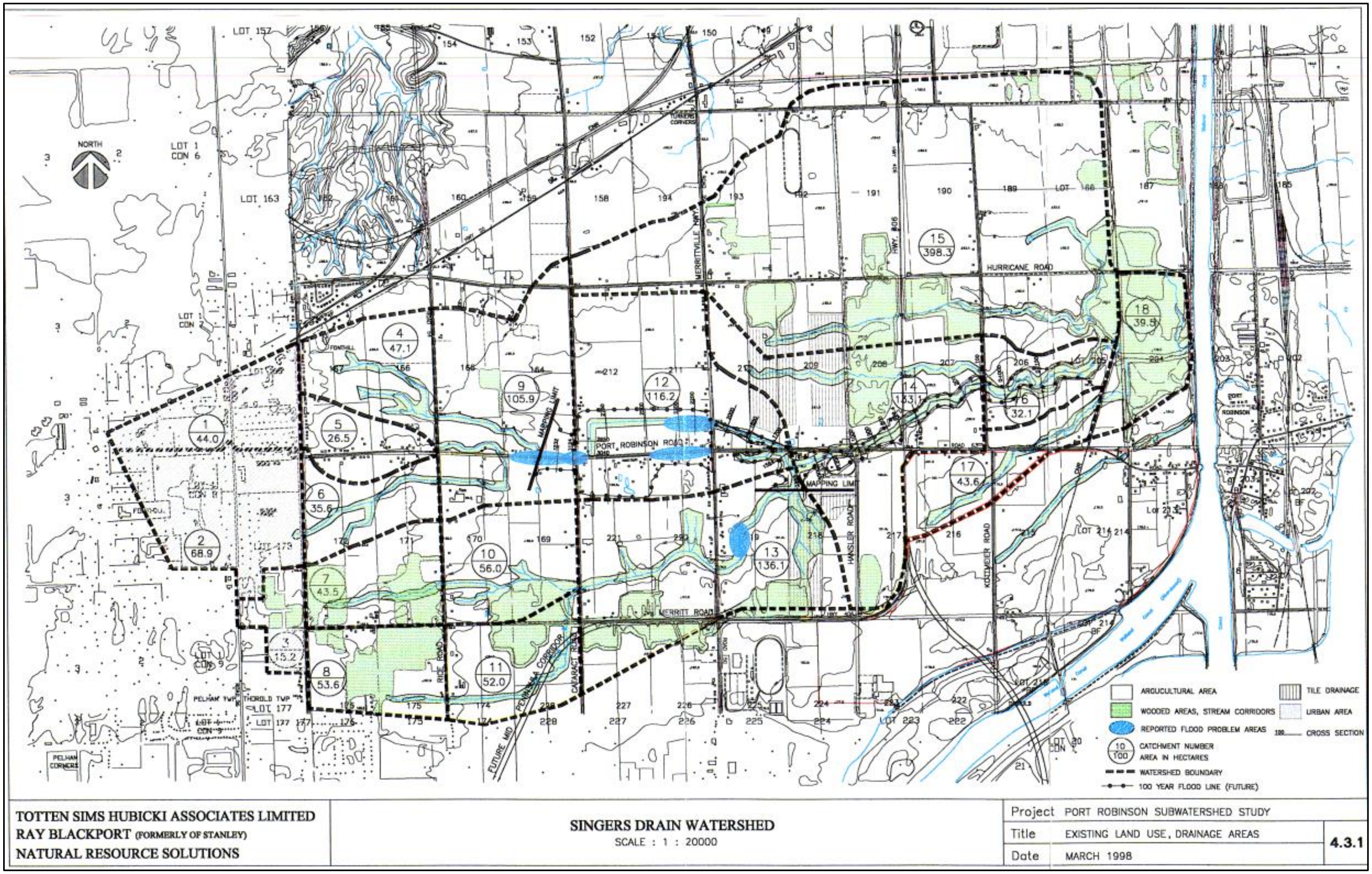


Figure 2-2: Singers Drain Watershed Catchment Plan (ref. Totten Sims Hubicki Associates, 1999)

Through review of the preceding studies, it has been identified that there are several known Flood Damage Centers within the Singers Drain system. Through discussions with the NPCA, it is understood that the area of Cataract Road and Merritt Road, directly north of the intersection of Segment 1 and Segment 2, is also a known Flood Damage Center (although not identified in the 2011 study). This area is understood to be prone to ponded water within the roadside ditches and overtopping the roadway crossing during significant events. While the scope of this study was not to investigate these off-site conditions or identify potential solutions, it is important to understand the local conditions as it relates to the preliminary assessment of the roadway designs.

The study area of Merritt Road and Rice Road contribute to the Singers Drain system in the headwaters, including Segment 1, Segment 2 and portions of Segment 3 and Segment 4 contributing to the regulated watercourses via roadside ditches. The roadway study area also has three (3) existing watercourse roadway crossings along Rice Road (Segment 4), and watercourses crossing through the unopened road allowance of Merritt Road (Segment 1). Further details with respect to the existing roadway drainage patterns are provided in the subsequent sections.

2.2.2 TOWPATH DRAIN

The Towpath Drain is a watercourse located within the Center Welland River Subwatershed system, and contributes to the Welland Canal system. The Towpath Drain Subwatershed has a drainage area of approximately 1700 hectares (+/-), and begins west of Claire Avenue, north of Quaker Road, and continues to drain west to east, through the municipalities of Pelham, Thorold, and Welland. The land use of the Towpath Drain subwatershed is a mix of urban, industrial, natural areas, and agricultural lands.

The Towpath Drain subwatershed has been assessed as part of several preceding studies, including but not limited to:

- Central Welland River Watershed Plan (NPCA, November 2010)
- Welland Northwest Area Secondary Plan, Stormwater Management Plan (Aquafor Beech Limited, 2020)
- Towpath Estates Functional Servicing Report (Upper Canada Planning and Engineering Ltd, August 2021)

Through the review of the preceding studies, it has been identified that the headwaters of the Towpath Drain are identified on the Fonthill Kame-Delta Complex, which is an area of significant groundwater recharge and an area of high groundwater vulnerability (ref. NPCA, 2011). The Central Welland River Watershed Plan identified several special studies to support reduction of contaminant and point source pollution throughout the Towpath Drain subwatershed (ref. NPCA, 2011).

The study area of Merritt Road and Rice Road contributes to the Towpath Drain system in the Upper-Mid area of the headwaters (southern portion of Segment 4), as well as further downstream near the eastern portion of Segment 3 approaching the Highway 406 interchange. The roadway study area also has one (1) existing watercourse roadway crossing along Rice Road (Segment 4), located north of Quaker Road. Further details with respect to the existing roadway drainage patterns are provided in the subsequent sections.

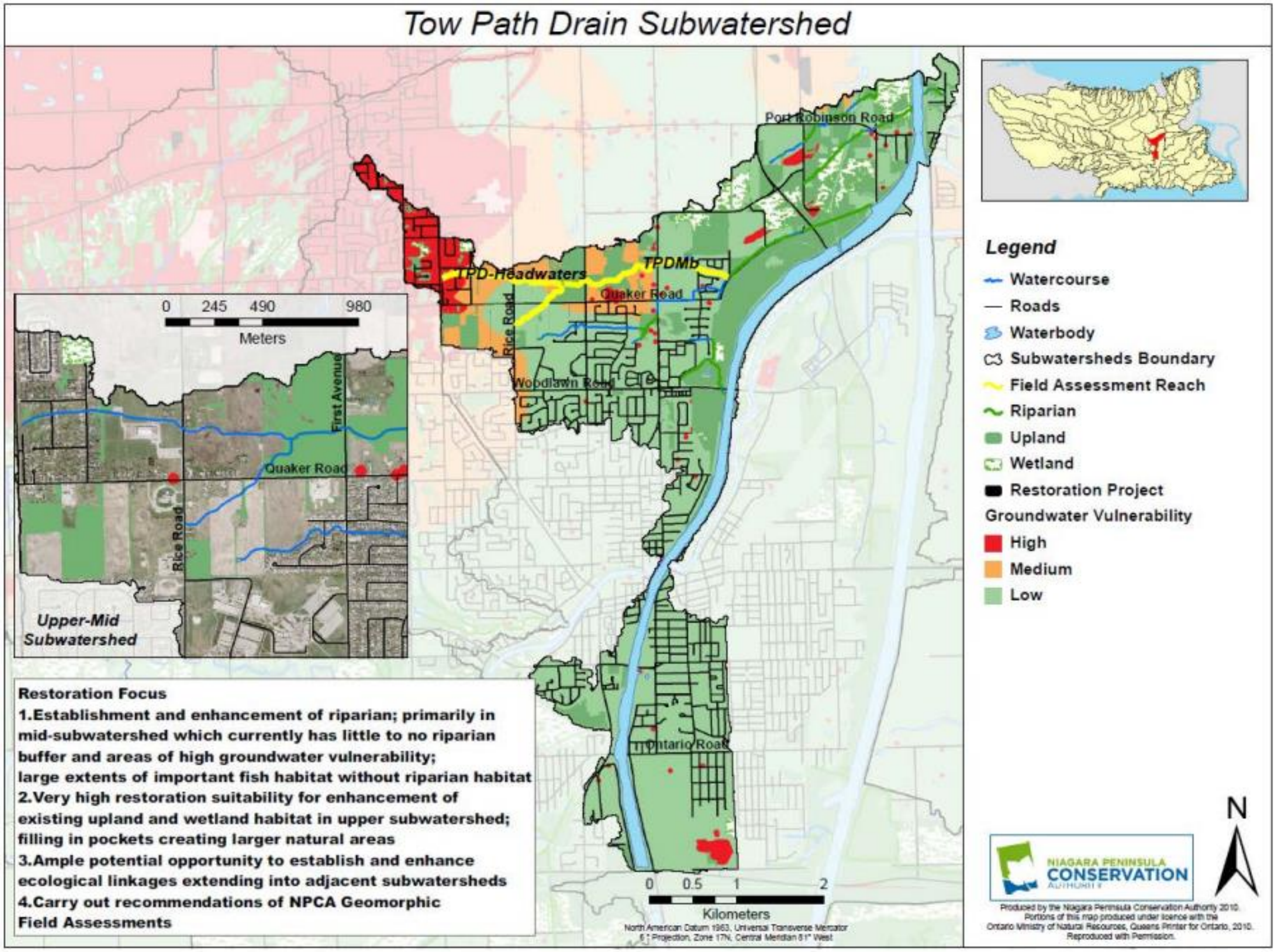


Figure 2-3: Towpath Drain Subwatershed (ref. NPCA, 2011)

2.3 STORMWATER MANAGEMENT DESIGN CRITERIA

As this assessment was completed for the Niagara Region as part the MCEA study, it is understood that the Niagara Region Stormwater Management Guidelines (dated December 1st, 2022) will likely take precedence. That being said, the study area is located within (3) lower-tier municipalities, namely the City of Thorold, the City of Welland and the Town of Pelham, and is also within the jurisdiction of the NPCA. Therefore, each of the respective SWM / Engineering guidelines have been reviewed to identify the applicable SWM criteria for the study area. Generally, the design guidelines from the local area municipalities and the Region specify the design criteria for stormwater management and identify other guidelines / standards that should be followed. These additional guidelines include provincial guidelines by the Ministry of the Environment, Conservation and Parks (MECP), and Ministry of Transportation (MTO) to inform other design requirements (i.e., watercourse crossings, etc.). The following documents have been reviewed:

- Niagara Region Stormwater Management Guidelines (December 2022)
- City of Thorold Official Plan (April 2016)
- City of Welland Municipal Standards (February 2013)
- Town of Pelham Municipal Engineering Design Criteria and Standard Drawings (August 2016)
- NPCA Stormwater Management Guideline (2010)
- MECP Stormwater Management Practices Planning and Design Manual (2003)
- MECP Draft LID Stormwater Management Guidance Manual (2017)
- MTO Design Flood Criteria Directive B-100

It should be noted that the current study is not guided specifically by a local Subwatershed Study (SWS), Master Drainage Plan (MDP) or Master Environmental Servicing Plan (MESP). Therefore, local applicable guidance may be refined as part of future detailed design phase. Based upon review of the above-mentioned documents, the Niagara Region Stormwater Management Guidelines (December 2022) has generally been found to be the most stringent, as it is the most recent guideline prepared to date and has included a jurisdictional scan of SWM criteria and requirements as part of the development of the guidelines for the Niagara Region.

The following has been concluded as the most stringent / current overarching SWM criteria for the study area:

- **Quantity Control:**
  - — Post-development runoff peak flows are to be controlled to pre-development levels (consistent across various guidelines).
- **Erosion Control:**
  - — The Niagara Region Guidelines identify the following options:
    - o Guidance from preceding studies including the assessment of downstream erosion susceptibility and critical flow values in conjunction with event modelling and assessment of downstream erosion critical velocity or shear forces in conjunction with continuous simulation techniques (duration analysis); or,
    - o Extended Detention storage for the 4-hour 25 mm rainfall event, or

    - Retention of the geographically specific 90th percentile precipitation storm event, which for the Niagara Region is between 28-29 mm (i.e., Runoff Volume Control Target, as per the MECP Draft LID SWM Guidance Manual).
  - Note, the current study has not included a stream morphological assessment to determine critical flows or erosion susceptibility of the receiving watercourses. Therefore, for the current assessment this option has been screened.

- **Water Quality Control:**
  - 80% average annual removal of Total Suspended Solids (TSS) removal, equivalent to the MECP "Enhanced" criteria, achieved through the treatment train process. Engineered technologies such as Oil-Grit Separators and Catch Basin inserts should be ETV certified.
- **Water Budget:**
  - Retention of the first 5 mm of rainfall (ref. Niagara Region, 2022).
- **Conveyance Criteria:**
  - Minor Systems are to be designed to accommodate the 5-year return period storm event; note that region-owned sewer systems should limit surcharging during the 100-year event.
  - Major Systems are to be designed to accommodate the 100-year storm event and will adhere to the maximum depth of flooding requirements based upon road classification.
- **Watercourse Crossings:**
  - Roadway crossings shall be designed in accordance with the MTO's Highway Drainage Standards (2008).
  - Consideration for the Regulatory event shall be given, to ensure no impact to the Regulatory floodplain regulated by NPCA.

The above summary represents the overarching SWM criteria that should be considered in determining the strategies for SWM design as it relates to the proposed design of Merritt Road and Rice Road. Further details in relation to the applicable SWM criteria and the options available for the proposed roadway design are provided in Section 3.2.

3 HYDROLOGY

3.1 EXISTING CONDITIONS

3.1.1 CHARACTERIZATION

As noted previously, the Merritt Road and Rice Road study area contributes to two (2) subwatershed systems, ultimately discharging to the Welland Canal. The subject roadways are rurally serviced by roadside ditches under existing conditions, and contribute to a variety of watercourses / drainage features throughout the study area (ref. Figure 3-1). This includes three (3) tributaries of the Singers Drain which cross Rice Road, namely North, Center and South Tributaries, as well as one (1) crossing of the Towpath Drain on Rice Road. Additional cross-culverts are found along the ROWs to facilitate other tributary drainage or convey ditch drainage to the ultimate outlet. The ditches within the study area have been surveyed as part of the current study which supported the characterization of the existing drainage conditions and development of the subcatchment plan.

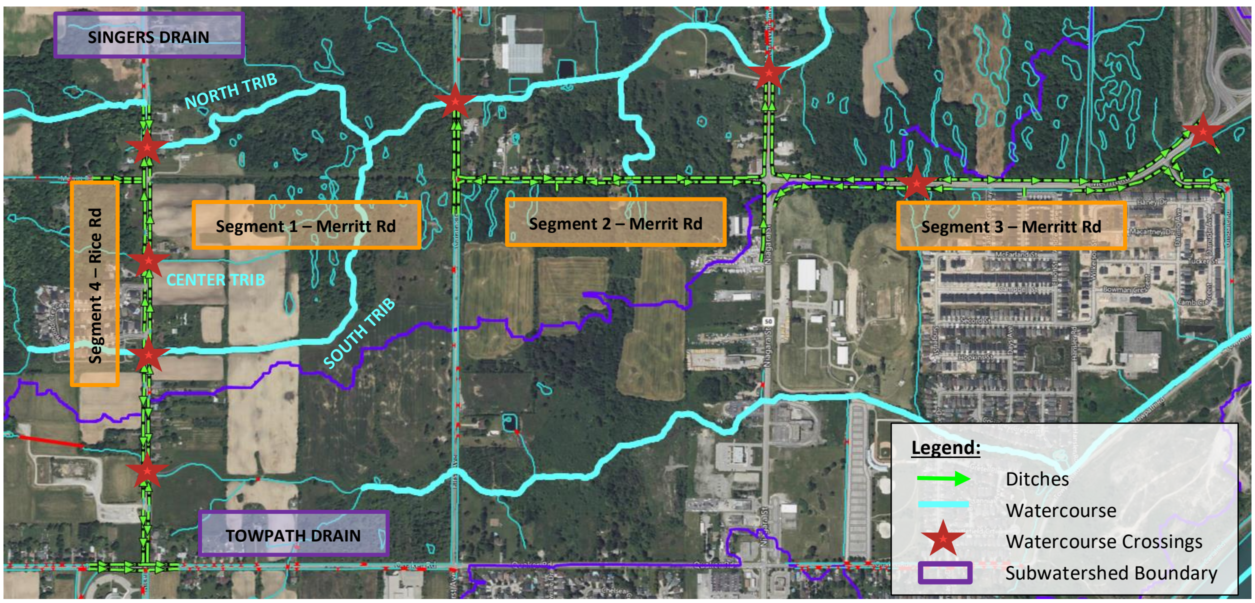


Figure 3-1: Study Area Drainage Conditions Overview

The overall existing drainage boundaries are presented in Appendix A. A description of the storm drainage systems, to each outlet is provided in the following sections and should be read in conjunction with the drainage figures provided within Appendix A. Road Stations corresponding to the drainage system boundaries have been provided for each drainage outlet. The delineation of the drainage catchments has been developed using the available background information, along with additional discretization of the external drainage areas. Further details are provided in subsequent sections, moving from west to east, upstream to downstream, starting from Segment 4, Segment 1, Segment 2 and Segment 3.

3.1.1.1 SEGMENT 4 – RICE ROAD

RICE RD. AT QUAKER RD. (10+150 TO 10+300) [DRAINING TO THE EAST]

The southern section of Quaker Rd. will remain unaffected by the proposed project, thereby eliminating the necessity to evaluate the drainage ditch on that side. Drainage originating from the external subcatchments and right-of-way, spanning from approximately Station 10+300 to Quaker Rd. (Station 10+150), naturally drains in a southerly direction via roadside ditches on both sides of Rice Rd. The western ditch confluences with the ditch located on the northern side of Quaker Rd. before crossing Rice Rd. through a 400 mm CSP culvert. Drainage then continues towards the east, designated as Outfall OF_R1 in the model.

RICE RD. AT TOWPATH DRAIN (10+300 TO 10+620) [DRAINING TO THE EAST]

Twin 600 mm diameter CSP culverts traverse Rice Rd. at approximately Station 10+410, conveying drainage from the external watercourse (Towpath Drain) and the drainage from the roadside ditch located on the western side of Rice Rd. to the east side of the road. Drainage conveyed by the eastern roadside ditches confluences with the drainage from the twin culverts and is then conveyed to the Towpath Drain in an eastward direction. The roadside ditches on both sides of Rice Rd. convey drainage from the external subcatchments and the ROW subcatchments encompassing the drainage area ranging from approximately Station 10+300 to Station 10+620.

RICE RD. AT SINGERS DRAIN SOUTH TRIBUTARY (10+620 TO 10+780) [DRAINING TO THE EAST]

The Singers Drain South Tributary intersects Rice Rd. at a low point in the road profile located approximately at Station 10+720, and traverses Rice Rd. through a 750 mm diameter CSP culvert. The culvert also conveys drainage from the ditch located on the western side of Rice Rd. The west ditch accommodates both external and ROW drainage originating from approximately Stations 10+620 to 10+780. Drainage from the culvert is conveyed by the Singers Drain South Tributary, to the wetlands adjacent to Segment 1.

RICE RD. AT SINGERS DRAIN CENTER TRIBUTARY (10+780 TO 11+020) [DRAINING TO THE EAST]

The western roadside ditch conveys the external and ROW drainage, spanning from approximately Station 10+780 to 11+040. Drainage is conveyed by the western roadside ditch which traverses Rice Rd., at approximately Station 10+960, through a 500 mm CSP culvert. The culvert’s outflow confluences with the drainage from the eastern roadside ditch and then the drainage is conveyed by the Singers Drain Centre Tributary to the wetlands adjacent to Segment 1.

RICE RD. AT SINGERS DRAIN NORTH TRIBUTARY (11+020 TO 11+380) [DRAINING TO THE EAST]

The western roadside ditch conveys the external and ROW drainage, spanning from approximately Station 11+040 to 11+380. Drainage conveyed by the western roadside ditch traverses Rice Rd., approximately at Station 11+270, through a 600 mm CSP culvert. The culvert’s outflow confluences with the drainage from the eastern roadside ditch and then, the drainage is conveyed by the Singers Drain Centre Tributary to the wetlands adjacent to Segment 1.

3.1.1.2 SEGMENT 1 – MERRITT ROAD

MERRITT RD. AT SEGMENT 1 (20+160 TO 20+960) [DRAINING TO THE NORTH]

As previously noted, Segment 1 is currently undeveloped. The subcatchments in this area drain overland to one of the wetland pockets or the Centre Tributary, which intersects with the proposed location of Merritt Rd. at Station 20+640. It is important to note that this particular location is characterized by a relatively low elevation, where a wetland pocket is also situated. Due to the flat terrain in this area, significant flooding can occur during major events, as elaborated upon in Section 4.

Similarly, the South Tributary also crosses the proposed location of Merritt Rd. at Station 20+720, where another wetland pocket is situated. Furthermore, an unnamed tributary, connecting a series of wetlands, intersects with the proposed location of Merritt Rd. at Station 20+880. The three watercourses converge north of Merritt Rd. before passing beneath Cataract Rd. through a 1.8 m by 1.5 m horizontal ellipse culvert.

3.1.1.3 SEGMENT 2 – MERRITT ROAD

MERRITT RD. AT CATARACT RD (20+960 TO 21+100) [DRAINING TO THE WEST]

The drainage system for Cataract Rd. consists of roadside ditches, which receive runoff from external subcatchments and direct it northward to join the main branch of Singer's Drain. Additionally, two ditches, located on either side of Merritt Rd., convey stormwater drainage from external subcatchments and the Merritt Rd. right-of-way, spanning from Station 20+960 to 21+100. The conveyed drainage of the northern roadside ditch confluences with the outflow from the elliptic cross culvert traversing Cataract Rd. The shallow depth of the roadside ditches in this area, combined with the generally flat terrain, poses a significant risk of frequent flooding. The existing drainage system performs inadequately. Improvements to the drainage system performance should be considered within the proposed right-of-way configuration.

MERRITT RD. AT SEGMENT 2 (21+100 TO 21+400) [DRAINING TO THE SOUTH]

Segment 2 of Merritt Rd., spanning from Station 21+100 to 21+400, has a relatively low elevation, resulting in flooding within the ROW. The drainage system within this area consists of roadside ditches which overflow due to both a lack of capacity and the receiving system's tailwater conditions. This overflow either spills westward to converge with the drainage from the east roadside ditch of Cataract Rd. or continues eastward along the roadside ditches of Merritt Rd. until the excess drainage can spill into an unnamed watercourse that drains northward. This watercourse eventually confluences with the main branch of Singer's Drain. A 350 mm diameter CSP cross culvert is situated approximately at Station 21+250, providing a hydraulic connection between the north ditch and the south roadside ditch of Merritt Rd.

MERRITT RD. AT SEGMENT 2 (21+400 TO 21+800) [DRAINING TO THE EAST]

The southern roadside ditch conveys external and ROW drainage, spanning from approximately Station 21+400 to 21+800 (Merrittville Hwy.). Drainage conveyed by the southern roadside ditch traverses Merritt Rd. through three CSP cross culverts. These culverts have varying sizes, ranging from 400 mm to 600 mm in diameter. The culverts' outflow confluences with the drainage from the western roadside ditch of Merrittville Hwy. and continues northward until it confluences with the main branch of Singer's Drain then traverses Merrittville Hwy, through a 3 m by 1.8 m box culvert.

3.1.1.4 SEGMENT 3 – MERRITT ROAD

MERRITT RD. AT MERRITTVILLE HWY (21+800 TO 22+340) [DRAINING TO THE WEST]

The section of Merritt Rd. extending from Station 21+800 (Merrittville Hwy.) to 22+340 drains via roadside ditches. Within this road section, the southern ditch of Merritt Rd. from Merrittville Hwy. to Station 22+060 conveys external and ROW drainage. Drainage conveyed by the southern roadside ditch traverses Merritt Rd., approximately at Station 21+940, through a 750 mm diameter CSP culvert. The culvert's outflow confluences with the drainage from the eastern roadside ditch of Merrittville Hwy. and continues northward until it confluences with the main branch of Singer's Drain.

It is important to note that the southern ditch of Merritt Rd. from Station 22+060 to 22+300 is at a sag point within the ditch profile. Drainage within this area remains confined within the southern ditch until the until drainage spills over the high points within the ditches. Alternatively, the drainage may pass through a 900 mm CSP cross culvert, located approximately at station 22+220, to reach the north ditch and drain westward.

MERRITT RD. AT SEGEMENT 3 (22+340 TO 23+100) [DRAINING TO THE EAST]

Under existing conditions, the section of Merritt Rd. extending from Station 22+340 to 23+100 is rurally serviced via roadside ditches. Generally, both the drainage is directed eastward along the road ROW and then contributes south near Grisdale Road. Drainage conveyed by the northern roadside ditch crosses Merritt Rd at approximately Station 23+010, and is conveyed through a 1050 mm CSP culvert, and is assumed to enter the treed area east of Grisdale Road. It should be noted that the southern half of the ROW of Merritt Rd. at the Eastman Gateway area (from Station 22+380 to 22+620) currently drains to an existing catch basin and contributes to the storm sewer along Andrew Lane.

3.1.2 HYDROLOGIC MODELLING

3.1.2.1 PCSWMM MODEL SET-UP

An integrated hydrologic/hydraulic model of the existing conditions of Merritt Rd. and Rice Rd. ROW has been developed in PCSWMM. The model has been discretized to include external subcatchments as well as the ROW subcatchments contributing to each side of the roadside ditches within the ROW. The following subsections provide a summary of the model set-up and parameterization.

SUBCATCHMENTS

The processed 2 m resolution Digital Elevation Model (DEM) from the 2015 SWOOP program has been utilized for the delineation of refined subcatchment boundaries. PCSWMM's automated watershed delineation tool has been applied for initial boundary determination based on the preceding DEM. The boundaries have been reviewed and refined based on aerial imagery, field reconnaissance, and Google Street View™ to ensure the boundaries are reasonable and reflective of existing conditions. The model development has resulted in a total of 152 subcatchments, with a total modelled area of approximately 575 hectares (+/-), equating an average subcatchment area of 3.75 hectares (+/-).

Following the development of the refined subcatchment boundaries, the surficial soil mapping developed by the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) has been reviewed to confirm surficial soil conditions within the study area. Based on the review of this data, the five (5) soil types that have been identified within the study area are presented in the Table 3-1 and shown in the figure provided in Appendix F. An area weighting approach has been used to determine the proportion of each Soil Type within the subcatchments.

Table 3-1: Identified Soil Types in the Study Area

SOIL TYPE	AREA (HA)	PERCENTAGE OF DRAINAGE AREA (%)
Other (i.e., Built-up Area)	190.0	33%
Loam	137.7	24%
Very Fine Sandy Loam	126.9	22%
Silt Loam	72.5	13%
Fine Sandy Loam	47.0	8%
Silty Clay Loam	1.0	0.2%

As indicated by **Error! Reference source not found.**, the majority of the drainage area is covered by Loam, with all other soil textures in the vicinity also containing some amount of loam, ranging from very fine sandy loam to silty clay loam. Using this area weighted soil data, the parameterization has been applied using the Green-Ampt infiltration methodology. Appropriate soil parameters for the hydraulic conductivity, suction head, and initial deficit have been applied from the User's Guide to SWMM5, 13th Edition, based on the available soil mapping. Table 3-2 indicates the Green-Ampt infiltration parameters used in the modelling process.

Table 3-2: Green-Ampt Infiltration Parameters Used in the Modelling Process

SOIL TYPE	CONDUCTIVITY (MM/HR)	SUCTION HEAD (MM)	INITIAL DEFICIT (FRACTION)
Sand	120.4	49.02	0.41
Loamy Sand	29.97	60.96	0.39
Sandy Loam	10.92	109.98	0.37
Loam	3.30	88.90	0.35
Silt Loam	6.60	169.93	0.37
Sandy Clay Loam	1.52	219.96	0.26
Clay Loam	1.02	210.06	0.28
Silty Clay Loam	1.02	270.00	0.26
Sandy Clay	0.51	240.03	0.21
Silty Clay	0.51	290.07	0.23
Clay	0.25	320.04	0.21

The land use mapping provided by the Niagara Region has been reviewed in conjunction with aerial imagery for the study area to determine impervious coverages for each type of land use category. This has been used to complete an areal weighting of imperviousness across the various subcatchments. Table 3-3Table 3-3 indicates the imperviousness percentage for each type of land use developed for use in the current study. A map of the land uses within the study area can be found in Appendix F.

Table 3-3: Imperviousness Percentage per Land Use Category

LAND USE CATEGORY	ASSUMED IMPERVIOUSNESS (%)
Commercial	95
Farm	10

LAND USE CATEGORY	ASSUMED IMPERVIOUSNESS (%)
Industrial	95
Institutional	70
Recreational	30
Residential-Low	45
Residential-Med	55
Residential-Out	55
Residential-Rural	35
Road	50

Additional parameters assigned to the subcatchments based upon industry standard values include the following:

- The Manning's 'n' value assigned to impervious surfaces is 0.013;
- The Manning's 'n' value assigned to pervious surfaces is 0.25;
- The depression storage assigned to impervious surfaces is 1 mm and 5 mm for pervious surfaces;
- Subarea routing has initially been assigned as 100% to pervious due to the rural nature of the study area (general lack of storm sewer systems).

ROUTING SYSTEM

As PCSWMM is capable of both hydrologic and hydraulic analysis. Routing elements have been incorporated for local watercourses, roadside ditches and cross culverts underneath the study area ROW. Watercourses have been incorporated by cutting representative cross-sections using the DEM data for the study area, whereby roadside ditches have been incorporated using survey data collected on-site. Existing cross culverts have also been included where appropriate, and have been coded based upon the inverts / diameter recorded through the field survey. The existing conditions drainage boundaries and routing system within the PCSWMM model are presented in Appendix A.

3.1.3 MODEL CALIBRATION

3.1.3.1 SURFACE WATER MONITORING PROGRAM

A Surface Water Monitoring program was designed with input from NPCA to collect surface water data to understand surface water input to the PSW along Segment 1 and support model calibration. Three (3) water level gauges and one (1) barologger for air pressure were installed to collect surface water data from June 15th to October 24th, 2022. Figure 3-2 indicates the locations of the monitoring gauges.

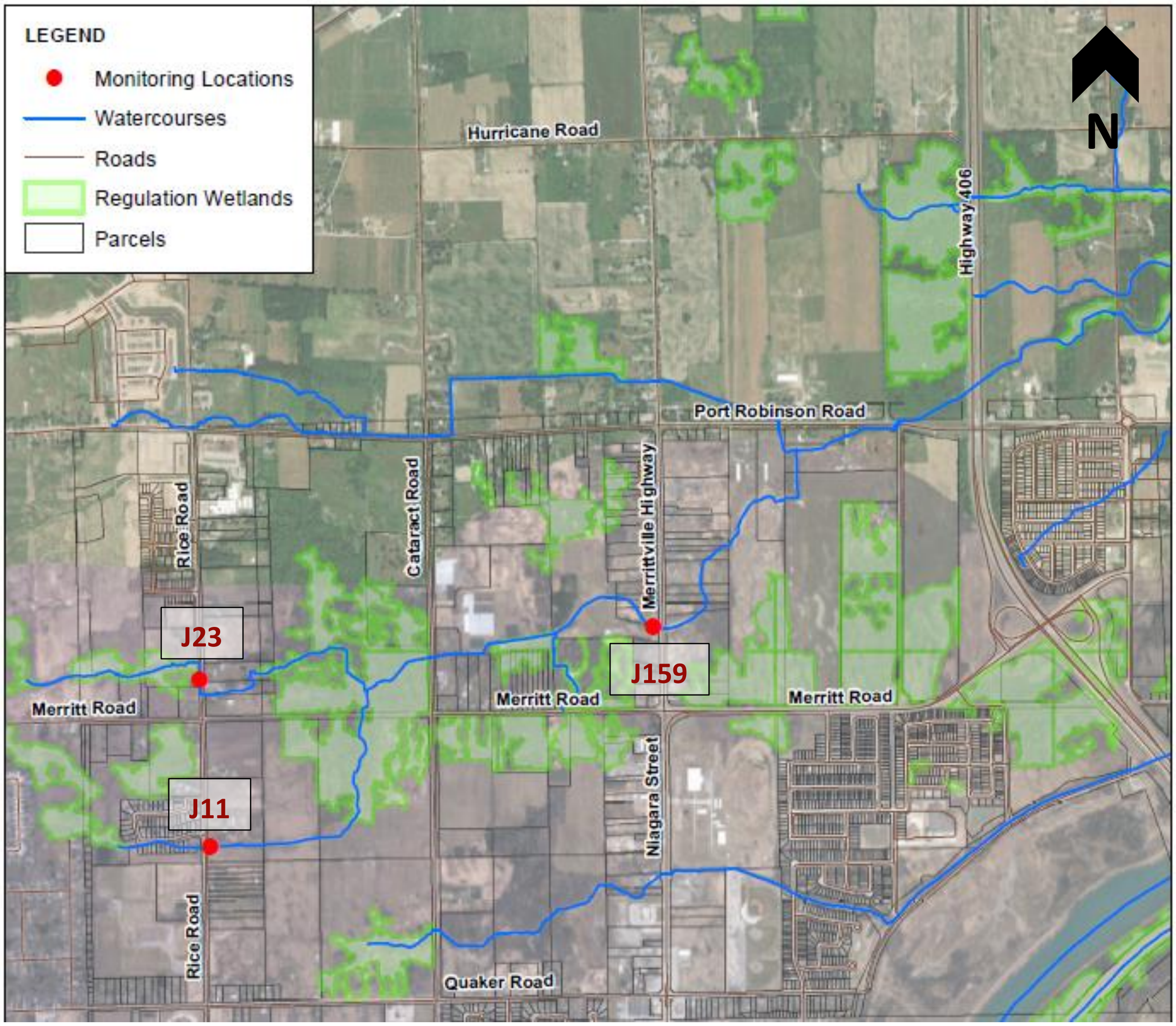


Figure 3-2: Surface Water Monitoring Locations

The first gauge (J23) was installed along the Singers Drain North Tributary at Rice Road, located north of Merritt Road, while the second gauge (J11) was installed along the Singers Drain South Tributary, also at Rice Road just south of Rosewood Crescent. The last gauge (J159) was installed on the main branch of Singers Drain, at the Merrittville Hwy. The combination of the three (3) gauges allowed for monitoring of the representative inflow and outflow of the PSW system. All recorded data was collected on a continuous basis throughout the five (5) month monitoring period at 15-minute intervals.

The gauges were located within the road ROW (public property access) along sections of open channel characterized by relatively straight and consistent bed slopes, both horizontally and vertically. The careful selection of gauge locations facilitated the development of rating curves to support the conversion of water level data to flow data, based upon in-field velocity measurements conducted during rainfall events. Each location was selected to minimize any potential backwater effects that may have resulted in distortions in the readings, however due to the flat nature of the study area and the densely vegetated watercourse systems, backwater effects could not be avoided.

It is important to clarify that the Study Team had also considered the stream crossing location at Cataract Road for a monitoring gauge, as it would have been preferred given the proximity to the wetland. However, the channels downstream and upstream of the Cataract Road, at this location, are heavily vegetated and not conducive to flow gauges (the flow gauges have to be in open watercourses). There is also the issue of the backwater in the channel from downstream at this location which impacts depth readings and can make it difficult to determine flows and can be a challenge to reproduce the results in hydrologic monitoring. Due to these reasons, the Study Team did not identify the stream crossing location at Cataract Road for surface water monitoring.

All gauges were removed by the end of October 2022 in advance of winter freeze-up conditions. Further discussions regarding the use of this data and the resulting calibration exercises are provided in the subsequent sections.

3.1.3.2 RAINFALL CHARACTERIZATION

To support the calibration of the PCSWMM model, local rainfall data for the monitoring period of June to November 2022 was sourced from the Humberstone Landfill Climate Station. This station is less than 7 Kilometers away from the study area and would therefore provide a local resource for rainfall / storms occurring during the monitoring period. The rainfall data downloaded from this climate station was recorded to a 5-minute time step, which was then converted to a 15-minute interval to align with the aggregation of water level and flow velocity data. A detailed record of the rainfall data for the monitoring period can be found in the Appendix B.

From review of the rainfall data, a total of six (6) events occurred within the observation period. Of those, a total of four (4) of them resulted in peak flows and water levels that had an acceptable level of correlation to the rainfall time series. Further details are provided in the following subsections.

3.1.3.3 FLOW CHARACTERIZATION

In addition to the preceding, rating curves (relationship between water depth and flow) have been developed for the three (3) monitoring sites in order to transform the observed water levels into an estimated flow series. The rating curves have been established using the following methodology:

- Channel cross-sections at each location are measured.
- During storm events, water levels and in-stream velocity measurements are collected using a velocity meter to estimate observed flow:
  - The channel is divided into representative sections depending on the observed flow conditions, with the approximate measurement locations recorded.
  - Both the observed depth and velocity (averaged by the velocity meter for the full depth profile) are recorded at each section.
  - Using the cross-section profile and these data, the total estimated flow is calculated as the sum of the individual flows, which is equal to the product of flow area and velocity.
  - Each measurement results in a single observed depth (water level) and velocity, used to determine flow for that location.
- A simplified hydraulic model is then developed for each site using the measured cross-section and the estimated channel (bed) slope, which is assumed to be constant.

- The resulting depth-flow curve from the HEC-RAS model is then “fit” to the observed points by varying the channel and overbank roughness values, and where necessary, the channel slope.

The resulting rating curves for each of the monitored sites are presented in Appendix B. In general, both the monitoring stations at the North and South Tributaries located upstream of the wetlands produced a general good fit, although it should be noted that the observed data points are primarily at the lower end of the curve. Due to the length of monitoring period, there was a lack of significant storm events which would help to refine the top end of the curves and better understand the high flow responses. Nonetheless, for the low flow events recorded, there is general alignment with the observed and simulated results.

The monitoring station located downstream of the PSW at the Merrittville Highway crossing was found to be difficult to generate a representative rating curve. Through the monitoring visits, it was understood that this channel had very slow flow / stagnant areas, which made velocity measurements very difficult to capture. This is likely due to the flat vegetated channel, and backup occurring during storm events. Overall, the main branch location did not produce an acceptable level of correlation between observed and simulated results, therefore this location was not prioritized as part of calibration as the accuracy of the field data is considered insufficient.

The rating curves have been used to develop resultant flow series for each gauge, which is also presented in Appendix B. Details relating to the subsequent calibration exercises is provided in the following subsections.

CALIBRATION EVENT SUMMARY

Table 3-4 presents a summary of the four (4) storm events selected for use in the existing conditions hydrologic model calibration process, as well as the recorded peak flow responses at both the North and South Tributary locations.

Table 3-4: Calibration Storm Event Selection Summary

DATE	RAINFALL EVENT				RICE NORTH (J23)		RICE SOUTH (J11)	
	AMOUNT (MM)	DURATION (HRS)	HOURLY PEAK INTENSITY (MM/HR)	15-MIN PEAK INTENSITY (MM/HR)[1]	PEAK FLOW (M3/S)	MAX WL (M)	PEAK FLOW (M3/S)	MAX WL (M)
June 16 2022	8.75	0.75	11.67	17	0.37	0.39	0.69	0.39
July 18 2022	37.5	9.75	3.85	18	0.26	0.36	0.63	0.38
Oct 18 2022	7.25	3	2.42	9	0.13	0.28	0.27	0.29
Oct 19 2022	22	6.5	3.38	8	0.09	0.26	0.17	0.26

Note: [1] This intensity peak is based on the 15-min time steps, and not the hourly data.

As evident in Table 3-4, a total of four (4) distinct storm events ranging between 7 mm (+/-) up to 37 mm (+/-) have been selected as part of the calibration set. These resulted in peak flow responses at both the North Tributary and South Tributary locations ranging upwards to 0.69 m^3/s. These have been carried forward as part of the hydrologic model calibration, described further in subsequent sections.

3.1.3.4 HYDROLOGIC MODEL CALIBRATION

INITIAL RESULTS

The PCSWMM model developed for the current assessment has been simulated on a continuous basis for the monitoring period of June to November 2022. Although the flow monitoring period started on June 15th, the local rainfall data time series was introduced to the model from June 1st to provide a 2-week warm-up period for the existing condition PCSWMM model. The total inflow and water depth hydrographs occurring from the uncalibrated model have been extracted at selected nodes and compared to the observed flow results described in the preceding section. Generally, the uncalibrated modelling results did not produce a strong fit to the observed results, with some locations generating flows that were too high and some which were too low in comparison to the observed monitoring data. This demonstrated the need for additional review and modification to the modelling.

Through review of the resulting graphs and comparison of the simulated results versus observed flows prompted a secondary review of external drainage areas contributing to both the North and South Tributaries. Based upon the monitoring data, the South Tributary was resulting in peak flows close to double the North Tributary, which was not reflected through the original simulation results. Through review of the DEM, flow paths and roadway alignments in the external drainage areas upstream of Rice Road, refinements were made to the contributing areas to each reach to support a more consistent peak flow response. These external area delineations should be investigated further as part of detailed design phase using additional data / drawings if available for these external areas.

The refined modelling delineation has been carried forward for a sensitivity analysis and further refinement as part of the calibration.

SENSITIVITY ANALYSIS

A sensitivity analysis has been conducted to assess the impact of variations in specific hydrologic parameters on the peak flow results for the four (4) selected calibration events. Drawing upon WSP's professional expertise in SWMM-based model calibration, certain hydrologic parameters have been excluded from the sensitivity analysis due to the low sensitivity in changes to these parameters. These screened parameters, include subcatchment slope, flow length, surface roughness, and depression storage values, as these are based upon either physical measurements and / or standard values for SWMM modelling. Imperviousness of the subcatchments is inherently a sensitive input parameter for hydrologic modelling. However, given the review completed of the study area for measured imperviousness per land use category, further adjustments to the imperviousness value are not considered appropriate.

The primary focus of the conducted sensitivity analysis was therefore to identify additional modelling parameters that could potentially enhance the calibration of the model through appropriate adjustments.

Soil Parameters (Green-Ampt)

The Green-Ampt infiltration parameters presented in Table 3-2 (hydraulic conductivity, suction head, initial deficit) have been individually varied by +/- 50 % to assess the impact on model outputs. The results of the sensitivity analysis have indicated that the hydrologic modelling is relatively insensitive to these changes. It is considered that this is attributable to the relatively lower intensity rainfall of the available calibration events. Based on the preceding, further modifications or adjustments to the soil infiltration parameters would appear to yield minimal additional benefit to the overall model calibration for the noted events.

Directly Connected Fraction (Imperviousness)

The directly connected fraction refers to the percentage of simulated runoff from the impervious land segment being directly routed to the subcatchment outlet (as opposed to being routed across the pervious land segment, which tends to promote further infiltration and flow attenuation through routing).

The original existing condition model assumed 100% of impervious area runoff as being routed to the pervious area (i.e., rural areas / roadside ditches). This parameter has been re-assessed by reducing the value to 50 % (i.e., 50% of runoff from the impervious land segment is directly routed to the outlet of the subcatchment, and the remaining 50% is routed across the simulated pervious land segment). As expected, this change has resulted in a notable increase in both simulated peak flow and runoff volume, given the fewer opportunities for infiltration.

The sensitivity analysis results indicated that increasing the directly connected fraction would effectively increase simulated peak flows and runoff volumes, improving the calibration for the four (4) noted events. Consequently, further variations of this parameter were tested through several iterations, ultimately resulting in a decision to use 25% routing of the runoff to the pervious area for the strongest improvement.

Routing Elements (Cross-section / Roughness)

Upon reviewing the resulting graphs of the sensitivity analysis, it was observed that peak flows were also responsive to the hydraulic characteristics of the monitoring locations and the immediate downstream segment of the stream network. Thus, the cross-sections of these segments were updated to reflect the watercourse characteristics to the best possible extent, using survey and DEM data. Moreover, other parameters that could potentially affect the routing elements, such as Manning's n coefficient of roughness, were recognized as potential influential factors impacting the results. Through the calibration process, it was determined that a roughness coefficient of 0.035 for the channel would yield more beneficial results.

3.1.3.5 CALIBRATION RESULTS

Based on the preceding sensitivity analysis, the primary focus of the updated model calibration effort has been on refinement to the directly connected fraction. The selected 25% routing of the runoff to the pervious area results in an improved simulation result, allowing a portion of the runoff to be directed to the pervious area for additional infiltration, while the remaining portion of the outflow is directed towards the outlet / routing system. Graphs presenting simulated and observed flow and depth have been generated and compared for the selected time periods at the Rice North (J23) and Rice South (J19) monitoring stations (ref. Appendix C). The outcomes of this analysis are presented in Table 3-5, where the computed peak flow values are compared with their corresponding observed values for the respective events for the four (4) simulated events.

Table 3-5: Comparison of the Observed and Computed Peak Flows at Selected Monitoring Locations

DATE	RICE NORTH (J23)			RICE SOUTH (J11)		
	OBSERVED PEAK FLOW (M3/S)	COMPUTED PEAK FLOW (M3/S)	PERCENT DIFFERENCE	OBSERVED PEAK FLOW (M3/S)	COMPUTED PEAK FLOW (M3/S)	PERCENT DIFFERENCE
June 16 2022	0.37	0.10	-72%	0.69	0.29	-58%
July 18 2022	0.28	0.18	-38%	0.63	0.64	1%
Oct 18 2022	0.13	0.07	-47%	0.27	0.27	-3%

DATE	RICE NORTH (J23)			RICE SOUTH (J11)		
	OBSERVED PEAK FLOW (M3/S)	COMPUTED PEAK FLOW (M3/S)	PERCENT DIFFERENCE	OBSERVED PEAK FLOW (M3/S)	COMPUTED PEAK FLOW (M3/S)	PERCENT DIFFERENCE
Oct 19 2022	0.10	0.06	-33%	0.17	0.39	126%

Based upon the results demonstrated in Table 3-5, the simulated results of the calibrated model provide a range in the fit with the observed data, most notably on the July 18th and October 18th events the computed peak flows for the Rice South (J11) are very close to the observed values for the same events. To further illustrate the correlation between the computed and observed peak flows, scatter plots were developed. Please refer to Figure 3-3 and Figure 3-4 for visual representations of these results.

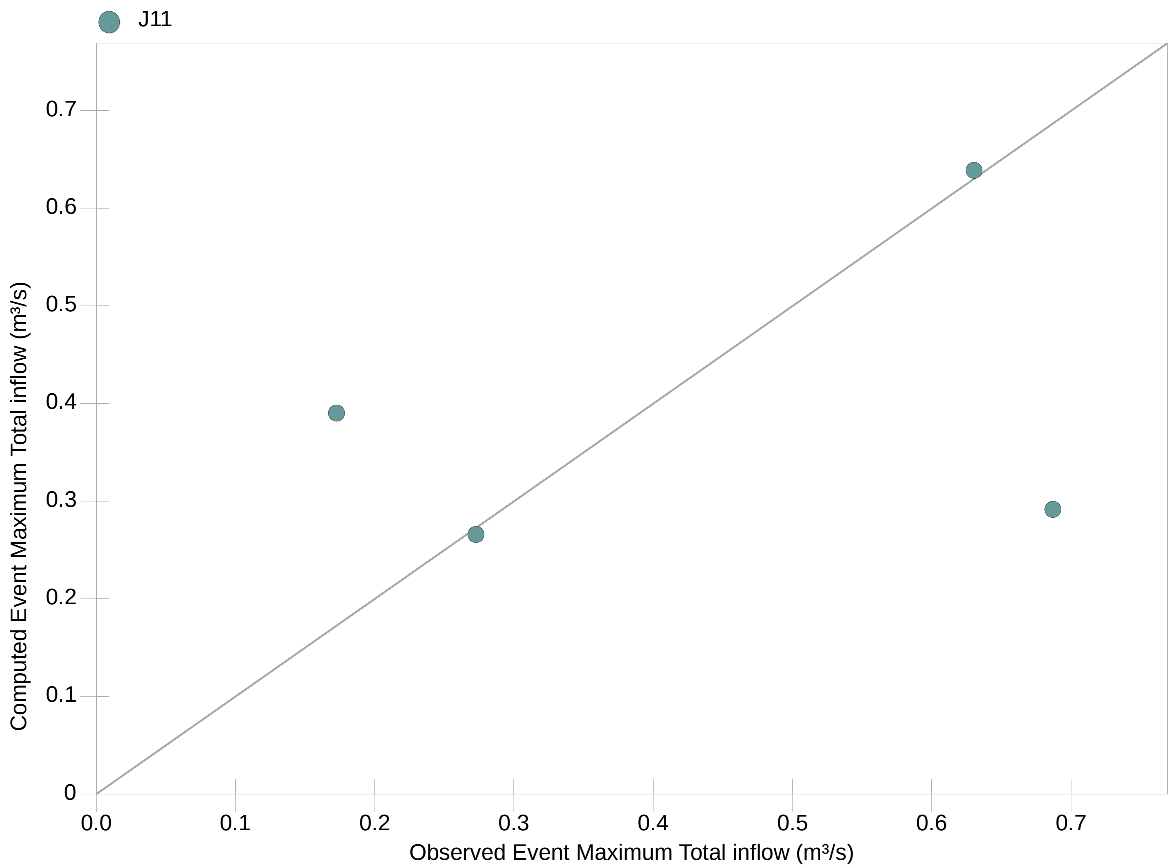


Figure 3-3: Scatter Plot of the Observed and Simulated Peak Flows (m^3/s) of Rice South Station (J11)

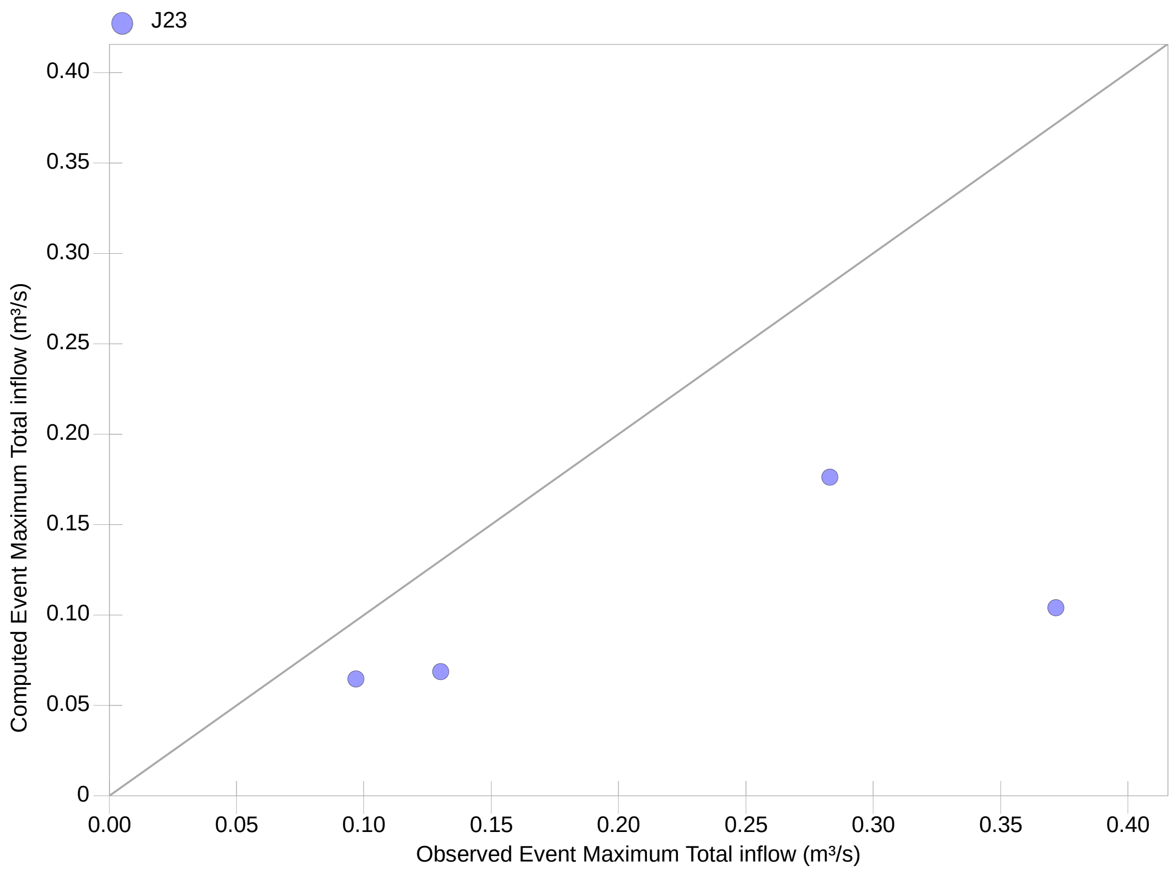


Figure 3-4: Scatter Plot of the Observed and Simulated Peak Flows (m³/s) of Rice North (J23)

It should be noted that there are limitations in hydrologic modelling to calibrating to such small peak flow events, as such the North tributary was challenging to achieve a strong calibration due to majority of the events being less than 0.30 m^3/s. There are also some concerns with respect to the accuracy of the rating curves developed at each station, due to the lack of formative events to confirm the upper range of the curve as well as the backflow influences occurring within these watercourses.

As a result, in addition to peak flow comparisons, a water level depth comparison was also completed for the four (4) selected calibration events, given that water depth was physically measured during the monitoring visits. The results of this comparison are presented in Table 3-6**Error! Reference source not found.**, which showcases the computed maximum flow depth alongside the corresponding observed values for these events.

Table 3-6: Comparison of the Observed and Computed Maximum Depths at Selected Monitoring Location

DATE	RICE NORTH (J23)			RICE SOUTH (J11)		
	OBSERVED DEPTH (M)	COMPUTED DEPTH (M)	PERCENT DIFFERENCE	OBSERVED DEPTH (M)	COMPUTED DEPTH (M)	PERCENT DIFFERENCE
June 16 2022	0.39	0.28	-28%	0.39	0.30	-23%
July 18 2022	0.36	0.35	-3%	0.38	0.37	-3%
Oct 18 2022	0.28	0.26	-6%	0.29	0.29	-1%
Oct 19 2022	0.26	0.26	0%	0.26	0.32	24%

As demonstrated in Table 3-7**Error! Reference source not found.**, the calibrated model exhibits a strong fit for majority of the selected events, and again most notably on July 18th and October 18th. To further illustrate the correlation between the computed and observed maximum flow depths, scatter plots were prepared. Please refer to **Error! Reference source not found.**Figure 3-5 and Figure 3-6**Error! Reference source not found.** for visual representations of these results.

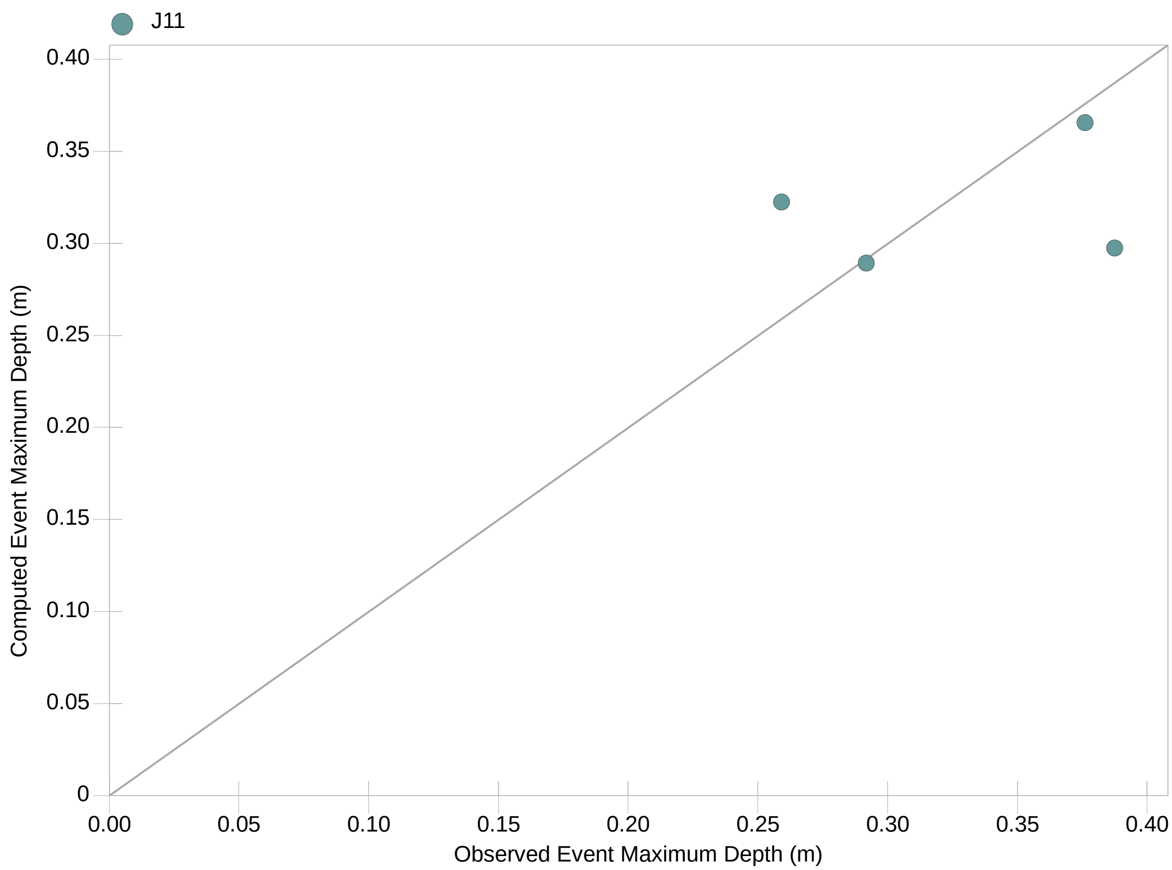


Figure 3-5: Scatter Plot of the Observed and Simulated Maximum Flow Depths (m) of Rice South Station (J11)

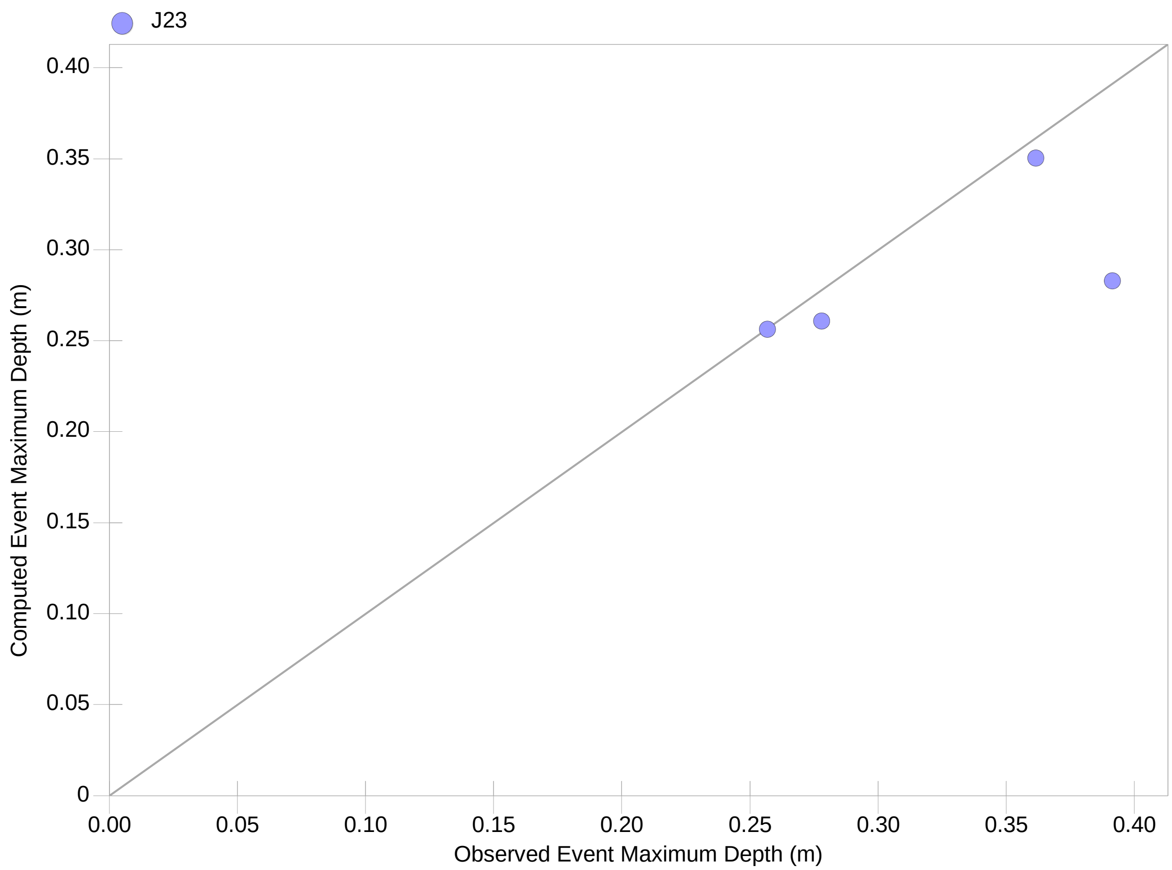


Figure 3-6: Scatter Plot of the Observed and Simulated Maximum Flow Depths (m) of Rice North Station (J23)

3.1.4 DESIGN STORM RESULTS

3.1.4.1 WITHOUT WETLANDS

The existing conditions modelling as described above has been used to simulate the 2 to 100-Year 6-hour Chicago design storm events based upon the City of Welland IDF parameters. However, it is important to note that as per the direction of the NPCA, the influence of wetlands on peak flows was not considered during these simulations, so no storage nodes for the wetlands were included in this model version. For the purposes of quantity control assessments under design storm scenarios, the influence of culverts in the PCSWMM model have also been excluded due to the possibility of backflow and storage upstream of undersized culverts influencing the target peak flows. To remedy this, culvert conduits have been converted to “dummy conduits” which conveys the full flows entering the conduit downstream. This has only been applied to the model scenarios for design storm analysis for the purposes of SWM sizing.

The results of the simulations have been summarized in Table 3-7 for each of the respective drainage system outlets along Rice Road and Merritt Road. These results represent the baseline conditions, and have been used to support separate hydraulic analysis for the Singers Drain floodplain system located within Segment 1 (ref. Section 4).

Table 3-7: Existing Condition Design Storm Event Peak Flows (m^3/s)

ROAD SEGMENT	LOCATION	STATION	PCSWMM NODE NAME	2-YEAR	5-YEAR	10-YEAR	25-YEAR	50-YEAR	100-YEAR
4	South side of Quaker Rd.	Rice Rd. 10+140	J40	0.42	0.51	0.69	0.69	0.76	0.83
4	North side of Quaker Rd.	Rice Rd. 10+160	J-OF01	0.79	1.00	1.41	1.41	1.62	1.83
4	Private Property @ Rice Rd.	Rice Rd. 10+390	J-OF02	1.67	1.96	2.71	2.71	3.36	3.89
4	South Trib. @ Rice Rd.	Rice Rd. 10+720	J-OF03	3.25	4.10	5.83	5.83	6.80	7.74
4	Center Trib. @ Rice Rd.	Rice Rd. 10+966	J-OF04	0.28	0.36	0.53	0.53	0.61	0.70
4	North Trib. @ Rice Rd.	Rice Rd. 11+270	J-OF05	1.09	1.44	2.24	2.24	2.71	3.18
1	Center Trib. @ Merritt Rd.	Merritt Rd. 20+640	J-OF06	0.34	0.47	0.74	0.74	0.89	1.03
1	South Trib. @ Merritt Rd.	Merritt Rd. 20+715	J-OF07	2.04	2.75	4.05	4.05	4.63	4.75
1	Wetland feature @ Merritt Rd.	Merritt Rd. 20+880	J-OF08	0.15	0.22	0.36	0.36	0.54	0.77
1	West side of Cataract Rd.	Merritt Rd. 20+960	J-OF09	0.07	0.09	0.11	0.11	0.19	0.65
1	Cataract Culvert	Merritt Rd. 20+970	J145	1.93	2.93	4.34	4.34	6.05	7.57
2	East side of Cataract Rd.	Merritt Rd. 20+980	J-OF10	0.15	0.19	0.25	0.25	0.27	0.31
2	Wetland south of Merritt Rd.	Merritt Rd. 21+235	OF_M3	0.23	0.30	0.37	0.45	0.52	0.60
2	West side of Merrittville Hwy.	Merritt Rd. 21+790	J-OF11	0.39	0.49	0.69	0.69	0.79	0.90
2	Merrittville Hwy.	Merritt Rd. 21+800	J158	1.73	2.59	4.60	4.60	6.18	7.46
3	East side of Merrittville Hwy.	Merritt Rd. 21+810	J-OF12	0.24	0.31	0.44	0.44	0.51	0.57
3	South side of Merrittville Hwy.	Merritt Rd. 21+820	OF_M6	0.21	0.26	0.30	0.37	0.42	0.48
3	Wetland south of Merritt Rd.	Merritt Rd. 22+220	OF_M7	0.16	0.20	0.23	0.27	0.31	0.35
3	Eastman Gateway @ Merritt Rd.	Merritt Rd. 22+480	OF_M8	0.06	0.08	0.09	0.10	0.11	0.13
3	West side of Grisdale Rd.	Merritt Rd. 22+860	OF_M9	0.05	0.06	0.07	0.08	0.10	0.11
3	East side of Grisdale Rd.	Merritt Rd. 22+880	OF_M10	0.05	0.07	0.08	0.09	0.10	0.12
3	Wetland east of Grisdale Rd.	Merritt Rd. 23+010	OF_M11	0.38	0.48	0.56	0.69	0.81	0.93
3	Final Outlet		O160	1.73	2.60	3.08	4.64	6.26	7.58

3.2 PROPOSED CONDITIONS

3.2.1 PROPOSED ROADWAY DESIGNS

The proposed roadway designs differ amongst the four (4) Segments along both Merritt and Rice Road. A description of the preferred design alternatives for each Segment is provided as follows, and are shown visually on the typical cross-sections and preliminary roadway profile attached in Appendix D:

- ***Segment 1 – Merritt Road from Rice Road to Cataract Road:*** The proposed cross-section for Segment 1 is a Hybrid (Rural-Urban) Cross-section with the following design features (based on Rural Scenic typology):
  - Two 3.3 m drive lanes with curbs
  - A 3.0 m multi-use path on the north side
  - Ditches on both sides
- ***Segment 2 – Merritt Road from Cataract Road to Merrittville Highway/Niagara Street:*** The proposed cross-section for Segment 2 is a Hybrid (Rural-Urban) Cross-section with the following design features (based on Urban General - typology):
  - Two 3.3 m drive lanes with curbs
  - A 3.0 m multi-use path on the north side
  - Ditches on both sides
- ***Segment 3 – Merritt Road from Merrittville Highway/Niagara Street to Highway 406 Overpass/Kottmeier Road:***
  - ***Merritt Road from Merrittville Highway/Niagara Street to Grisdale Road:*** The proposed cross-section for Segment 3 is an Urban Cross-section with the following design features (based on Urban General typology):
    - Four 3.3 m drive lanes separated by a 2.5 m median
    - 1.8 m sidewalk on the south side
    - A 3.6 m separated two-way cycle track on the south side
  - ***Merritt Road from Grisdale Road to Highway 406 Overpass/Kottmeier Road:*** The design for Regional Road 37 (Merritt Road) east of Grisdale Road over Highway 406 overpass and up to Kottmeier Road was determined in consultation with the Ministry of Transportation. Key features of MTO approved the preferred design of Merritt Road, east of Grisdale Road over Highway 406 overpass and up to Kottmeier Road are discussed below:
    - The design for Regional Road 37 (Merritt Road) east of Grisdale Road over Highway 406 overpass and up to Kottmeier Road was determined in consultation with the Ministry of Transportation. Key features of MTO approved the preferred design of Merritt Road, east of Grisdale Road over Highway 406 overpass and up to Kottmeier Road are discussed below:
    - Provision of a multi-use path on the south side, which would transition to the north side at Highway 406 off-ramp and on-ramp intersection. Provision of a traffic signal at Highway 406 off-ramp and on-ramp intersection. The multi-use path east of this intersection would be a raised facility. This option will provide a safer pedestrian crossing at the proposed signalized intersection and not yielding at on-ramps.
    - Maintaining an existing eastbound left turn and providing additional eastbound through lane at the off-ramp and on-ramp intersection at Merritt Road., while matching eastbound lanes prior to bridge westerly abutment to avoid impacts and widening of the existing bridge structure over the highway.

- Permitting a westbound left turn at Grisdale Road/Merritt Road intersection along with eastbound right and northbound right turning movements, in other words, a right-in right-out plus westbound left turn (left-in). A Northbound left turn from Grisdale Road to Merritt Road is not permitted under this option. The median island and right-turn channel have been proposed to ensure that the northbound left turn is completely restricted. This option would facilitate a safer turn onto Grisdale Road from Merritt Road with a provision of a dedicated westbound left turn lane.
- Removal of the westbound right turn channel (due to low traffic volumes) and provision of a short westbound right turn lane instead at the intersection. Removal of the westbound right turn lane over the bridge will be a cost-effective solution where the MUP could be provided without widening the bridge structure. Initially, a concrete median was proposed between the vehicular traffic lanes and the MUP. However, based on the feedback provided by MTO Executive Review Meeting (held March 21, 2023), the concrete median was removed from the proposed cross-section. Further, the multi-use path was proposed as a raised multi-use path.

- ***Segment 4 – Rice Road from Quaker Road to Merritt Road:*** The proposed cross-section for Segment 4 is an Urban Cross-section with the following design features (based on Urban General typology):
  - Four 3.3 m drive lanes with a 2.5 m median or 3.3 m two-way left turn lane in the centre
  - 1.8 m sidewalk on the east side
  - A 3.0 m multi-use Path on the west side
  - Ditches on both sides

These proposed designs will result in a change in both impervious area within the road ROW, as well as some changes in local grading and associated subcatchment boundaries as a result of road profile shifts and/or drainage divides. Further description regarding the impacts on the hydrologic / hydraulic conditions is provided in the following section.

3.2.2 PROPOSED CONDITIONS – UNCONTROLLED PCSWMM MODELLING

From a hydrologic and hydraulic perspective, the proposed roadway designs will have impacts on the local conveyance system, as well as the downstream systems if left uncontrolled. The PCSWMM modelling developed for existing conditions has been modified based upon the aforementioned roadway designs, to generate an "uncontrolled" proposed conditions model, which will help to identify the potential hydrologic impacts to the local system. A summary of the changes within each roadway Segment is outlined as follows:

- **Segment 1:**
  - Under the existing condition, there is no constructed road in Segment 1. Consequently, the amount of additional impervious area that drains into each outlet is considerably higher, ranging between 5.2% and 34.8% under the proposed conditions. This substantial increase highlights the larger impact that the proposed condition will have on the overall imperviousness of the area if left uncontrolled.
  - The proposed roadway profile for Segment 1 has identified four (4) low spots / outlet locations, including a total of three (3) required cross-culverts (for both regulated watercourses / connections through the PSW), as well as the eastern portion of Segment 1 draining to Cataract Road and continuing north to the main branch of Singers Drain.

- **Segment 2:**
  - In Segment 2, there is an estimated increase of approximately 2.4% in impervious areas under the proposed conditions due to the addition of the multi-use path on the north side of the roadway. It is

crucial to emphasize that this specific area has a history of recurrent flooding issues, mainly due to localized low points and very flat topography on Merritt Rd, resulting in standing water.

— The proposed roadway profile for Segment 2 has attempted to rectify the local grading issues by providing a positive slope towards both Cataract Road and Merrittville Highway, however there are limitations given the grading impacts to the adjacent properties.

- **Segment 3:**
  — Segment 3 road improvements consist of urbanization of rural road sections with curb and gutter, revisions to intersections, and adding a cycle track and a sidewalk on the south side of the road. As such, the approximate total impervious area will increase by 6.8% and the storm drainage will be collected through a future storm sewer system. The roadway profile is generally maintained as per existing conditions; therefore, the impacts are expected to be a result of the increased impervious areas only.
- **Segment 4:**
  — Segment 4 roadway improvements consist of adding two (2) drive lanes, a multi-use path on the west side of the road, and a sidewalk on the east side, which would increase the total impervious area draining to each outlet between 0.4% to 5.6%. As this is an existing roadway with several watercourse crossings, the drainage divides amongst the existing roadway profile should be maintained to the best extent possible. This should be further reviewed as part of the detailed design phase in terms of offsite grading impacts.

The following Table 3-8 presents the existing and proposed conditions drainage area comparison to quantify the changes in the contributing impervious areas to each drainage outlet within each roadway Segment. The proposed subcatchment boundaries and routing elements are provided in Appendix E.

Table 3-8: Existing and Proposed Conditions Drainage Area Comparison

ROAD SEGMENT	LOCATION	STATION	EXISTING TOTAL AREA (HA)		PROPOSED TOTAL AREA (HA)		DIFFERENCE (HA)		DIFFERENCE (%)	
			TOTAL	IMP.	TOTAL	IMP.	TOTAL	IMP.	TOTAL	IMP.
4	South side of Quaker Rd.	Rice Rd. 10+140	11.66	3.23	11.66	3.23	0	0	0	0
	North side of Quaker Rd.	Rice Rd. 10+160	15.99	7.51	15.97	7.63	-0.019	0.122	-0.1%	1.6%
	Private Property @ Rice Rd.	Rice Rd. 10+390	72.88	36.48	72.80	36.63	-0.085	0.151	-0.1%	0.4%
	South Trib. @ Rice Rd.	Rice Rd. 10+720	76.19	30.68	76.47	30.96	0.279	0.280	0.4%	0.9%
	Center Trib. @ Rice Rd.	Rice Rd. 10+966	9.83	3.11	9.83	3.29	0.008	0.174	0.1%	5.6%
	North Trib. @ Rice Rd.	Rice Rd. 11+270	30.72	4.26	30.67	4.34	-0.051	0.079	-0.2%	1.9%
1	Center Trib. @ Merritt Rd.	Merritt Rd. 20+640	17.78	2.41	17.74	2.80	-0.041	0.398	-0.2%	16.5%
	South Trib. @ Merritt Rd.	Merritt Rd. 20+715	13.19	1.23	13.10	1.30	-0.083	0.064	-0.6%	5.2%
	Wetland feature @ Merritt Rd.	Merritt Rd. 20+880	9.81	0.50	9.68	0.66	-0.133	0.161	-1.4%	32.3%
	West side of Cataract Rd.	Merritt Rd. 20+960	0.47	0.23	0.59	0.31	0.123	0.081	26.3%	34.8%
2	East side of Cataract Rd.	Merritt Rd. 20+980	6.35	1.12	7.65	1.69	1.302	0.573	20.5%	51.2%

ROAD SEGMENT	LOCATION	STATION	EXISTING TOTAL AREA (HA)		PROPOSED TOTAL AREA (HA)		DIFFERENCE (HA)		DIFFERENCE (%)	
			TOTAL	IMP.	TOTAL	IMP.	TOTAL	IMP.	TOTAL	IMP.
	Wetland south of Merritt Rd.	Merritt Rd. 21+235	12.15	1.28	10.82	0.72	-1.330	-0.565	-10.9%	-44.0%
	West side of Merrittville Hwy.	Merritt Rd. 21+790	10.71	2.67	10.74	2.78	0.029	0.112	0.3%	4.2%
	East side of Merrittville Hwy.	Merritt Rd. 21+810	6.82	1.89	4.93	1.74	-1.887	-0.145	-27.7%	-7.7%
	South side of Merrittville Hwy.	Merritt Rd. 21+820	3.38	1.16	3.35	1.15	-0.033	-0.007	-1.0%	-0.6%
	Wetland south of Merritt Rd.	Merritt Rd. 22+220	3.49	0.80	3.19	0.75	-0.295	-0.046	-8.5%	-5.8%
3	Eastman Gateway @ Merritt Rd.	Merritt Rd. 22+480	0.34	0.17	0.39	0.31	0.052	0.140	15.4%	82.8%
	West side of Grisdale Rd.	Merritt Rd. 22+860	0.46	0.23	5.28	1.64	4.473	1.259	555.7%	327.0%
	East side of Grisdale Rd.	Merritt Rd. 22+880	0.35	0.16						
	Wetland east of Grisdale Rd.	Merritt Rd. 23+010	17.72	2.65	13.36	1.93	-4.357	-0.722	-24.6%	-27.2%
TOTAL MODEL SUMMARY			320.27	101.75	318.23	103.86	-2.048	2.109	-0.6%	2.1%

As demonstrated in Table 3-8, the proposed roadway design results in a range of differences in both total contributing drainage area (due to any grading / high point shifts), as well as changes to the level of imperviousness for each respective outlet. Most outlets experience increases in either drainage area or level of imperviousness, however, some outlets experience a decrease in contributing drainage area or imperviousness due to any grading changes which might impact the outlet locations. These changes in drainage area will inherently have an impact on both the amount and quality of stormwater runoff, resulting in a need for stormwater management controls to minimize any risk to downstream receivers. The proposed uncontrolled peak flow results at each outlet are provided in Section 3.2.4, and a description of the SWM opportunities assessed as part of this study are provided below.

3.2.3 STORMWATER MANAGEMENT OPPORTUNITIES

3.2.3.1 GENERAL STORMWATER MANAGEMENT

Stormwater Management (SWM) practices for the management of roadway runoff generally fall into two (2) categories: those that address stormwater quantity (including erosion) and those that manage the stormwater quality of surface runoff. In addition, Low Impact Development (LID) best management practices (BMPs) are designed to provide water quality treatment and quantity control for smaller, more frequent storm events (i.e., typically for the 90th percentile storm events).

Stormwater quantity management issues relate to the proper sizing of the minor (sewer) and major (overland flow) conveyance systems for roadway runoff. In addition, stormwater quantity management strategies can include the need for facilities to address downstream flow constraints and erosion potential from alterations of the roadway right-of-way (ROW). Based upon the proposed changes to both Merritt Road and Rice Road, including some widening and additional paved areas through the addition of multi-use paths, sidewalks and cycle track, quantity controls are required for the road ROW drainage prior to discharging to the watercourse systems to reduce or maintain existing peak flows. As Segments 1 & 2 (Merritt Road) and Segment 4 (Rice Road) will have hybrid / rural cross-sections, opportunities for SWM and improved conveyance will largely be focused within the roadside ditches. As Segment 3 (Merritt Road) will have an urbanized cross-section, new storm sewer systems will be required to capture and convey the local ROW drainage and discharge to the existing outlets.

In terms of stormwater quality control, the SWM practices are assumed to be focused upon the “new” impervious areas resulting from the proposed design. Typically, the treatment level is related to the standards defined in a watershed or subwatershed planning study, which are dependent on the quality and sensitivity of the receiving stream system (i.e., Type 1, Type 2, etc.), as well as local engineering guidance manuals which set the precedent for minimum levels of control. The receiving watercourses for both Merritt Road and Rice Road both require an Enhanced Level of water quality treatment, which will require 80% average annual removal of Total Suspended Solids (TSS). Water quality control can be provided through a range of different SWM practices, including LID BMPs as well as conventional end of pipe practices. The applicability of these options will depend upon the type of roadway and servicing design. Depending upon the selected SWM practice and design, practices such as LID BMPs can also be used to satisfy water balance criteria for the study area.

Various SWM practices and BMPs are available to designers to address both the water quantity and quality of stormwater runoff. However, due to the linear nature of roadway corridors versus larger property developments, not all stormwater management practices are considered to be appropriate. The following subsections provide an overview of several SWM practices and discusses the applicability to the proposed designs for Merritt Road and Rice Road.

ALTERNATIVE STORMWATER MANAGEMENT PRACTICES

QUANTITY CONTROL (FLOOD & EROSION)

Providing quantity control through stormwater management facilities requires both land for the actual design and construction of the facility, as well as future management/maintenance by municipal staff to ensure functionality over the lifespan of the facility. The advantages of implementing quantity control facilities include maintaining existing downstream capacities and minimizing any risks to downstream receivers (both natural and infrastructure). Disadvantages include the cost of land, infrastructure and maintenance which will be required throughout the lifespan of the facticity. Increasing the size of receiving drainage infrastructure, while somewhat more costly to the municipality, may reduce the need for additional future maintenance and eliminates the need for the dedication of stand-alone land for surface controls. Inter-subcatchment diversions can also be effective on a minor scale in optimizing and/or reducing the number of crossings and are typically pursued to address both major and minor runoff conditions.

For erosion control, on-site measures to reduce peak flow impacts can be highly constraining due to the general lack of properly configured land. Roadway corridors, due to their inherent linear nature, can only effectively manage relatively small volumes of increased runoff (peak flows), in the absence of stand-alone land acquisition.

The following quantity control measures have been considered and have undergone a screening process to identify measures which may be appropriate in both a rural and urban road ROW setting:

Wet ponds/wetlands/hybrids

Constructing a new wet pond, wetland or hybrid pond is not feasible within or beyond the Merritt Road and Rice Road ROWs based on space constraints. As such this alternative has not been considered further.

Super Pipe Storage

Super pipe storage would require either upgrading existing storm sewers to a larger storm sewer or sizing a new sewer capable of storing additional runoff to meet flood control and erosion control targets. Super pipe storage is one of the higher cost methods of providing underground storage, due to the length and size of pipe which may be required. However, based upon the current proposed design, Segment 3 (Merritt Road) is proposed to be urbanized and would require a new storm sewer system to convey local drainage to the existing receivers. Therefore, the option for super pipe storage can be advanced for further consideration for Segment 3. As the other Segments 1, 2 and 4 are proposed as hybrid urban/rural and are to be serviced through roadside ditches, super pipe storage is not considered to be feasible for these segments of the proposed roadway.

Surface Storage through Ditches / Earth Check Dams

Similar to the concept of super pipe storage, rurally serviced roadways can utilize the roadside ditches as surface storage in combination with earth check dams / orifice outlets to support temporary detainment of runoff and peak flow control within the roadway conveyance system. Given that Segments 1, 2 and 4 are proposed as hybrid urban/rural cross-sections, this is a key option that could be utilized to provide the necessary level of control.

Conventional Underground Storage (Concrete Tanks)

Conventional underground storage implemented within the proposed ROW would require multiple concrete tanks, based upon the various watercourse outlets within the study area. The concrete tanks would need to be connected to the downstream end of the proposed roadside ditches and/or proposed storm sewers, in order to maximize the contributing drainage area to the storage elements and provide sufficient levels of control. Underground concrete tanks are considered costly to implement, and depending upon their required size, can have conflicts with other subsurface infrastructure. In addition, conventional underground tanks do not filter, or infiltrate captured runoff, and offer only temporary detention benefits. As such conventional underground storage (concrete) tanks have been screened for further consideration for all roadway segments.

Conventional Underground Storage (Cellular Systems)

Notwithstanding the preceding, more cost-effective underground storage systems could be considered to achieve quantity control requirements. This includes cellular type tank systems such as Stormcon™, Brentwood™, Cultec™, or Triton™ systems. While the same constraints as outlined above may exist with cellular systems, the application of cellular systems provides some flexibility in the orientation/shape of the underground storage and can also be designed as open bottom to provide retention benefits and achieve other SWM criteria (i.e., water quality / water balance). Therefore, cellular systems that would provide underground storage have been advanced for further consideration as part of the proposed SWM strategy, where required.

Low Impact Development Best Management Practices (LID BMPs)

Low Impact Development Best Management Practices (LID BMPs) can address erosion control requirements by retaining and infiltrating stormwater runoff for more frequent storm events, which are typically those of concern for erosion impacts. LID BMPs are not typically credited as part of flood control options, as the design and function of LID BMPs are typically focused on those more frequent storm events. These options have been discussed further in the subsequent section with respect to quality control, however, are considered a feasible alternative for erosion control as well.

QUALITY MANAGEMENT

There are numerous stormwater management practices which can be used to treat contaminated stormwater runoff from roadway surfaces. These generally include the following categories:

- Wet ponds/wetlands/hybrids (generally linear facilities)
- Enhanced grass swales
- Filter strips
- Oil and grit separators
- Off-site stormwater management facilities (existing, retrofitted and/or proposed)
- Catch basin Inserts / Shields
- LID BMPs – (Bioretention systems, permeable pavement, and other infiltration systems)

The respective characteristics, advantages and disadvantages of the foregoing have been well documented in existing municipal and provincial literature and hence this information has not been repeated within this document. Some brief advantages and disadvantages, in relation to the current project are discussed in the following subsections.

Wet ponds, Wetlands, Hybrids

These systems generally require the dedication of land that most often is not available in linear corridors for roadway projects. Most often when applied to roadway runoff, these SWMPs are located adjacent to creek crossings of roads. Typically, these systems provide an excellent level of treatment and as end-of-pipe systems, the management and performance are more visible, hence less prone to failure. For Merritt Road and Rice Road, this particular type of practice is not considered appropriate due to the lack of available land.

Oil and Grit Separators (OGS)

These end-of-pipe systems tend to service smaller drainage areas (2 ha +/-) and provide varying levels of stormwater quality treatment depending on the model selected. OGS units are typically encouraged as part of a “treatment train” approach. Many municipalities and regulators will not credit the full TSS removal function of OGS units accordingly (i.e., typical maximum credit of 50% to 70% TSS removal) and will require the selected technology to be verified through the Environmental Technology Verification (ETV) testing procedure. Disadvantages include the need for frequent maintenance, as well as relatively high capital costs and the ability to service smaller drainage areas. As a pre-treatment approach for other stormwater quality measures, or for providing water quality treatment as part of a treatment train approach, OGS units have been carried forward for further consideration, particularly for Merritt Road Segment 3, due to it’s proposed urban cross-section and new storm sewer system.

Off-Site Stormwater Management Facilities

While facilities can often not be constructed within roadway right-of-way lands, roadway runoff can be directed towards existing and proposed subdivisions, which would have their runoff managed by future stormwater management facilities. As there are no available SWM Facilities located close to the study area, and the mixing of public and private drainage is not considered preferred, this option has been screened for further consideration.

Catch Basin Shields

Catch basin (CB) shields are the application of a catch basin insert to shield accumulated sediment in the catch basin sump from resuspension and washout. The CB shields can increase TSS capture by up to 50 % as shown in

Environmental Technology Verification (ETV) testing. The application of CB shields is not to be applied as a stand-alone treatment approach, however, can be combined with other treatment technologies to mitigate water quality, and does not provide any infiltrative capacities. Implementation costs would be comparatively low to other forms of water quality treatment and frequent maintenance would be required to remove accumulated sediment from the catch basin sump to ensure acceptable long-term performance. For the current assessment, CB Shields have remained an option for Segment 3.

Low Impact Development Best Management Practices

LID represents the application of a suite of BMPs normally related to source and conveyance storm water management controls to promote infiltration and pollutant removal on a local site-by-site basis. These measures rely on eliminating the direct connection between impervious surfaces such as roads and the storm drainage system, as well as the promotion of infiltration of road drainage. General design guidelines and considerations for source and conveyance controls have been advanced since the early 1990's as part of the Ministries of Municipal Affairs and Housing's "Making Choices" and in 1994 as part of the Ministry of the Environment's original Best Management Practices Guidelines.

Subsequent to the 1994 MOE Guidelines, technologies and standards have been developed further for the application of source and conveyance controls. These have evolved into a class of BMPs referred to as LID practices, which have advanced as an integrated form of site planning and storm servicing to maintain water balance and providing storm water quality control for urban developments. Initial results from studies in other settings have demonstrated that LID practices provide benefits by way of reducing the erosion potential within receiving watercourses and thereby reducing the total volume of end-of-pipe storm water erosion control requirements. In addition, due to volumetric controls afforded by LID BMPs, water quality is also improved through a reduction in mass loading. The benefits from LID storm water management practices are generally focused on the more frequent storm events (e.g., 2-year storm) of lower volumes as opposed to the less frequent storm events (e.g., 100-year storm) with higher volumes. It is also recognized that the forms of LID practices which promote infiltration or filtration through a granular medium provide thermal mitigation for storm runoff.

Guidelines regarding the application of LID practices and techniques have been developed within various jurisdictions in the United States and Canada. The Toronto and Region Conservation Authority and Credit Valley Conservation have produced the 2010 Low Impact Development Stormwater Management Manual, for the design and application of LID measures, which is used across various jurisdictions across southern Ontario. Most recently, the MECP has released a Draft LID SWM Guideline in January 2022, which outlines latest provincial guidance as it relates to LID BMP design, analysis and implementation through treatment train processes. All of these guidance manuals provide key resources to design and implement LID BMPs as part of SWM strategies.

Bioretention Systems

Bioretention systems provide effective removal of pollutants by sedimentation, filtering, soil adsorption, microbial processes and plant uptake. Bioretention systems should be approximately 10% to 20% in size of the contributing drainage area, with typical drainage areas of 0.50 ha and a maximum drainage area of 0.8 ha. Surface slopes within bioretention systems are typically 1% to 5 %. Bioretention systems are preferred in areas that have reasonable infiltration properties (15 mm/hr, 1x10-6 cm/s), but can be implemented in all soil types as long as the water quality event can be temporarily stored (typical depths 0.15 m to 0.25 m) before infiltrating and an underdrain is provided to promote proper drainage.

Bioretention systems could be added as an infiltrative LID BMP at specific locations or as supplemental SWM control beyond requirements within the proposed road ROW. Seeing as these would be applied in the road ROW, these systems would more likely be designed in a linear fashion, such as bioswales with plantings. The bioretention systems should have forebays for a form of surface water pre-treatment. Catch basins fitted with goss traps should also be used to filter out floatable debris before directing runoff to the infiltrative component of the bioretention system. Due to the need for regular maintenance and additional landscape features bioretention systems have been screened from further consideration.

Enhanced Grassed Swales

Grassed swales designed with a trapezoidal geometry and flat longitudinal profiles with largely un-maintained turf can provide excellent filtration and treatment for storm runoff from roadways. It is generally conceded that treatment levels are at a minimum, Normal (formerly Level 2) 70% TSS removal water quality treatment and combined with other practices can provide Enhanced (Level 1) 80% TSS removal stormwater quality treatment. Their application in linear corridors is also particularly appropriate and can be further enhanced through the introduction of check dams to provide additional on-line storage and slow the velocities for improved filtration. Their application in urbanized roadway cross-sections (i.e., curb and gutter) often requires alternative grading and roadway configurations which can compromise the function of the roadway itself and are therefore typically not preferred in those cases. Notwithstanding, gutter outlets along outside lanes have been demonstrated to function effectively where the right-of-way can accommodate the design. Enhanced grass swales could be strategically placed within the Merritt Road and Rice Road corridors where sufficient area is available to provide potential attenuation, infiltration and filtration of runoff. Therefore, enhanced grass swales have been carried forward for further consideration.

Filter Strips

Filter strips are typically designed for small drainage areas (less than 2 ha +/-) and are applied as part of a treatment train. Filter strips require flat areas with slopes ranging from 1% to 5% and are usually in the range of 10 to 20 m in length in the direction of flow. Flow leaving filter strips should be a maximum of 0.10 m depth, based on a 10 mm storm event. Based on the limited space within the Merritt Road and Rice Road ROW, filter strips are not considered a practical stormwater quality solution and have been screened from further consideration.

Infiltrative Trenches

Infiltrative Trenches could be implemented as they are similar to bioretention systems but could be positioned not only within the 1 m bed width of roadside ditches' areas, but under the proposed multi-use pathways. All inlets to the infiltrative trenches should be fitted with goss traps to filter floatable debris. The infiltration trench could be designed to capture a range of runoff volumes, and could therefore be used as a means to achieve erosion control, water quality or water balance criteria. Due to their inherent nature of being subsurface practices, they would have lower maintenance requirements than vegetated / planted practices. Infiltrative Trenches have been carried forward for further consideration.

Silva Cells

Silva Cells are modular suspended paved systems with a cellular soil storage system providing structural support and allows for overland road and pavement drainage to be captured and infiltrated within the cellular soil storage system. Trees are planted within the cellular soil storage system which also use the collected drainage and provide evapotranspiration. Silva cells can be used in confined spaces within urban environments and provide additional stormwater quality benefits. Silva Cells would not be considered to be a standalone water quality measure. Silva Cells have been carried forward for further consideration as possible solution for Merritt Road Segment 3.

Permeable Pavers/Pavement

Permeable pavement could be used either for the entire length or for sections of the proposed 3 m wide multi-use trail. As a standalone LID BMP, a permeable paved multiuse path would not meet either stormwater quality and/or erosion control targets for the whole study area, as it would treat a limited area and would not treat the roadway itself (which would be expected to generate the highest contaminant loadings). However, a permeable MUP would reduce the runoff volume from paved surfaces within the urban road ROW. This LID BMP would have to be selected by the Region to complement other SWM measures during the detailed design phase for road sections that would incur increased roadway pavement area in addition to the proposed MUP and sidewalk. Other municipalities have noted concerns with the application of permeable pavers/pavement due to life cycle costs and operation and maintenance requirements. For the current assessment, permeable pavers/pavement has been screened from further consideration.

Pervious Pipes

Pervious pipes could be used in combination with either bioretention systems or infiltration trenches. As a standalone SWM measure, pervious pipes can be a cost-effective and relatively simple method to accomplish erosion control and infiltration requirements, while eliminating the need for surface space within the right-of-way. Pervious pipes have been carried forward for further consideration.

Based on the foregoing, the following erosion, infiltration and water quality controls have been short-listed:

- Enhanced Grass Swales
- Oil and Grit Separators
- Infiltration Trenches
- Silva Cells
- Pervious Pipes (used with infiltration trenches)

The following figures illustrate typical examples of the recommended LID BMP source controls:

Figure 3-7 Enhanced Grass Swale (ref. Low Impact Development Stormwater Management Planning and Design Guide, Version 1.0, CVC and TRCA, 2010)

Figure 3-8 Enhanced Grass Swale (ref. Low Impact Development Stormwater Management Planning and Design Guide, Version 1.0, CVC and TRCA, 2010)

Figure 3-9 Infiltration Trench Construction (ref. Low Impact Development Stormwater Management Planning and Design Guide, Version 1.0, CVC and TRCA, 2010)

Figure 3-10 Silva Cell Construction (ref. www.smartcitiesdive.com, 2020)

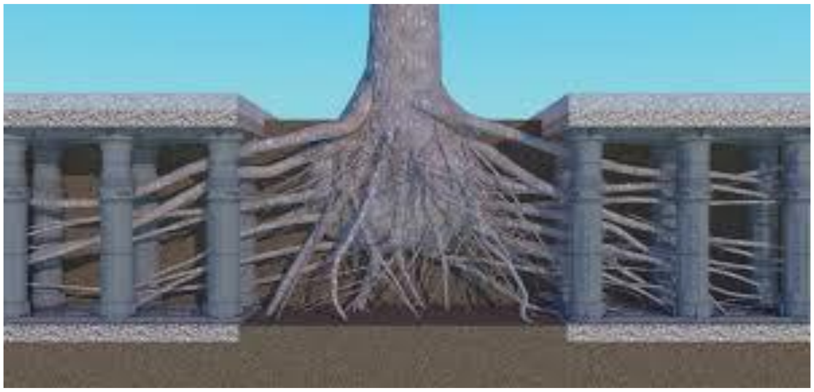


Figure 3-11: Silva Cell Cross Section (ref. info.cambrianrisevt.com, 2020)

3.2.3.2 SHORT-LISTED STORMWATER MANAGEMENT ALTERNATIVES ASSESSMENT

As noted in the preceding sections, a long list of SWM alternatives have been reviewed and undergone preliminary screening in relation to the currently proposed design for Merritt Road and Rice Road. It should be noted that while the preliminary screening process outlined above has been completed as part of the current preliminary SWM strategy assessment, SWM opportunities remain flexible as the design advances through detailed design phase. As part of subsequent studies, other SWM opportunities can be reviewed and identified in order to achieve the local SWM criteria, in consultation with both the Region and NPCA. A summary of the short-listed measures in relation to each roadway Segment is provided in Table 3-9.

Table 3-9: Short-Listed Stormwater Management Alternatives

ROADWAY	SEGMENT	CROSS-SECTION TYPE	QUANTITY CONTROL	QUALITY CONTROL
Merritt Road	1	Hybrid / Rural	• Swale Storage (Check Dams) • Cellular Underground Storage	• Infiltration Trenches • Enhanced Grass Swales
	2	Hybrid / Rural	• Swale Storage (Check Dams) • Cellular Underground Storage	• Infiltration Trenches • Enhanced Grass Swales
	3	Urban	• Super Pipes • Cellular Underground Storage	• Silva / Soil Cells • OGS Units • CB Shields
Rice Road	4	Hybrid / Rural	• Swale Storage (Check Dams) • Cellular Underground Storage	• Infiltration Trenches • Enhanced Grass Swales

Further description regarding the preliminary design concepts and the implementation considerations for the short-listed alternatives is described in subsequent sections.

3.2.4 PROPOSED CONDITIONS – WITH SWM CONTROLS

An updated version of the proposed conditions scenario described in Section 3.2.2 has been generated in PCSWMM in order to plan and verify an appropriate SWM strategy to mitigate the potential increases and impacts associated with uncontrolled conditions. Consistent with the direction from NPCA, the model has been simulated without the storage provided by the wetlands. The proposed SWM strategy involves a combination of storage via roadside grass swales with check dams and underground storage units (i.e., cellular units / super pipes in Segment 3) for quantity control and LID BMPs to promote infiltration and achieve water quality benefits in combination with conventional treatment practices. Details regarding the proposed SWM strategy are presented in the following sections.

3.2.4.1 WATER QUANTITY CONTROLS

FLOOD CONTROL

The proposed conditions PCSWMM model described in Section 3.2.2 has been used as part of an iterative analysis to determine the preliminary quantity control requirements at each respective drainage outlet. It should be noted that during this assessment, it was found that certain locations within the model were experiencing backflow influences from the receiving watercourses, which was influencing the peak flow targets and ultimately the storage requirements. In areas where this was a significant challenge, the target locations were disconnected from the downstream routing system to limit any backwater impacts on the results. The resulting preliminary storage volume requirements for peak flow control of the 100-year storm at each respective outlet is summarized in Table 3-10.

Table 3-10: Preliminary 100-year Quantity Control Sizing per Drainage Outlet

ROAD SEGMENT	OUTLET LOCATION	STATION	PCSWMM SWM NODE	100-YEAR EXISTING TOTAL PEAK FLOW (M^3/S)	100-YEAR PROPOSED UNCONTROLLED PEAK FLOW (M^3/S)	100-YEAR PROPOSED SWM PEAK FLOW (M^3/S)	STORAGE VOLUME REQUIRED (M^3)
4	South side of Quaker Rd.	Rice Rd. 10+140	-	0.83	0.83	0.83	-
	North side of Quaker Rd.	Rice Rd. 10+160	SWM-01	1.83	1.88	1.83	73
	Private Property @ Rice Rd.	Rice Rd. 10+390	SWM-02	3.88	3.97	3.87	78
	South Trib. @ Rice Rd.	Rice Rd. 10+720	SWM-03	7.74	7.77	7.73	198
	Center Trib. @ Rice Rd.	Rice Rd. 10+966	SWM-04	0.70	0.83	0.70	132
	North Trib. @ Rice Rd.	Rice Rd. 11+270	SWM-05	3.18	3.13	3.19	27
1	Center Trib. @ Merritt Rd.	Merritt Rd. 20+640	SWM-06	1.00	1.11	0.95	53
	South Trib. @ Merritt Rd.	Merritt Rd. 20+715	SWM-07	6.40	6.40	6.39	-
	Wetland feature @ Merritt Rd.	Merritt Rd. 20+880	SWM-08	0.33	0.31	0.31	-
	West side of Cataract Rd.	Merritt Rd. 20+960	SWM-09	0.12	0.16	0.12	51
2	East side of Cataract Rd.	Merritt Rd. 20+980	SWM-10	0.56	0.65	0.56	291
	Wetland south of Merritt Rd.	Merritt Rd. 21+235	-	0.57	0.36	0.36	-
	West side of Merrittville Hwy.	Merritt Rd. 21+790	SWM-11	1.26	1.27	1.26	54
3	East side of Merrittville Hwy.	Merritt Rd. 21+810	-	0.57	0.53	0.53	-
	South side of Merrittville Hwy.	Merritt Rd. 21+820	-	0.48	0.48	0.48	-
	Wetland south of Merritt Rd.	Merritt Rd. 22+220	SWM-12	0.48	0.43	0.43	-
	Eastman Gateway @ Merritt Rd.	Merritt Rd. 22+480	SWM-13	0.13	0.15	0.12	36

ROAD SEGMENT	OUTLET LOCATION	STATION	PCSWMM SWM NODE	100-YEAR EXISTING TOTAL PEAK FLOW (M^3/S)	100-YEAR PROPOSED UNCONTROLLED PEAK FLOW (M^3/S)	100-YEAR PROPOSED SWM PEAK FLOW (M^3/S)	STORAGE VOLUME REQUIRED (M^3)
	West side of Grisdale Rd.	Merritt Rd. 22+860	SWM-14	0.11	0.62	0.33	604
	East side of Grisdale Rd.	Merritt Rd. 22+880	-	0.12			
	Wetland east of Grisdale Rd.	Merritt Rd. 23+010	-	0.93	0.82	0.82	-

The storage requirements range depending upon the level of change with respect to the contributing drainage area / imperviousness. There are several outlet locations that experienced a reduction in drainage area from the ROW and would therefore have lower peak flows under proposed conditions and not require quantity controls. Other outlet locations which experienced an increase in imperviousness or ROW drainage area have storage requirements ranging from approximately 27 m^3 up to over 600 m^3 to control the 100-year storm to existing levels.

The required SWM sizes and the controlled peak flows have been used to generate Unitary Discharge and Unitary Storage that can be used as a high-level indicator of required storage for each outlet. Table 3-11 indicates the preliminary unitary values for the proposed quantity control measures for the 100-year storm.

Table 3-11: Preliminary 100-year Unitary Quantity Control Sizing per Drainage Outlet

ROAD SEGMENT	LOCATION	STATION	PCSWMM SWM NODE	100-YEAR UNITARY DISCHARGE ($M^3/S/HA$)	100-YEAR UNITARY STORAGE ($M^3/IMP.HA$)
4	South side of Quaker Rd.	Rice Rd. 10+140	-	-	-
	North side of Quaker Rd.	Rice Rd. 10+160	SWM-01	0.115	600
	Private Property @ Rice Rd.	Rice Rd. 10+390	SWM-02	0.053	518
	South Trib. @ Rice Rd.	Rice Rd. 10+720	SWM-03	0.101	707
	Center Trib. @ Rice Rd.	Rice Rd. 10+966	SWM-04	0.071	759
	North Trib. @ Rice Rd.	Rice Rd. 11+270	SWM-05	0.104	343
1	Center Trib. @ Merritt Rd.	Merritt Rd. 20+640	SWM-06	0.053	133
	South Trib. @ Merritt Rd.	Merritt Rd. 20+715	SWM-07	-	-
	Wetland feature @ Merritt Rd.	Merritt Rd. 20+880	SWM-08	-	-
	West side of Cataract Rd.	Merritt Rd. 20+960	SWM-09	0.200	633
2	East side of Cataract Rd.	Merritt Rd. 20+980	SWM-10	0.073	508
	Wetland south of Merritt Rd.	Merritt Rd. 21+235	-	-	-
	West side of Merrittville Hwy.	Merritt Rd. 21+790	SWM-11	0.117	482
3	East side of Merrittville Hwy.	Merritt Rd. 21+810	-	-	
	South side of Merrittville Hwy.	Merritt Rd. 21+820	-	-	-
	Wetland south of Merritt Rd.	Merritt Rd. 22+220	SWM-12	-	-
	Eastman Gateway @ Merritt Rd.	Merritt Rd. 22+480	SWM-13	0.316	254
	West side of Grisdale Rd.	Merritt Rd. 22+860	SWM-14	0.062	480
	East side of Grisdale Rd.	Merritt Rd. 22+880			

ROAD SEGMENT	LOCATION	STATION	PCSWMM SWM NODE	100-YEAR UNITARY DISCHARGE ($M^3/S/HA$)	100-YEAR UNITARY STORAGE ($M^3/IMP.HA$)
	Wetland east of Grisdale Rd.	Merritt Rd. 23+010	-	-	-

As indicated in Section 3.2.3.2, the proposed quantity control strategy varies per road segment due to the type of proposed cross-section. For the hybrid Segments 1, 2 and 4, quantity control is proposed through temporary storage within the roadside ditches which are equipped with rock check dams. Whereas the urbanized Segment 3 would more likely utilize underground storage through the application of a super pipe system and/or cellular storage tanks as it is not limited to surface storage only.

To provide an indication of the space requirements for the hybrid segments, the 100-year storage volume requirements summarized in Table 3-12 have been reviewed against the proposed length of ditches to identify the proportion of the roadside ditches that would be utilized for temporary quantity control storage. This is summarized in Table 3-12. It should be noted that check dams are required to enhance the storage capacity of proposed swales.

Table 3-12: Approximate Length of Roadside Grass Swales Required for Quantity Control

ROAD SEGMENT	LOCATION	STATION	APPROXIMATE PROPOSED SWALE LENGTH (M)[1]	APPROXIMATE PERCENTAGE OF SWALE LENGTH REQUIRED (M)
4	North side of Quaker Rd.	Rice Rd. 10+160	260	41%
	Private Property @ Rice Rd.	Rice Rd. 10+390	520	22%
	South Trib. @ Rice Rd.	Rice Rd. 10+720	418	70%
	Center Trib. @ Rice Rd.	Rice Rd. 10+966	430	45%
	North Trib. @ Rice Rd.	Rice Rd. 11+270	235	17%
1	Center Trib. @ Merritt Rd.	Merritt Rd. 20+640	1136	7%
	West side of Cataract Rd.	Merritt Rd. 20+960	100	75%
2	East side of Cataract Rd.	Merritt Rd. 20+980	850	50%
	West side of Merrittville Hwy.	Merritt Rd. 21+790	800	10%

Note: [1] As indicated in Section 3.2.1 the size of the roadside ditches are assumed to be 3 m top width, 1 m bottom width, 3:1 side slopes and approximately 0.30 m of depth.

As demonstrated in Table 3-12, the quantity control required for the select outlets along Segments 1, 2 and 4 are capable of being accommodated through the roadside ditches. This is to be further evaluated as part of detailed design phase, to confirm the size and alignment of the roadside ditches and the locations for rock check dams to accommodate the required storage.

PRELIMINARY CULVERT SIZING

There are various cross-culverts located within the study area, which include both watercourse crossings as well as general ditch conveyance culverts. The PCSWMM modelling has been used to identify preliminary culvert upgrades for the cross-culverts within the study area, in order to convey the major system (100-year storm), as several of them are considered to be undersized under existing conditions. Culvert sizing for the tributaries of the Singers Drain have been assessed as part of a separate hydraulic analysis (ref. Section 4).

The existing culvert sizes and the resulting preliminary proposed structure upgrades are summarized in Table 3-13. The culverts are also shown visually on the Drainage Plans in Appendix A and Appendix E, with a list in Appendix F.

Table 3-13: Existing and Proposed Conditions Culvert Sizes

SEGMENT	CULVERT ID	EXISTING CONDITIONS		PROPOSED CONDITIONS	
		TYPE	SIZE (M)	TYPE	SIZE (M)
4	R02	CIRCULAR	0.4	CIRCULAR	0.9
	R03-1	CIRCULAR	0.6	CIRCULAR	0.9
	R05	CIRCULAR	0.45	CIRCULAR	0.6
	R06	CIRCULAR	0.45	CIRCULAR	0.6
	R07	CIRCULAR	0.5	CIRCULAR	0.75
	R08	CIRCULAR	0.6	CIRCULAR	0.75
1	M04	CIRCULAR	0.3	CIRCULAR	0.6
2	M05	CIRCULAR	0.4	CIRCULAR	0.75
	M07	CIRCULAR	0.5	CIRCULAR	0.9

The sizes noted in Table 3-13 are considered preliminary and are to be confirmed at the detailed design phase, to ensure that minimum cover requirements are met with the proposed roadway profile and that the ditch grading can accommodate positive drainage to each of the culvert locations.

EROSION CONTROL

As noted in Section 2.3, the Niagara Region's SWM Guidelines identify a range of criteria which are to be followed for erosion control purposes. It is ultimately recommended that site investigations be completed for determining the critical erosion thresholds in the receiving watercourses, to identify any erosion sensitive receivers and to design any SWM controls to those standards. Seeing as geomorphological assessments are not a part of the current EA being completed for this study, this is a future requirement which needs to be completed as part of future studies in support of detailed design phase.

In the absence of site-specific field data, there are two (2) other alternatives to achieve erosion control in relation to the additional impervious area resulting from the proposed roadway design. These include either storage and controlled release of the 4-hour 25 mm Chicago Storm event, or the retention of the MECP's runoff volume control target (RVCT) outlined in the provincial Draft LID SWM Guideline, which for the study area of Merritt Road and Rice Road would fall within the 28-29 mm range (ref. MECP, 2022).

Seeing as majority of the study area is proposed to have a hybrid urban/rural cross-section serviced by roadside ditches, it is anticipated that extended detention of the 25 mm Chicago storm would not be preferred, as this would require standing water in the ditches for all frequent storm events. Therefore, for the current assessment it is assumed that retention of the MECP's RVCT associated with the increased impervious area within each segment would be the preferred approach to mitigating any erosion risks to downstream receivers. The associated control volume required for each segment is summarized in Table 3-14.

Table 3-14: Control Volume Required for Each Segment

ROADWAY	SEGMENT	PROPOSED CHANGE IN IMP AREA (HA)	RVCT RAINFALL DEPTH (MM)	RVCT VOLUME (M3)
Merritt Road	1	0.98	29	283.8
	2	0.09	29	24.7
	3	0.83	29	241.0

ROADWAY	SEGMENT	PROPOSED CHANGE IN IMP AREA (HA)	RVCT RAINFALL DEPTH (MM)	RVCT VOLUME (M3)
Rice Road	4	0.76	29	220.5

As a result of the proposed roadway design, the increased impervious area within each segment would have a resulting RVCT volume ranging from approximately 25 m^3 (+/-) up to 284 m^3 (+/-), which is required to be retained on site through infiltrative best management practices. It should be noted that the current study has not included a geotechnical investigation throughout the study area to verify the subsurface conditions, including soil type, infiltration rate or groundwater table elevations throughout the study area. This type of site-specific assessment would be required to be completed through future stages of detailed design phase. As such, the following LID BMP sizing should be taken as preliminary, under the assumption that subsurface soil conditions would support full infiltration. The required volumes to achieve the RVCT could be achieved through the practices summarized in Table 3-15.

Table 3-15: Approximate Percentage of Retention Practice required within ROW

ROADWAY	SEGMENT	RVCT VOLUME (M^3)	LID BMP OPTION	PRELIMINARY SIZE REQUIRED[1]	APPROX PERCENTAGE OF RETENTION PRACTICE WITHIN ROW
Merritt Road	1	283.8	Infiltration Trench	1 m wide x 0.6 m deep x 1185 m long	75%
	2	24.7	Infiltration Trench	1 m wide x 0.6 m deep x 105 m long	10%
	3	241.0	Dual Row Silva Cell[2]	1.2 m wide x 1.1 m deep x 475 m long	20%
Rice Road	4	220.5	Infiltration Trench	1 m wide x 0.6 m deep x 920 m long	35%

Note: [1] Assumed a Void Ratio of 0.4 for all infiltrative practices.
[2] Preliminary sizing of Silva Cell system is based upon a double row 3X unit.

As noted in Table 3-15, the RVCT volume resulting from the increased impervious areas within each roadway segment can be retained on site through the application of infiltration trenches and Silva Cells within the ROW. For the rurally serviced segments 1, 2 and 4, the infiltration trench is proposed to be designed within the bottom of the roadside ditch cross-section. The preliminary sizing of the infiltration trenches has assumed a standard cross-section of 1 m wide (i.e., bottom of the ditch), 0.6 m deep granular base and a void ratio of 0.4. However, this will need to be confirmed through detailed design phase. The required lengths of infiltration trench within each segment range from approx. 105 m (+/-), up to 1185 m (+/-), depending upon the required control volume. The retention volumes could be accommodated within the proposed ROW and would require that approximately 10% (+/-) to up to 75% (+/-) of the roadway ditches to have an infiltration trench component.

For the urbanized ROW of Segment 3, Silva Cells can be installed in connection to the local storm sewer system and be planted as part of the boulevard within the ROW. The sizing has assumed a dual row of the largest modular Silva Cell system (3X), however seeing as these are modular systems there is flexibility with respect to the ultimate design and implementation. Silva Cells or equivalent units can provide retention and infiltration throughout an urbanized roadway ROW, while also allowing flexibility within the boulevards for plantings and mature trees to assist with aesthetics.

It should be noted that there are several different outlet locations within each roadway segment. In order to provide adequate erosion control for each receiving system, the retention practices identified within Table 3-15 would need to be implemented upstream of each drainage outlet to ensure the full benefits are provided to each receiving system.

As noted previously, the subsurface soil conditions are required to be confirmed through detailed design phase throughout the road ROW to confirm that these practices can be designed as full infiltration / retention. If the results of the site scale investigations identify potential constraints to infiltrative practices, then a flexible combination approach between detention within the swales via earth check dams / orifices, as well as partial retention may be required for the rural segments. The urbanized segment may provide temporary storage through storage pipes and orifice controls, in combination with partial retention through soil cells, as needed. The ultimate design, sizing, orientation and implementation, including infiltration / soil testing to validate appropriate subsurface conditions for full infiltration, would need to be confirmed through future stages of detailed design phase.

Based on the foregoing, the Runoff Volume Control Target of 28-29 mm is to be provided to the extent feasible based on physical and site constraints with a flexible approach to both surface and subsurface storage systems, acknowledging that the target may not be feasible in some locations due to local constraints.

3.2.4.2 WATER QUALITY CONTROLS

As noted in Section 2.3, the Niagara Region's SWM Guidelines identify that an Enhanced Level of water quality control would be required through achieving a long-term 80% TSS removal from urban runoff. This is assumed to be associated with the increased impervious area occurring from the proposed roadway design. As identified in the preceding sections, there are a variety of options available to provide water quality control, including source controls such as LID BMPs, as well as end of pipe controls / manufactured devices. Each of these alternatives have advantages and disadvantages depending upon their design and implementation requirements.

Based upon the proposed strategy for achieving erosion control identified in the preceding section, it is preferred for the MECP's RVCT to be retained on-site (i.e., within the ROW) where possible. This is currently being proposed through the application of infiltration trenches beneath the roadside ditches in Segments 1, 2 and 4, and through Silva Cells within the boulevard area and connected to the proposed storm sewer system in the urbanized Segment 3. Both of these options would provide the dual benefits of both runoff retention through infiltration, as well as water quality benefits by treating and retaining the additional runoff associated with the increased impervious areas.

It is recommended that where possible, pre-treatment measures be incorporated into the design to support a treatment train approach to water quality control. For rurally serviced segments (i.e., 1, 2 and 4), the options for pre-treatment are often limited to practices which would fit within roadside ditches. These would include designing certain portions of the roadway ditches as enhanced grass swales upstream of the infiltration trenches, which would require the following design considerations (ref. STEP, 2023):

- *Treat drainage areas of <2 hectares*
- *Minimum residence time of 5 minutes.*
- *Maximum flow velocity 0.3 m/s*
- *Bottom width between 0.75 - 3.0 m*
- *Minimum length 30 m*
- *Minimum length between check dams > 5m*

- *Maximum depth of flow should be 50% height of grass for regularly mown swales, to a maximum of 100 mm, or 33% - height of vegetation for infrequently mown swales.*
- *Cross-section shape may be parabolic or trapezoidal, but parabolic is preferable for aesthetics, maintenance, and hydraulics.*

As for the urbanized Segment 3, pre-treatment should be installed upstream of the Silva Cells to ensure initial removal of floatable materials and larger debris; these could be in the form of either OGS units or CB shields depending upon the contributing drainage areas to each system.

3.2.4.3 WATER BALANCE CONTROLS

As noted in Section 2.3, the Niagara Region's SWM Guidelines identify that in absence of a hydrogeologic water balance assessment, a minimum requirement of 5 mm retention should be applied. The current study has not completed a hydrogeologic assessment focused upon a water balance assessment for the entirety of the roadway study area, therefore it is assumed that the 5 mm retention would be the governing criteria. As noted in the preceding Erosion Control section, retention of the MECP's RVCT associated with a 29 mm rainfall event may be achieved through the application of LID BMPs such as infiltration trenches and Silva Cells, or approved equivalents. The volume associated with the 29 mm RVCT exceeds that of the 5 mm water balance criteria, therefore through the implementation of the MECP's RVCT, the water balance criteria would also be met for the increased impervious area.

It is acknowledged that the Runoff Volume Control Target of 28-29 mm is to be provided to the extent feasible based on physical and site constraints with a flexible approach to both surface and subsurface storage systems, and that the target may not be feasible in some locations due to local constraints.

3.2.5 HIGHWAY 406 – GRISDALE ROAD DESIGN

As noted in preceding sections, the key focus for the study area includes Rice Road from Quaker Road up to north of Merritt Road, and Merritt Road from Rice Road to Highway 406. The focus for the preceding SWM analysis has largely been focused upon these primary sections of the ROW, evaluating the changes at the respective outlet locations based upon the standard cross-sections selected for each segment. Based upon the current design, there are also proposed changes required at the Grisdale Road and Highway 406 Interchange, at the eastern limit of the Merritt Road ROW.

An assessment of design options for the interchange was completed under separate cover (ref. Merritt Road, Grisdale Road & Highway 406 Interchange Design Options Memorandum, May 25, 2023), which highlighted a total of six (6) different options and completed a traffic analysis to inform the selected alternative. Based upon this analysis the following was determined (ref. WSP, May 25, 2023):

- ***Option 6** is recommended as the preferred option in terms of traffic safety, constructability, and cost-effectiveness. This option maintains the existing EBL turn lane and provides an additional EBT lane at Highway 406 N-E/W Off-Ramp and E/W-S On-Ramp intersection at Merritt Road, while matching eastbound lanes prior to bridge westerly abutment to avoid impacts and widening of the existing bridge structure over the highway. This option eliminates the need to widen the existing bridge structure through the removal of WBR turn channel and provision of a short WBR turn lane instead at the intersection. It should be noted that minor impacts to vegetated area are anticipated due to re-grading embankment on the south side of Merritt Road and relocation of guiderail. In this option, a WBL turn is permitted at*

Grisdale Road/Merritt Road intersection along with eastbound right (EBR) and northbound right (NBR) turning movements, in other words a RIRO plus WBL. Since NBL is again not permitted under this option, the median island and right-turn channel is designed to ensure that NBL is completely restricted. This option would facilitate safer turn onto Grisdale Road from Merritt Road with a provision of a dedicated WBL turn lane. A MUP is also provided on the north side of the bridge structure as per the MTO Bikeways Design Manual (March 2014). The existing and proposed cross-section at the bridge structure are shown in the figure below.

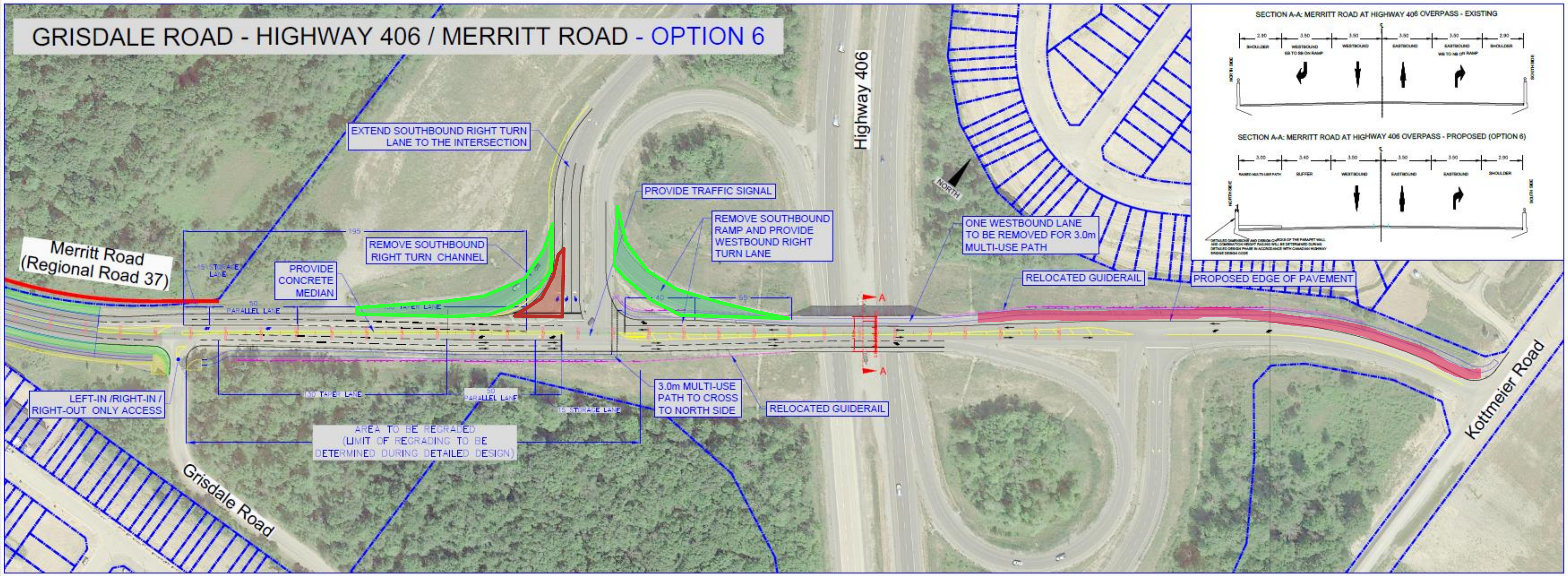


Figure 3-12: Grisdale Rd. - Highway 406 / Merritt Rd. – Option 6

From a SWM perspective, the change in impervious coverage is one of the key components of the design which will drive the associated management requirements. From review of Option 6 demonstrated in Figure 3-12, two (2) lanes are proposed to be removed, which include the southbound ramp and southbound right turn channel. In its replacement, an intersection is proposed which will include a southbound right turn lane and a westbound right turn lane to maintain the direction of traffic. In addition to the lane changes, the MUP is proposed to be connected across the bridge and extend to the eastern limit of the Highway 406 interchange, connecting to Kottmeier Road.

Any increases in impervious area would warrant quantity and erosion control through SWM, whereas water quality control would typically only be considered for roadway / vehicular traffic areas, as opposed to a MUP, which would only be for pedestrian and cyclists' use and would not provide increased risk to water quality. As a result of this proposed design, there are changes in the amount of impervious coverage which may require SWM control.

Through review of the plan view of this preliminary design option, there are both reductions in impervious area (elimination of vehicular lanes, shown in green on Figure 3-12) and additions of impervious area (intersection connection and MUP, shown in red on Figure 3-12). Based upon the current preliminary design, the footprint of the reduced impervious areas appears to exceed the footprint of the increased impervious areas, which would therefore result in an overall net decrease of impervious area associated with this design option. As such, quantity and quality controls are likely not required for this portion of the roadway design. However, the final footprints should be confirmed through detailed design phase to determine if SWM controls are in fact required.

Other elements to be confirmed through detailed design phase include the drainage / conveyance system. It is understood that under existing conditions, this area is rurally serviced through roadside ditches and cross-culverts. Therefore, the drainage infrastructure will be required to be confirmed during detailed design phase to be of adequate capacity and condition to support the changes proposed within the interchange area.

It should be noted that unconventional underground storm storage systems such as chambers and infiltration systems are not permitted by MTO. Underground storage provided in manholes, storm sewers, super pipes or storage tanks are permitted as such storage measures are accessible through a manhole and can be easily inspected for their continued functionality. Unconventional storm storage systems will not be considered by the MTO in the determination of controlled post development peak flows and ponding limits. Calculations and assessment of peak flows and ponding limits in the detailed design stage without the unconventional storm storage systems will be required by the MTO to confirm that the proposed development will not impact the MTO's drainage system. (Ref. Appendix G).

4 HYDRAULICS

The contents of this section provide an overview of the hydraulic assessment within Segment 1 of the study area. This assessment included the base hydraulic model development, the existing conditions characterization and the proposed conditions analysis. It should be noted that the modelling and associated results presented in the subsequent sections do not represent or warrant changes to the regulatory mapping limits currently used and approved by the NPCA. The efforts associated with the refined modelling have been used to generate a more refined understanding of the flood hazards present within the subject area and have been used as a baseline when assessing the potential impacts associated with the proposed roadway design.

4.1 BACKGROUND DATA

The following data has been provided and/or sourced to support the hydraulic analysis for the tributaries of Singer's Drain, passing through Road Segments 1 and 2 (Merritt Road) and Road Segment 4 (Rice Road) within the study area:

Mapping Data:

- Topographic Survey for the Road Right-of-Way (Wood, 2021)
- SWOOP 2015 LiDAR Data – 2 m Resolution Raster (LIO, 2015)
- NPCA Digital Elevation Model – 5 m Resolution Raster (NPCA, 2015)
- NPCA Digital Terrain Model – Polyline File (NPCA, 2020)
- Contemporary Watercourse Mapping (NPCA)
- Major Watercourse Mapping (Niagara Region)
- Cross Culvert Mapping (Niagara Region)

Reports:

- Singer's Drain Floodplain Update Report (AMEC, June 2011)
  - HEC-RAS Model Version 4.1 & SWMHYMO Model

The hydraulic modelling generated as part of the Singer's Drain Floodplain Update Report (June 2011) was based upon previous HEC-2 modelling provided by the NPCA and included the full Singer's Drain subwatershed down to the outlet at the Welland Canal. In reviewing the existing modelling within the subject area (Road Segments 1, 2 and 4), the previous modelling was found to be too coarse (3 cross-sections per reach) to accurately represent the watercourses of focus, which pass through the subject Rice Road and Merritt Road right-of-ways. Therefore, a new hydraulic model was proposed to be developed, which would place the focus upon the tributaries of the Singer's Drain which pass through the subject area (ref. Figure 4-1). Further description regarding model development and preliminary results are provided in the subsequent sections.

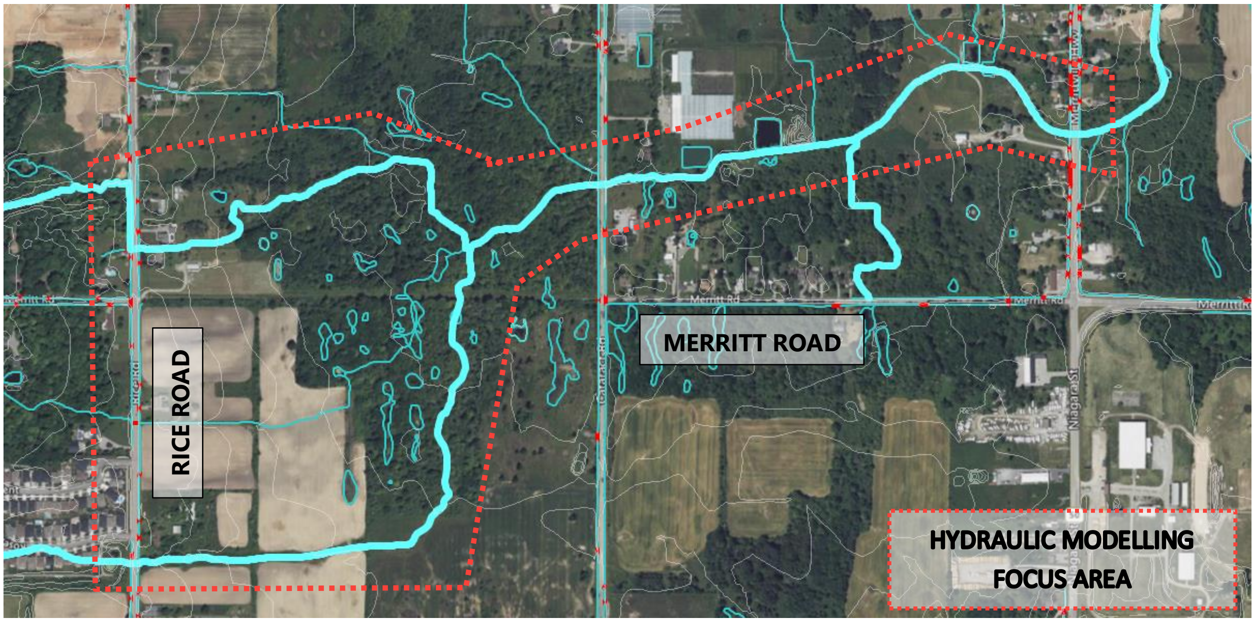


Figure 4-1: Hydraulic Modelling Focus Area – Merritt Road & Rice Road

4.2 HYDRAULIC MODELLING METHODOLOGY

A new 1-dimensional (1D) hydraulic modelling for the subject area was proposed and has been completed in the most recent non-beta version of HEC-RAS, which at the time of the completion of this study, was version 6.4. Further details regarding the base model development are provided in the subsequent sections.

4.2.1 BASE MODEL DEVELOPMENT

4.2.1.1 TOPOGRAPHIC DATA

As mentioned in Section 4.1, two (2) sets of LiDAR data have been received/sourced and reviewed accordingly. These include the 2 m resolution SWOOP DEM, which was based upon orthophotography collected by the Ministry of Natural Resources and Forestry in 2015 (ref. Land Information Ontario, 2015), and a 5 m resolution DEM provided by the NPCA in 2022. In comparing the two data sets, it was found that the SWOOP DEM had a better resolution (2 m) and had the potential to provide further detail in the areas of focus. Accordingly, the SWOOP DEM has been used for model development. Nonetheless, the NPCA DEM was also used to compare the findings from the SWOOP DEM and confirm the understanding of the features of interest.

The SWOOP DEM was compared against topographic survey data collected by WSP staff in 2021 in support of this project. This data collection included full survey of the road right-of-way, including the roadway, ditches, and culverts. Using these survey points, the SWOOP DEM has been compared against the surveyed elevations, with focus placed upon the roadway centreline data of both Merritt Road and Rice Road within the extent of the project, as these represent hardscaped surfaces more easily picked up through SWOOP orthophotography.

A comparison of the of the DEM versus topographic survey data is presented in Table 4-1.

Table 4-1: DEM Comparison to Topographic Survey Data – Correction Factor Summary

Location	# of Centreline Survey Points	Difference between Survey & LIO DEM (m)		
		MAXIMUM	MINIMUM	AVERAGE
Rice Rd.	123	0.453	-0.341	0.181
Merritt Rd.	218	0.428	0.034	0.204
Total	**341**	**0.453**	**-0.341**	**0.196**

Based upon the results presented in Table 4-1, a total of 341 points were compared along both Merritt Road and Rice Road. The results of the comparison demonstrate that the differences between the topographic survey and the DEM range from +0.453 m to -0.341 m, with the survey on average being +0.196 m higher than the DEM in the tested locations. Therefore, it was proposed to apply a correction factor to the SWOOP15 DEM by increasing the elevation of the entire DEM by 0.196 m, to improve accuracy and correlation with the survey data, which has formed the basis for the roadway assessment and design. The hydraulic structure coding (inverts / road deck) has been sourced from the topographic survey and remains unchanged, whereas the DEM has been adjusted accordingly for cross-section geometry only.

4.2.1.2 RIVER CENTRELINE

Two (2) watercourse mapping files were provided for use in the current study. These include the Contemporary Watercourse Mapping from NPCA, and the Major Watercourse Mapping from the Region. Both have been used to delineate the HEC-RAS River centrelines. A total of three (3) watercourse tributaries pass through the subject Rice Road corridor (Segment 4) and combine just north of the subject Merritt Road unopened road allowance (Segment 1) to form the main branch within the study area (ref. Figure 3-2). All three (3) tributaries (named North, Centre and South) have been included in the hydraulic model, beginning west of Rice Road to include the associated cross-culverts, and join at the confluence point upstream of Cataract Road. The main branch has been included in the modelling from the confluence point and continues east to the termination point of the revised model, located east of Merrittville Highway (ref. Figure 4-2).

4.2.1.3 CROSS-SECTION GEOMETRY

The basis of the hydraulic model geometry is the development of cross-sections. The cross-sections have been cut perpendicular to the river centreline from left to right looking downstream and have been extended to natural high points in the landscape, based upon the DEM and contour mapping files for the study area. The cross-sections have also been reviewed and extended where necessary based upon preliminary results, to ensure that all cross-sections are contained where possible. Initial flow paths have been assumed based upon the approved regulatory floodplain mapping, and bank lines have been estimated based upon aerial imagery. Through the review of the cross-section data, the bank stations have been manually corrected to more accurate locations within the channel formation.

The cross-section elevations have been based upon the updated SWOOP DEM (MNRF, 2015). However, the main channel elevation, and the right and left bank area elevations have been updated in select locations based upon topographic survey data, where available. It should be noted that low flow channel adjustments surrounding the structures and throughout select parts of the reaches were necessary in order to match the channel elevations to the existing structures (i.e., culverts) which have been modelled according to the topographic survey data. It is noted that the SWOOP DEM is unable to pick up the accurate bottom of the channel inverts and surrounding bare-ground elevations due to the 2 m resolution of the data, ponded water, and the dense vegetation coverage (particularly in the wetland area). Table 4-2 indicates the number of cross-sections per reach and the average spacing within the model.

Table 4-2: Cross-Section Density Summary per River Reach

RIVER	REACH	TOTAL LENGTH (M)	TOTAL # OF CROSS-SECTIONS	AVG CROSS-SECTION SPACING (M)
North Tributary	North Trib	864.4	19	48
Center Tributary	Center Trib	820.7	25	32.8
South Tributary	South Trib	1,128	36	32.2
Main Branch	Main Branch	1,340	33	41.9
Total Model		**4,153.2**	**113**	**37.8**

Based upon the model summary in Table 4-2, the new hydraulic model has a total river length of approximately 4.2 km (+/-), and 113 cross-sections, with an average spacing of approximately 38 m (+/-). This demonstrates the resolution and detail in the current model to assist with better understanding the local flood hazard within the subject area. Figure 4-2: represents the current cross-section alignment.

4.2.1.4 HYDRAULIC STRUCTURES

A total of five (5) existing structures are located within the study area limits and have been included in the modelling based upon WSP field inventory, topographic survey, and confirmed through the Existing HEC-RAS model (ref. AMEC, 2011). Table 4-3 provides a summary of each hydraulic structure.

Table 4-3: Hydraulic Structure Summary

WSP STRUCTURE ID	RIVER	ROAD / LOCATION	STRUCTURE TYPE / SIZE	DATA SOURCE
N1	North Tributary	Rice Road (north of Merritt Road)	0.6 m CSP Culvert	Field Inventory / Survey & Previous HEC-RAS
C1	Centre Tributary	Rice Road (south of Merritt Road)	0.5 m CSP Culvert	Field Inventory / Survey & Previous HEC-RAS
S1	South Tributary	Rice Road (south of Rosewood Crescent)	0.75 m CSP Culvert	Field Inventory / Survey & Previous HEC-RAS
M1	Main Branch	Cataract Road	1.5 m (W) x 1.15 m (H) CSP Arch Culvert	Field Inventory / Survey & Previous HEC-RAS
M2	Main Branch	Merrittville Hwy	3.0 m (W) x 1.38m (H) Open Bottom Box Concrete Culvert	Field Inventory / Survey & Previous HEC-RAS

As mentioned previously, field inventory / survey and previous HEC-RAS modelling have been used to define the structure-related parameters, as well as the deck elevations based upon the surveyed roadway centreline (where available). Other parameters that have been used in modelling the culverts (i.e., Manning's 'n', entrance and exit coefficients, ineffective flow areas, etc.) have been determined as per HEC-RAS manual's recommendations.

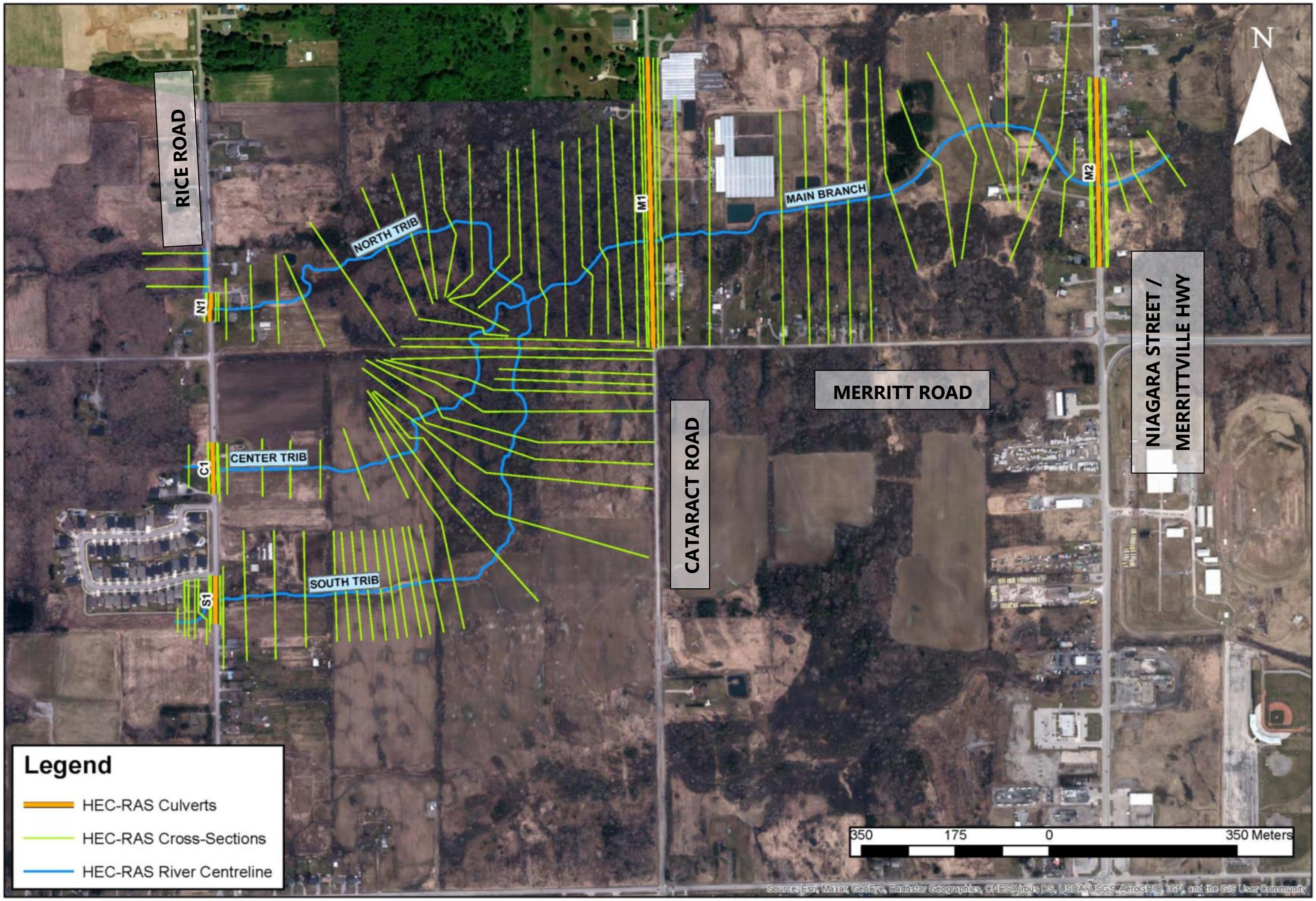


Figure 4-2: Refined Hydraulic Model Geometry Schematic

4.2.1.5 OTHER GEOMETRY FACTORS

Ineffective flow areas have been assigned at each hydraulic structure crossing, applied to both the upstream and downstream bounding cross-sections. The approach is consistent with the HEC-RAS methodology, where a 1:1 contraction rate has been applied for placing the ineffective flow areas on both sides of the structure face. On the upstream side, the ineffective flow area elevation has been assigned based upon the low point (spill point) in the roadway deck. Whereas on the downstream side, the elevation has been assigned based upon the midpoint between the bridge/culvert obvert and the deck low point, as WSP has applied in other hydraulic modelling projects. The ineffective flow areas are assigned as “non-permanent”, as once the roadway is overtopped, the full cross-section is capable of being used for flow computations.

An additional geometry feature that has been included in the modelling is the addition of levees, in areas where there are several low points throughout the cross-section / floodplain, which may not accurately represent the primary flow path. To determine areas where levees may be appropriate, the baseline geometry file has been simulated with no levees, which allows for the RAS mapper program to plot the inundation limits freely within the bounds of the cross-sections. This can demonstrate the potential spill paths and / or external channels which may not be representative of the primary active channel.

An example of the scenarios where levees have been applied are provided in Figure 4-3 below.

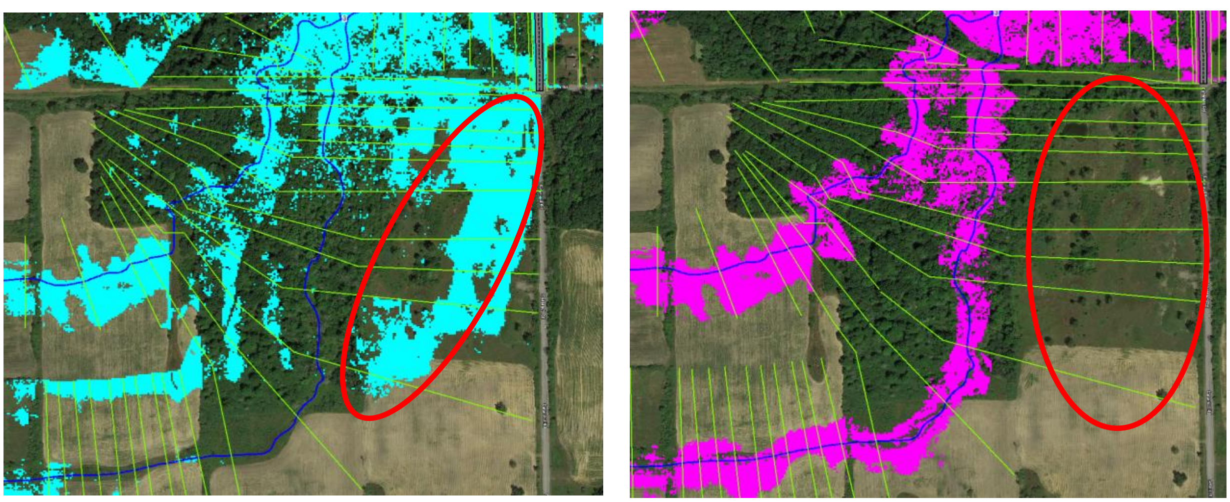


Figure 4-3: Example of “No Levees” Scenario vs. “with Levees” Scenario
(a – on the left side): Example of “No Levees” Scenario – No simulated flow within the main channel due to other low points within the floodplain.
(b – on the right side): Example of “with Levees” Scenario – Cut off storage available within the overbank areas, focusing computations within primary channel.

As demonstrated in Figure 4-3 (a), the right overbank area approaching the Segment 1 unopened road allowance has lower elevations than those within the primary watercourse channel. From the example RAS mapper results presented in (a), there is not a connection between the main channel and the right overbank area which would facilitate this flow path. Therefore, levees have been added to allow for the WSE computations to be focused within the main channel.

While the application of levees assists with the WSE computations and results within the main channel, it is important to note that levees prevent RAS mapper from plotting any backwater impacts from the channel into the low areas of the floodplain. This can be remedied through the delineation of floodplain limits through other software platforms (i.e., CAD, GIS); however, for the current assessment, the WSE results form the basis of the comparison and characterization of the potential impacts, therefore the RAS mapper limits are considered appropriate for the current assessment.

4.2.1.6 HYDRAULIC PARAMETERS

Manning's Roughness Coefficients

Initial estimation of Manning's roughness coefficients has been based upon urban land use mapping, field observation and review of aerial imagery. Based upon this review, the roughness coefficients for the channel geometry have been assigned as the three (3) standard zones, including the overbank areas and the main channel. These include the following:

- Overbank Areas (Left & Right): 0.06 – Brush / Vegetated Floodplain
- Main Channel: 0.035 – Vegetated or Natural Rock Channel

These roughness coefficients are consistent with what was applied in the previous Singer's Drain Floodplain Mapping Update (ref. AMEC, 2011).

Expansion & Contraction Coefficients

Expansion and contraction coefficients for normal channel cross-sections have been set to 0.1 and 0.3, respectively. For cross-sections bounding hydraulic structures and for locations where there is a rapid change in cross-section/valley geometry, expansion and contraction coefficients have been set to 0.3 and 0.5, respectively. These ratios are used by HEC-RAS in the computation of energy losses due to flow contraction and expansion between adjacent cross-sections. The noted values are consistent with those recommended in the HEC-RAS Technical Reference Manual, and with those applied in the previous Singer's Drain Floodplain Mapping Update (ref. AMEC, 2011).

It should also be noted, with regard to structure coding, that coefficients of 0.3 and 0.5 (expansion and contraction respectively) have been applied to the two (2) cross-sections upstream of a structure, and the one (1) cross-section immediately downstream of a structure. This application of expansion and contraction coefficients reflects the anticipated rapid changes occurring at these cross-sections. This approach is consistent with other floodplain mapping work WSP has completed in southern Ontario.

4.2.1.7 STEADY FLOW DATA

As discussed during the correspondence with NPCA in January/February and March of 2022, the Singer's Drain Floodplain Update Report (ref. AMEC, 2011), which included both updates to hydrologic modelling (SWMHYMO) and hydraulic modelling (HEC-RAS Version 4.1), was to be used to support steady flow data generation and the current hydraulic model boundary conditions. During the meeting with NPCA in January 2022, and as part of correspondence related to scope development for this work, it was noted that the current study being completed for Merritt Road and Rice Road includes a new hydrologic / hydraulic model (using PCSWMM). This model is further refined than that developed for the Singer's Drain subwatershed, due to the varying scales of study (subwatershed scale versus local scale). Therefore, the PCSWMM model had been recommended to be used for the steady flow data for the current hydraulic analysis, seeing as the catchments and routing elements are further refined to represent the localized features within the subject area.

It should be noted that due to the updates in hydrologic modelling, the steady flow data supporting the delineation of the local flow hazard will differ from the flows determined as part of the previous study (ref. AMEC, 2011). To support this discussion, the following Table 3-4 outlines the differences / discrepancies determined for the two (2) hydrologic models with respect to the areas draining to the subject area of Segment 1, 2 and 4.

Table 4-4: Comparison of Hydrologic Modelling Efforts (Previous vs Current)

COMPARISON ELEMENT	SINGER'S DRAIN FLOODPLAIN MAPPING UPDATE (REF. AMEC, 2011):	CURRENT MERRITT & RICE ROAD CLASS EA STUDY (REF. WSP, 2023):
Hydrologic Modelling Platform	SWMHYMO	PCSWMM
IDF Curve Source	City of Port Colborne	City of Welland
Storm Duration & Distribution	6-hour Chicago	6-hour Chicago
Design Storms	2, 5, 10, 25, 100-year	2, 5, 10, 25, 50 and 100-year
Subcatchment Delineations (Focus on Merritt/Rice Rd Area Only)		
Total Drainage Area	414.2 ha (+/-)	440.1 ha (+/-)
# of Subcatchments	11	109 (+/-)
Avg Area per Subcatchment	37.6 ha (+/-)	4.04 ha (+/-)
# of Watercourses	Three (3) – North Tributary, South Tributary (combined with Centre Tributary), and Main Branch	Four (4) – North Tributary, Centre Tributary, South Tributary and Main Branch
Land Uses / Imperviousness	All subcatchments were assumed to be 30% impervious (TIMP of 0.30 ha/ha) and 50% directly connected impervious (XIMP of 0.15 ha/ha)	Imperviousness based upon land use mapping and aerial imagery – Average Imperv of 22.9 % Assumed 75% directly connected imperviousness (surface runoff, no storm sewers)
Soil Parameterization	Curve Number	Green-Ampt Infiltration (Supporting subsequent continuous simulation modelling for wetland assessment)
Routing Elements	Simplified Channel Routing (Main Branches only)	Detailed Routing for Watercourses (Tributaries / Main Branches), Ditches, etc.
Calibration	No	Yes

As indicated in Table 4-4, there are several differences between the previous hydrologic modelling and the current model developed for the Merritt Road and Rice Road study area. The differences include the software being used, the IDF parameters, the storm events that were simulated, the level of detail in the discretization, and the parameterization of the subcatchments. Each of these will have an impact on the resulting peak flow to be used in the hydraulic and hydrologic analysis.

Based upon the current PCSWMM model developed for this study (further described in the previous Section 3), the peak flow results for each simulated design storm are presented in Table 4-5, along with the 100-year steady flow data which was applied in the previous regulatory modelling. It should be noted that these represent a "no wetland" scenario, removing the influence of the wetland storage features within Segment 1.

Table 4-5: Hydraulic Model Steady Flow Data Comparison

River	Flow Change XS	PCSWMM Model Results (WSP, 2023)						Singer's Drain (AMEC, 2011)
		2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	100-yr
North Tributary	924	1.07	1.41	1.67	2.18	2.64	3.11	-
	779	0.87	1.21	1.46	2.00	2.28	2.77	1.99
Center Tributary	900	0.32	0.43	0.51	0.64	0.74	0.84	-
	825	0.30	0.42	0.50	0.69	0.80	1.07	N/A[1]
South Tributary	1182	3.28	4.14	4.88	5.93	6.89	7.85	-
	1029	2.05	2.77	3.35	4.11	4.71	4.81	4.871
Main Branch	1348	1.98	2.98	3.74	4.53	6.31	7.83	14.31
	1057	1.75	2.66	3.14	4.79	6.46	7.83	14.08

Note: [1] In the previous Singer's Drain hydraulic model, the Center Trib. and the South Trib. watercourses were lumped and treated as a single watercourse in both the hydrology and the hydraulics.

As demonstrated in Table 4-5, two (2) flow change locations were initially extracted for each modelled reach. For the North, Center and South tributaries, these include applying the flow from the hydrologic modelling node located at the Rice Road crossing (natural drainage divide), and then a second flow change applied based upon the downstream peak flow prior to the confluence. For the Main Branch, this includes the application of the flow node at the Cataract Road crossing, and then the flow at the hydrologic modelling outlet located downstream of the Merrittville Highway crossing. In each case, the flow change has been applied at the upstream extent of the respective reach, consistent with common floodplain mapping practices (ref. Table 4-5).

In comparison to the previous study, the PCSWMM model is resulting in a higher 100-year simulated peak flow in the North Tributary, and a higher 100-year simulated peak flow in the South Tributary (+ Center Tributary), and then a lower simulated peak flow along the Main Branch. These changes can be attributed to the varying differences in the model type and development, as outlined previously (ref. Table 4-4).

It should be noted that through review of the two (2) flow change locations per branch, both the North Tributary and the South Tributary seem to have peak flows that reduce moving further downstream. The PCSWMM modelling used as flow input has removed the influence of the wetland storage units and undersized culverts, however due to the very flat nature of the study area, the channel routing elements appear to attenuate some of the flow and flattens the hydrograph moving downstream. In order to be conservative for the floodplain assessment in Segment 1, the higher peak flows for both the North and South Tributaries have been applied for the entirety of the branch.

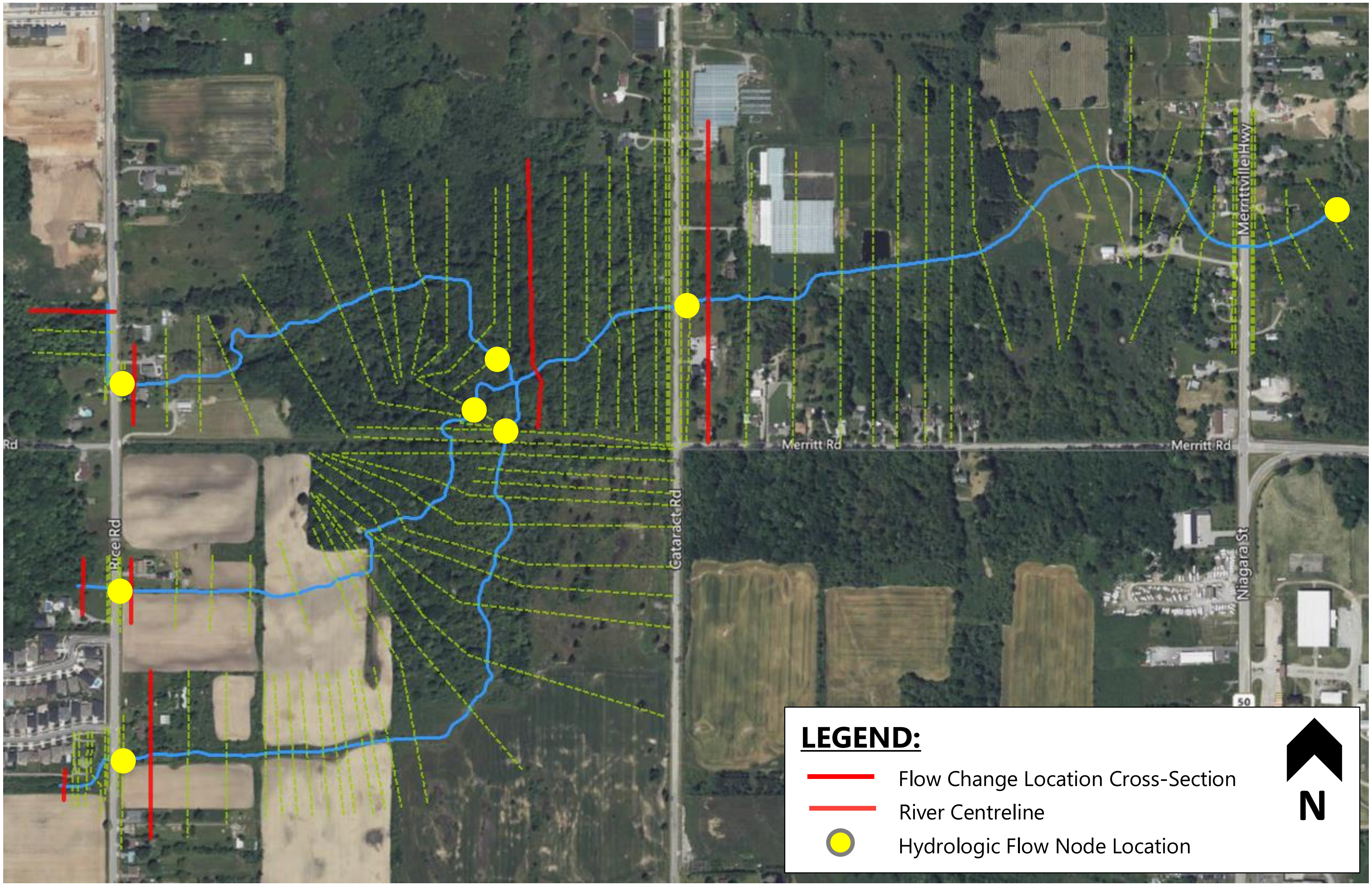


Figure 4-4: Flow Change Location Plan

Boundary Conditions

The boundary conditions applied at the downstream end of the current hydraulic model have been sourced from the previous HEC-RAS model, by taking the resulting WSE from the nearest cross-section to the downstream limits of the current model, being Cross-Section #8 on the Main Branch, located downstream of the Merrittville Highway crossing. The resulting WSE from each simulated event has been used as a known boundary condition for the current simulation; this data is summarized in Table 4-6.

Table 4-6: Hydraulic Model Boundary Condition – Main Branch – Known Water Surface Elevation

STORM EVENT	STEADY FLOW (M^3/S)	WATER SURFACE ELEVATION RESULT (M)
2-yr	1.75	179.79
5-yr	2.66	179.97
10-yr	3.14	180.09
25-yr	4.79	180.21
50-yr*	6.46	180.31
100-yr	7.83	180.41

Note: * The previous hydraulic modelling did not simulate a 50-year event. Therefore, the average between the 25-year and the 100-year WSE has been used as the boundary condition for the 50-year simulation.

4.3 EXISTING CONDITIONS

The baseline existing conditions hydraulic model described in the preceding sections has been simulated for the 2-year, 5-year, 10-year, 25-year, 50-year and 100-year design storm events. As described previously, the current modelling effort and associated results are not representative of changes to NPCA's regulatory mapping. The purpose of the modelling and associated results is rather to be used as part of the current study to identify the baseline existing conditions and determine potential impacts to the local flood hazard and any required mitigation measures for the proposed roadway design.

The draft flood hazard mapping has been plotted on the SWOOP LiDAR data using RAS Mapper to identify the approximate limits of the 100-year simulated floodplain; these are demonstrated in . As noted previously, RAS Mapper does not plot the WSE beyond the levees applied in a cross-section, therefore the full inundated limits including areas of backwater may not be demonstrated in the current mapping, however the resulting water surface elevations can be used as the baseline point of comparison.

As demonstrated in , the draft results differ than the current regulatory floodplain mapping, some of the trends observed include:

- The North Tributary has expansions in the floodplain, likely due to the higher steady flow applied within the reach in comparison to the previous study.
- The Centre Tributary was not mapped as part of the previous study; therefore, the floodplain delineations provide further detail regarding the flow paths and floodplain spread within this agricultural floodplain.
- The South Tributary results generally demonstrates an expanded floodplain, likely due to the higher steady flow applied within the reach in comparison to the previous study. The current results demonstrate some spill beyond the channel limits, and an expanded right overbank approaching the Segment 1 ROW.

- The area surrounding the Confluence point and upstream of Cataract Road is also observed to have a narrower floodplain along the northern limit; again, likely due to the lower flow rates applied, as well as the application of levees focusing the flow within the primary channels.
- The portion of the Main Branch directly downstream of Cataract Road to approximately the midway point of the reach demonstrates an expansion in the floodplain, both north and south of the primary watercourse, which includes floodplain area expansions in both agricultural and residential lands. From the midway point to the downstream extent of Merrittville Highway, the floodplain demonstrates a constriction in comparison to the previous mapping. These changes can be attributed to the lower flows applied in the current assessment, as well as a more refined terrain to plot the inundation limits.

In terms of the performance results at the existing structures, the overtopping depths of each structure for the 25-year, 50-year and 100-year storm events are summarized in Table 4-7.

Table 4-7: Overtopping Depths (m) at Hydraulic Structures

Structure ID#	Roadway	Structure Type / Size	Overtopping During:			Maximum Overtopping Depth (m)
			25-year	50-year	100-year	
N1	Rice Rd	0.6 m CSP Culvert	0.09	0.10	0.12	0.12
C1	Rice Rd	0.5 m CSP Culvert	0.05	0.06	0.06	0.06
S1	Rice Rd	0.75 m CSP Culvert	0.24	0.26	0.27	0.27
M1	Cataract Rd	1.5 m (W) x 1.05 m (H) CSP Arch Culvert	0.47	0.43	0.41	0.47
M2	Merrittville Hwy	3.0 m (W) x 1.1m (H) Open Bottom Box Concrete Culvert	-	-	-	-

The draft results demonstrate that structures N1, C1, S1 and M1 each overtop during the 25-year to 100-year events, whereas structure M2 does not overtop during the reported events. Of those structures which overtop, the maximum overtopping depth ranges from 0.06 m (+/-) up to 0.47 m (+/-). In comparison to the previous hydraulic modelling, both the M1 and M2 structures overtopped during the 25-year and 100-year event, with a maximum overtopping depth ranging from 0.29 m up (+/-) to 0.36 m (+/-). Structures N1, C1 and S1 along Rice Road were not included in the previous modelling, and therefore cannot be compared.

Cross-sections have been generated in the current hydraulic modelling surrounding the unopened road right-of-way along Merritt Road within Segment 1. This applies to both the Centre Tributary and the South Tributary. The simulated WSE and resulting water depths for each return period have been summarized in Table 4-8 for both the upstream and downstream cross-sections along each reach.

Table 4-8: Existing Conditions Simulated Water Surface Elevation and Water Depth – Segment 1

River	Cross-Section ID	Data Type	Simulation Results					
			2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
Centre Tributary	185	Depth (m)	0.18	0.20	0.21	0.23	0.25	0.28
		WSE (m)	182.02	182.04	182.05	182.07	182.09	182.12
	160	Depth (m)	0.18	0.22	0.24	0.27	0.32	0.36
		WSE (m)	181.92	181.96	181.98	182.01	182.06	182.10
South Tributary	100	Depth (m)	0.20	0.25	0.28	0.30	0.34	0.36
		WSE (m)	181.96	182.01	182.04	182.06	182.10	182.12

River	Cross-Section ID	Data Type	Simulation Results					
			2-yr	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
	83	Depth (m)	0.19	0.24	0.28	0.30	0.34	0.36
		WSE (m)	181.94	181.99	182.03	182.05	182.09	182.11

Based upon the results within Table 4-8, the simulated flood depths range from 0.18 m (+/-) up to 0.36 m (+/-) within this area for the range of simulated events, and the maximum WSE in the South and Centre Tributary is approximately 182.12 m. It should be noted that while in reality, these reaches have the potential to overtop and spill into the adjacent reach generating a combined floodplain, the current 1D modelling treats the two (2) reaches as independent watercourses and does not allow for spill flows to leave or join the adjacent watercourse.

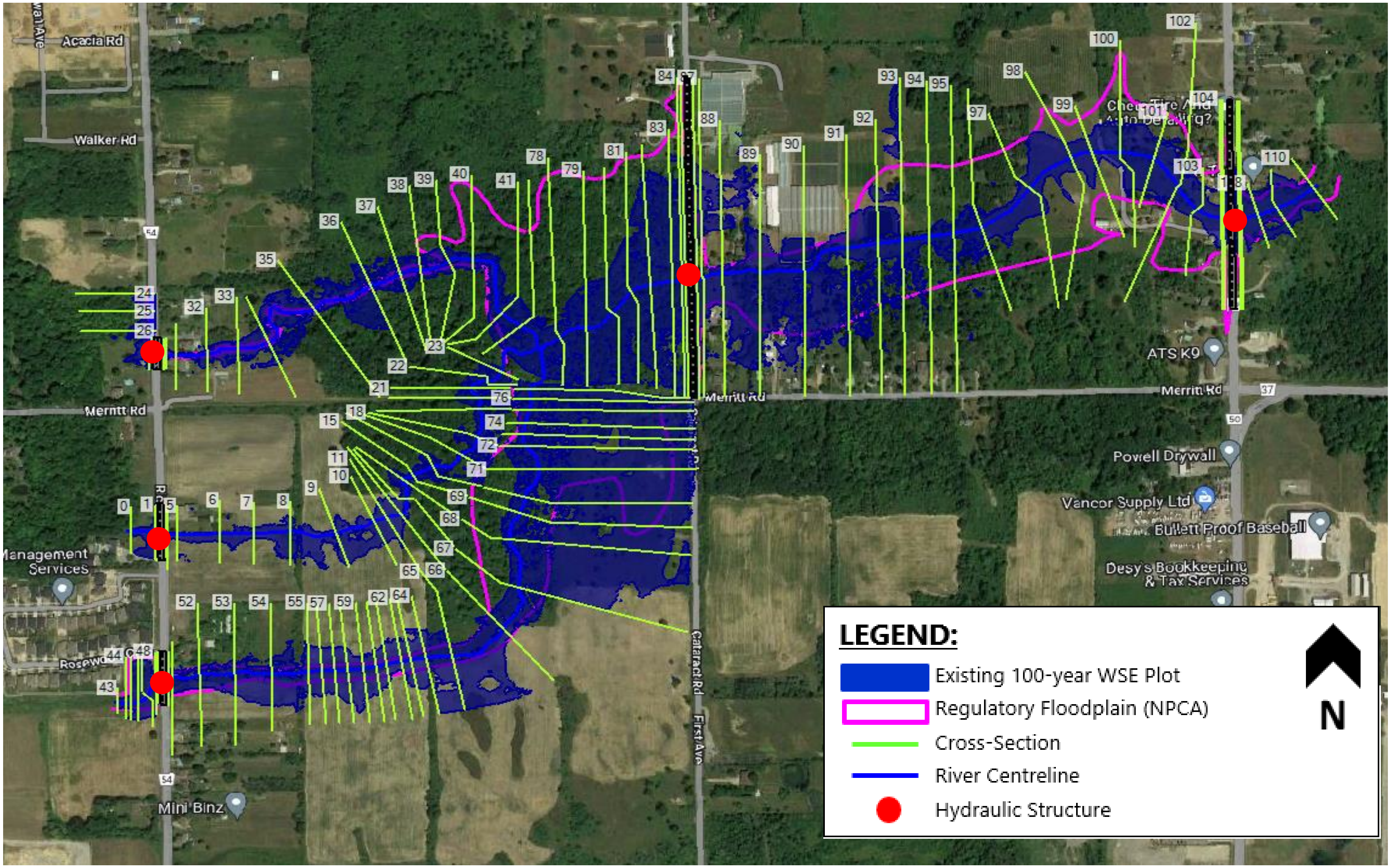


Figure 4-5: Baseline 100-year Hydraulic Model Results – Comparison to Existing Regulatory Floodplain

4.4 PROPOSED CONDITIONS

The updated existing conditions HEC-RAS model described in the preceding sections has been refined to represent proposed conditions. The changes reflected in the proposed conditions modelling includes updating the road deck information at the three (3) existing culverts along Rice Road, and the addition of the two (2) new roadway crossings within Segment 1, associated with the Centre and South Tributaries, which drain north to Cataract Road. The crossings at both Cataract Road and Merrittville Highway have remained as per existing conditions.

As described in Section 2.0, the design event and freeboard requirements for hydraulic crossings are dependent upon the roadway class, and proposed structure size. Based upon the proposed roadway being a hybrid (urban/rural) cross-section and crossing design, the following Ministry of Transportation (MTO) drainage design criteria apply:

- Culverts / bridges crossing beneath roads classified as Major Collector, with a span less than 6.0 m, are to convey the peak flow generated from a 25-year storm event; and
- Culverts / bridges crossing beneath roads classified as Major Collector, with a span greater than 6.0 m, are to convey the peak flow generated from a 50-year storm event.
- Culverts / bridges crossing beneath roads classified as Major Collector are required to provide a freeboard greater than or equal to 1.0 m for the 50-year storm.

The preliminary structure sizing has been determined through an iterative analysis in attempt to achieve the design criteria mentioned above, as well as to minimize any impacts to the 100-year floodplain within Segment 1. The proposed conditions HEC-RAS model has been simulated for the 2, 5, 10, 25, 50 and 100-year events, to complete a validation of the aforementioned design criteria, and indicate any potential impacts for local flood hazards. A summary of the evaluation of design criteria for each new or upgraded structure has been summarized in Table 4-9, documenting the WSE and freeboard during the 25-year, 50-year as well as the 100-year events.

Table 4-9: Preliminary Structure Size Performance – Clearance and Freeboard

STRUCTURE ID (ROAD)	PRELIMINARY STRUCTURE SIZE	STORM EVENT	Q (M^3/S)	U/S WSE (M)	UPSTREAM SOFFIT ELEV. (M)	SAG POINT IN ROAD (M)[1]	FREEBOARD FROM SAG POINT (M)	MEETING MTO CRITERIA?
N1 (Rice Rd)	**3 m (W) x 0.9m (H)**	25Y	2.18	185.48	185.82	186.36	+0.88	No
		50Y	2.64	185.58	185.82	186.36	+0.78	No
		100Y	3.11	185.67	185.82	186.36	+0.69	No
C1 (Rice Rd)	**3m (W) x 0.6m (H)**	25Y	0.64	186.93	187.10	188.00	+1.07	Yes
		50Y	0.74	186.95	187.10	188.00	+1.05	Yes
		100Y	0.84	186.98	187.10	188.00	+1.02	Yes
C2 (Merritt Rd)	**6m (W) x 0.9m (H)**	25Y	0.69	182.04	182.63	183.22	+1.18	Yes
		50Y	0.80	182.08	182.63	183.22	+1.14	Yes
		100Y	1.07	182.13	182.63	183.22	+1.09	Yes
S1 (Rice Rd)	**6m (W) x 0.9m (H)**	25Y	5.93	186.78	186.68	187.12	+0.34	No
		50Y	6.89	186.82	186.68	187.12	+0.30	No
		100Y	7.85	186.87	186.68	187.12	+0.25	No
S2 (Merritt Rd)	**15m (W) x 0.9m (H)**	25Y	5.93	182.1	182.44	182.62	+0.52	No
		50Y	6.89	182.14	182.44	182.62	+0.48	No

STRUCTURE ID (ROAD)	PRELIMINARY STRUCTURE SIZE	STORM EVENT	Q (M^3/S)	U/S WSE (M)	UPSTREAM SOFFIT ELEV. (M)	SAG POINT IN ROAD (M)[1]	FREEBOARD FROM SAG POINT (M)	MEETING MTO CRITERIA?
		100Y	7.85	182.17	182.44	182.62	+0.45	No

Note: [1] Sag point elevation is based upon the preliminary road profile; the sag points may be offset from the culvert crossing and may not be indicative of cover on top of the culvert.

Based upon the performance results provided in Table 4-9, the preliminary structure sizing includes open bottom concrete box culverts ranging in span from 3 m wide, upwards of 15 m wide, and are relatively shallow at depths of 0.6 m or 0.9 m. In terms of the MTO criteria, the two (2) structures along the Centre Tributary are capable of providing the 1 m freeboard for the 25-year, 50-year and 100-year storm events. The North Tributary structure has a freeboard of approximately 0.7 m up to 0.9 m, through the range of events; this does not meet the MTO requirements, however through some minor refinement of the road profile and localized grading at the culvert crossing, it is likely that the 1 m minimum could be met for the 25-year storm. These design modifications should be assessed at detailed design.

The South Tributary has the highest design flows, and therefore has the largest preliminary structure sizes. Both structures (on Rice Road and Merritt Road) are capable of conveying storms up to the 100-year without overtopping the roadway, however, do not currently achieve the minimum freeboard requirements of 1 m. This can likely be remedied through a review of the sag points within the road profile, as well as the invert elevations within the watercourses to identify potential modifications as part of detailed design. A review of the minimum cover requirements should also be reviewed as part of the future detailed design; this may include a refinement of the roadway profile, applying a distribution slab on top of the culverts, and/or reducing the rise of the culverts and potentially increasing the span as required.

It should be noted that the floodplain within the Segment 1 ROW area is very shallow (generally less than 0.5 m in depth) and very wide (over 250 m) due to the area's flat topography. As a result of the new proposed roadway within this area, the required structure sizing not only needs to provide the necessary flow capacity, but has also been sized to minimize any impacts to the 100-year floodplain. Due to the wide and shallow floodplain, the preliminary size determined for Structure S2 within the Segment 1 ROW resulted in a wide and shallow structure (approx. 15 m x 0.9 m), with the sizing minimizing the impacts of the new ROW within the 100-year floodplain. The difference in the sizing of S1 further upstream versus S2, which both convey the same peak flows, is due to the fact that Rice Road is an existing roadway, and therefore the proposed adjustments to the road profile do result in significant changes to the grades within the floodplain, and therefore the size of the S2 structure has been primarily based upon MTO design flow requirements, instead of a new roadway acting as a flow obstruction within a wide shallow floodplain as per the S2 crossing..

In addition to the regulatory design criteria for the structures, an assessment of the potential impacts to the local flood hazards within Segment 1 has been completed by comparing the water depth and the computed water surface elevation (WSE) surrounding the Segment 1 ROW for both existing and proposed roadway conditions. The proposed hydraulic conditions results are documented in Table 4-10, with a comparison to existing conditions in Table 4-11.

Table 4-10: Proposed Conditions Simulated Water Surface Elevation and Water Depth – Segment 1

RIVER	CROSS-SECTION ID	DATA TYPE	SIMULATION RESULTS					
			2-YR	5-YR	10-YR	25-YR	50-YR	100-YR
Centre Tributary	203	Depth (m)	0.22	0.25	0.27	0.30	0.34	0.39
		WSE (m)	181.96	181.99	182.01	182.04	182.08	182.13
	167	Depth (m)	0.29	0.31	0.33	0.35	0.39	0.43
		WSE (m)	181.96	181.98	182.00	182.02	182.06	182.10
South Tributary	121	Depth (m)	0.45	0.49	0.52	0.55	0.59	0.62
		WSE (m)	181.99	182.03	182.06	182.09	182.13	182.16
	90	Depth (m)	0.47	0.50	0.53	0.55	0.58	0.60
		WSE (m)	181.97	182.00	182.03	182.05	182.08	182.10

Table 4-11: Comparison of Proposed vs. Existing Conditions – WSE and Floodplain

RIVER	REFERENCE CROSS-SECTION ID		DATA TYPE	SIMULATION RESULTS					
	EX	PROP		2-YR	5-YR	10-YR	25-YR	50-YR	100-YR
Center Tributary	203	203	Depth (m)	+0.05	+0.05	+0.07	+0.08	+0.11	+0.14
			WSE (m)	-0.11	-0.11	-0.09	-0.08	-0.05	-0.02
	185	167	Depth (m)	+0.25	+0.25	+0.26	+0.26	+0.28	+0.29
			WSE (m)	-0.06	-0.06	-0.05	-0.05	-0.03	-0.02
South Tributary	118	121	Depth (m)	+0.08	+0.08	+0.08	+0.08	+0.09	+0.09
			WSE (m)	+0.02	+0.02	+0.02	+0.02	+0.03	+0.03
	100	90	Depth (m)	+0.27	+0.25	+0.25	+0.25	+0.24	+0.24
			WSE (m)	+0.01	-0.01	-0.01	-0.01	-0.02	-0.02

Based upon the comparison between the computed WSEs and resulting water depths under both proposed and existing conditions, the results demonstrate an increase in the operational depth (all less than 0.30 m increase) which is a result of some assumed minor grading changes within the watercourses in order to implement the proposed culvert crossings underneath the proposed roadway. The resulting change in the computed WSEs demonstrates relatively minor differences between existing and proposed conditions, with the Center Tributary demonstrating reduced WSEs by -0.02 m to -0.11 m during the range of events, and the South Tributary demonstrating changes between -0.02 m up to +0.03 m. This demonstrates that with the preliminary structure sizing determined through this assessment, the proposed roadway could be designed to minimize the impacts on the regulated floodplain within Segment 1.

In addition to the localized review of results surrounding the Segment 1 ROW, an assessment of the potential impacts to the overall flood hazards has been completed by comparing the computed water surface elevation (WSE) and top width of the floodplain for the 100-year storm between existing and proposed conditions upstream of Cataract Road (i.e., areas of change). The comparative summary is documented in Table 4-12 and the proposed floodplain limits are shown on Figure 4-6.

Table 4-12: Comparison of Proposed vs. Existing Conditions – 100-year WSE and Floodplain Width

RIVER	CHANGE IN 100-YEAR WSE (M)			CHANGE IN 100-YEAR FLOODPLAIN WIDTH (M)		
	MAX	MIN	AVERAGE	MAX	MIN	AVERAGE
North Trib	0.00	-0.54	-0.06	0.1	-44.6	-5.02
South Trib	0.11	-0.36	0.00	40.2	-91.2	-1.69
Center Trib	0.04	-0.04	0.01	6.1	-0.9	0.49
Total Model	0.11	-0.54	-0.01	40.2	-91.2	-2.93

The results demonstrated within Table 4-12 show that under proposed conditions, across the three (3) branches upstream of Cataract Road there is a maximum WSE increase of +0.11 m, a decrease of -0.54 m which equates to an average WSE change of -0.01 m (+/-). This in turn relates to localized changes in the floodplain width, ranging from -91.2 m up to +40.2 m, with an average change of approximately -2.93 m (+/-). These changes are largely localized surrounding the watercourse crossings, and when plotted demonstrate marginal differences to the existing conditions floodplain (ref. Figure 4-6). Any changes to the local floodplain as a result of the final detailed design will need to be reviewed in consultation with the NPCA and any potential landowners who might be impacted by the change.

It should be noted that the current assessment has focused only on the testing of the two (2) structures which would be required along the two (2) regulated watercourses, and has not incorporated any additional culvert crossings which may be required as part of the wetland conveyance / connectivity. Therefore, the floodplain impacts may change and/or be optimized as part of future studies for detailed design.

Through the results of this hydraulic analysis, it has been determined that the watercourses located within Segment 1 are interconnected and operate as a single floodplain unit. To better understand the way the watercourse systems function, it is recommended that at the detailed design stage, a 2D modelling exercise is undertaken to allow the watercourses to freely spill to better understand the flow paths and associated flood risks within the PSW area of Segment 1. Through this exercise, the details related to the localized grading needs can be incorporated and the structure sizing along Segment 1 can be optimized / verified to identify the most beneficial combination of structure sizing / number of crossings to minimize the flood risks and maintain hydrologic connections throughout the PSW within Segment 1.

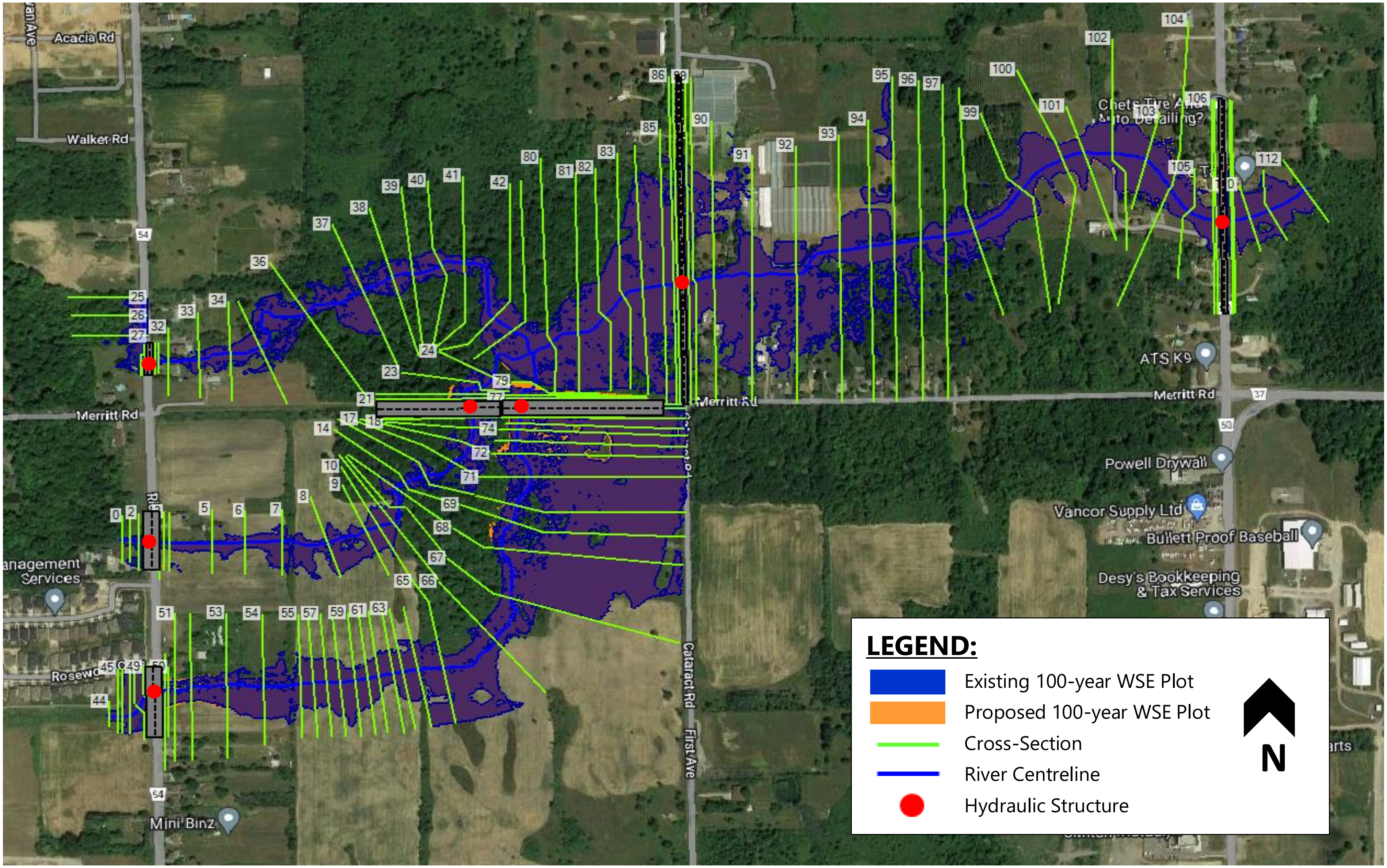


Figure 4-6: Proposed Floodplain 100-year Hydraulic Model Results – Comparison to Existing Floodplain

5 WETLAND ASSESSMENT

A Wetland Water Balance Risk Assessment has been conducted for the PSW located within the vicinity of the proposed Merritt Road Segment 1, as requested by the NPCA through previous project discussions. The following provides an overview of the methodology and results of the hydrologic component of the assessment and should be read in conjunction with the Environmental Impact Study (EIS) completed under separate cover (ref. WSP, June 16, 2023).

5.1 METHODOLOGY

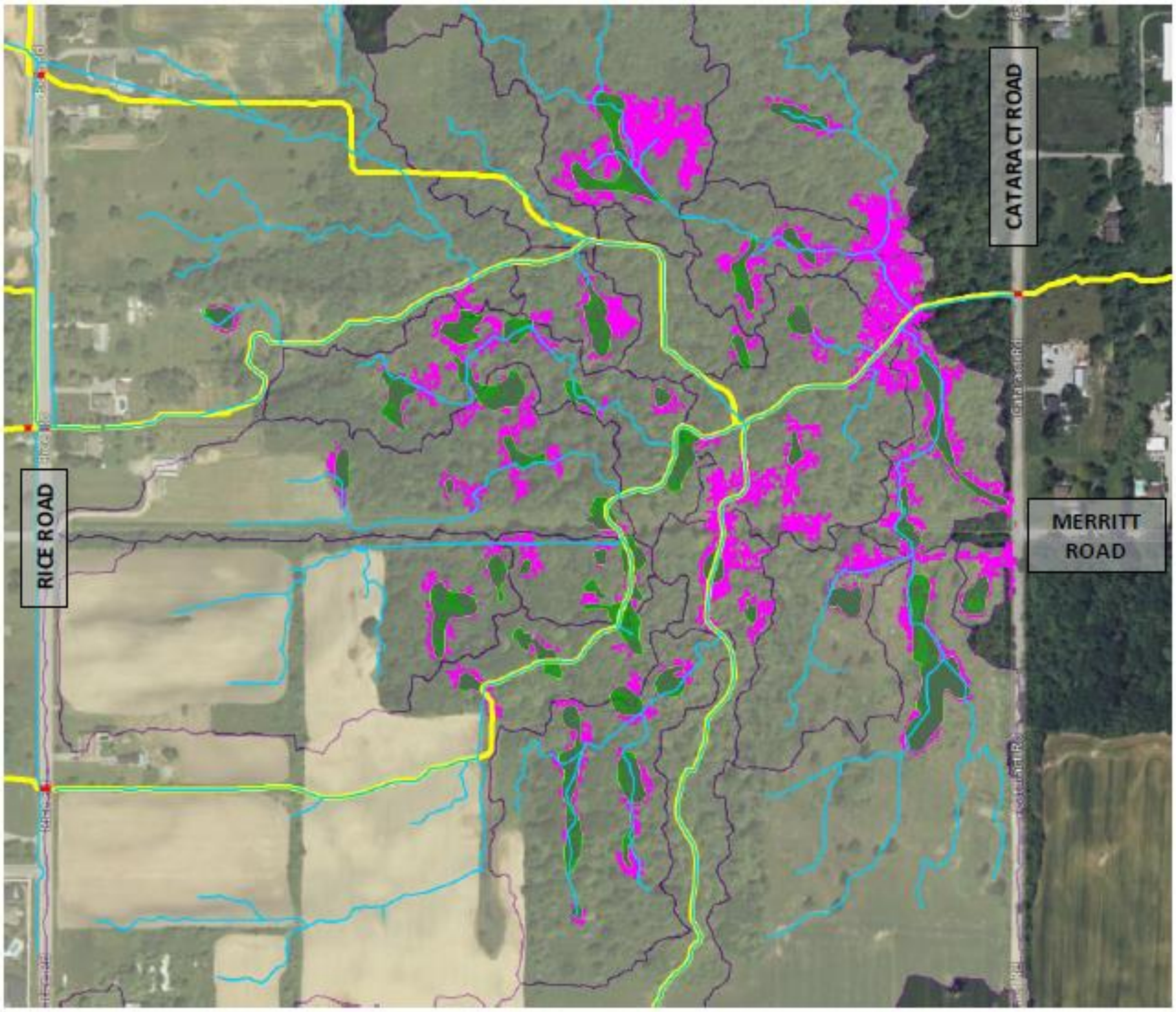
An estimation of the magnitude of hydrological change for the wetlands in proximity of Segment 1. As outlined in the May 10, 2022 correspondence with the Region, and approved by NPCA, the hydrological change is required for the Wetland Water Balance Risk Evaluation (TRCA, November 2017). The Wetland Water Balance Risk Evaluation (TRCA, November 2017) has identified several factors will influence the magnitude of hydrological change which include the following:

- Wetland feature limits
- Extent and size of pre-development catchments
- Total development area of catchment
- Area of the wetland catchment owned by the proponent
- Percent of impervious cover planned within the proponent's holdings
- Proposed extent and size of the post-development catchment
- Anticipated magnitude and duration of water taking
- Location and extent of any locally significant recharge areas

As previously communicated to the NPCA (ref. Talpur-NPCA, September 22, 2022), in order to generate a baseline representation of the hydrologic storage capacity of the wetland features within Segment 1, a review of both the NPCA's Contemporary Mapping of Watercourses and the DTM (2020) has been completed, which identified several pockets / depressions of ponding areas throughout the PSW.

Using the Storage Creator tool in PCSWMM, the 2015 Southwestern Ontario Orthophotography Project (SWOOP), DEM has been processed to identify the storage capacities based upon the local topography available in the DEM, located within the PSW. The resulting boundaries have been determined through an iterative analysis to produce storage area delineations which are consistent with the ponded area limits identified in the NPCA mapping and/or the watercourse mapping (to the best extent possible). The results of this mapping analysis are represented in Figure 5-1.

The resulting storage areas identified from the DEM have been processed by the tools in PCSWMM to generate stage-storage curves for each of the individual wetland pockets. As some of these smaller wetland pockets are hydrologically connected (flow paths are demonstrated in Figure 5-2) and fall within consistent subcatchments / drainage areas, these features have been lumped into single storage units (on a case-by-case basis) to more appropriately represent the combined storages and simplify the modelling requirements.



NOTES / LEGEND:

- Green Polygon: Wetlands based upon the Contemporary Watercourse Mapping and the DTM-2020 Polylines from the NPCA
- Pink Polygon: Storage Polygons created in PCSWMM using SWOOP2015 DEM
- Purple Polygon: Subcatchments delineated in PCSWMM using SWOOP2015 DEM
- Yellow Line: Contemporary Watercourse from the NPCA
- Blue Line: Flow Path for the subcatchments delineated by PCSWMM using SWOOP2015 DEM

Figure 5-1: Existing Conditions Subcatchment Plan and Wetland Storage Analysis (DEM)

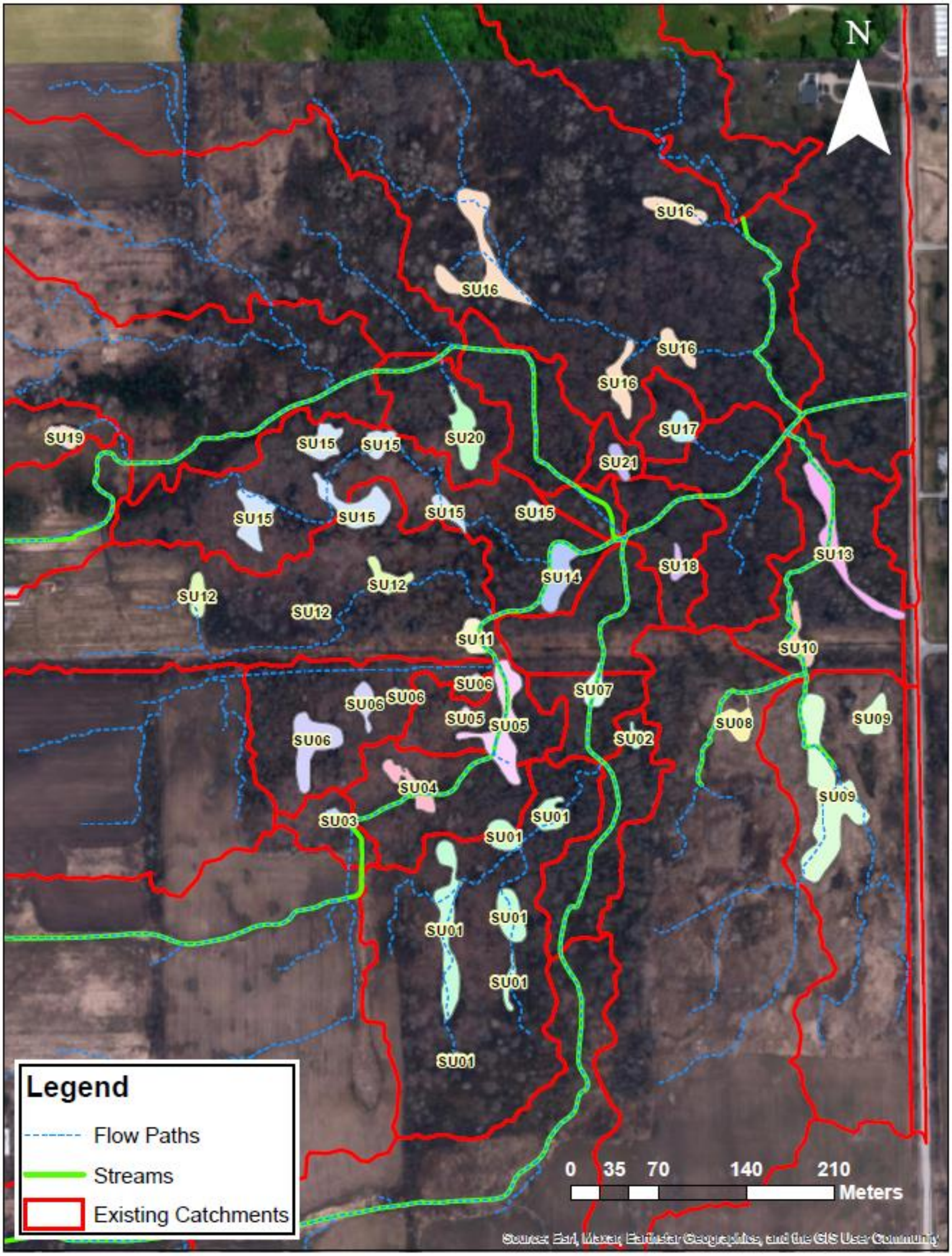


Figure 5-2: Wetland Group Identification Plan

Although the calculated storage units (as per DEM) can generally estimate the storage capacity of the wetland units, the DEM is unlikely to be able to accurately represent the storage volumes for the depressional areas below the water surface; this is likely only to impact the larger ponded areas which may have more standing water, but it's important to note that the conditions of the site at the time of the SWOOP data collection is unknown. Bathymetric survey was initially proposed to be completed within the unopened road allowance; however, given the time of the study the vegetation coverage / foliage was found to be too dense to accurately capture the necessary data. Therefore, it is recommended that the future detailed design complete more detailed topographic and bathymetric survey within this area to support the analysis and future design.

The above DEM analysis for determining the storage units within the wetland pockets as well as the contributing catchment areas to each subsystem within the PSW system has formed the basis for the hydrologic analysis component of the wetland impact assessment. It should be noted that the current proposed works within the road ROW would not result in any additional water takings, and the Preliminary Hydrogeological Investigation completed within Segment 1 found that groundwater is not expected to be a substantial source of water in terms of quantity to support the PSW (ref. WSP, September 2022). Therefore, neither water takings nor significant recharge areas are considered as part of this assessment.

The following subsections provide further information as to the general hydrological characterization of the wetland features and the results of the preliminary wetland risk assessment.

5.2 WETLAND RISK RANKING

5.2.1 EXISTING HYDROLOGIC CONDITIONS

The PSW located within Segment 1 is primarily a surface water fed system and has a total of three (3) watercourses contributing to the system, generally draining from west to east across the study area. Two (2) of the watercourses cross Rice Road, south of Merritt Road, and drain north crossing the unopened road allowance of Segment 1, and the third watercourse contributes to the PSW north of Merritt Road. All three (3) watercourses combine to form the upstream extent of the main branch of the Singer's Drain, prior to crossing at Cataract Road.

As noted in the preceding section, the PSW system consists of a several localized wetland pockets, some of which are located on-line within the watercourse features (i.e., receive drainage from the contributing road ROW), whereas others are more isolated and would receive local drainage. These wetland pockets have been assessed as per the methodology outlined previously, which utilized the DEM to interpret the representative storage volume and surface area of the individual features, which have then been grouped into localized systems where appropriate. A summary of these wetland groupings summarizing the number of wetland pockets, whether the wetland groupings are on-line features, whether the wetlands groupings are located within the proposed Segment 1 ROW, and the associated storage volume and drainage characteristics is provided in Table 5-1.

Table 5-1: Associated Storage Volume and Drainage Characteristics of the Wetlands Under the Existing Condition

WETLAND GROUP / TYPE			HYDROLOGIC REPRESENTATION OF WETLAND GROUP			EXISTING HYDROLOGIC DRAINAGE CHARACTERISTICS		
WETLAND GROUP REFERENCE ID#	NUMBER OF WETLAND POCKETS IN GROUP (REF. NPCA MAPPING)	IS THE WETLAND GROUP ON-LINE? (WATERCOURSE)	IS THE WETLAND STORAGE LOCATED WITHIN THE SEGMENT 1 ROW?	SURFACE AREA (M^2)	APPROX. MAXIMUM VOLUME (M^3)	CUMULATIVE TOTAL DRAINAGE AREA (HA)	TOTAL IMPERVIOUS DRAINAGE AREA (HA)	AVERAGE IMPERVIOUSNESS (%)
SU01	6	No	No	3552	6098	3.5	0.2	6%
SU02	1	No	No	136	88	0.8	0.0	5%
SU03	1	Yes	No	232	151	18.8	4.1	22%
SU04	1	Yes	No	636	333	19.8	4.2	21%
SU05	2	Yes	Yes	1712	1180	20.5	4.2	21%
SU06	4	No	No	2376	5160	1.4	0.1	9%
SU07	1	Yes	Yes	408	150	89.1	31.9	36%
SU08	1	Yes	No	636	561	6.3	0.3	5%
SU09	2	Yes	No	3716	1240	3.2	0.2	5%
SU10	1	Yes	Yes	516	489	9.5	0.5	5%
SU11	1	Yes	Yes	520	343	26.8	5.4	20%
SU12	3	No	No	884	2209	4.0	0.4	11%
SU13	1	Yes	No	1420	1216	11.2	0.6	5%
SU14	1	Yes	No	848	417	33.5	6.0	18%
SU15	6	No	No	3412	5291	2.7	0.2	6%
SU16	4	No	No	24248	67622	19.7	2.9	15%
SU17	1	No	No	420	234	0.3	0.0	5%
SU18	1	No	No	192	48	0.6	0.0	5%
SU19	1	No	No	344	182	0.8	0.2	25%
SU20	1	No	No	884	690	0.7	0.0	5%
SU21	1	No	No	204	173	0.2	0.0	5%
TOTAL SYSTEM	**41**	-	-	**47296**	**93875**	**292.8**	**68.5**	**23%**

As noted in Table 5-1, a total of twenty-one (21) wetland groups have been identified, which represent a total of forty-one (41) individual wetland pockets. Of the wetland groups, ten (10) of them are situated on-line within the watercourses and would therefore receive drainage from either the Rice Road ROW (Segment 4) or the Merritt Road ROW (Segment 1). The other eleven (11) groups are situated off-line and are anticipated to receive more localized drainage as opposed to drainage from upstream contributing drainage systems. Of the wetland groups, four (4) are physically located within the Segment 1 ROW, which is anticipated to be the greatest area of change due to the proposed roadway. It should be noted that this is based upon the proposed ROW limits only and does not account for any anticipated grading changes or temporary construction activities which may occur beyond the noted limits.

As for the hydrologic representation of the wetland systems, the total surface area of the various wetland groupings is approximately 47,300 m^2 (+/-), which generally provides an estimated total storage volume of approximately 94,000 m^3 (+/-). The drainage areas to each wetland group range from 0.17 ha (i.e., off-line group), up to 89.11 ha (on-line group), and have an average imperviousness ranging from 5% up to 36%. However, on average, at the downstream extent of the total PSW system (i.e., upstream of Cataract Road), the total drainage area is 292.8 ha, with an average existing imperviousness of 23%. This will formulate the baseline conditions to support the risk assessment and subsequent analysis.

5.2.2 PROPOSED CONDITIONS

As described through preceding sections, the proposed works consist of roadway widening along Rice Road (Segment 4) as well as the construction of a new roadway for Merritt Road which will connect between Rice Road and Cataract Road (Segment 1), both of which will be rurally serviced via a hybrid rural cross-section. Other works are proposed within the other portions of Merritt Road (Segment 2 & 3); however, these are located east of the PSW and are not within the contributing drainage areas to the PSW units.

The proposed changes include additional impervious areas associated with the roadway widening / new construction and the addition of the multi-use path. As Segment 4 and Segment 1 fall within the contributing drainage areas to the PSW system, it is expected that these proposed designs would result in some level of impacts to the receiving PSW. As noted in Section 3.2, it is anticipated that the future detailed design of the roadway would aim to maintain existing drainage areas to each of the respective outlets to the extent possible through ditch grading / direction. This will be an important consideration for the protection of the receiving systems to ensure that impacts caused by both increased imperviousness as well as redirected drainage areas are minimized.

A review of these proposed changes has been conducted and a summary has been prepared for each of the wetland groups to identify any changes with respect to both the wetland footprint and associated storage, as well as the hydrologic changes for the contributing drainage areas. This summary is presented in Table 5-2. The results of this analysis have also been compared back to existing conditions, to identify the respective percentage changes to determine the associated risk level based upon the following for both total drainage area and imperviousness (ref. TRCA, 2017):

- High = > 25% Change
- Medium = 10 – 25% Change
- Low = < 10% Change

The results of this risk analysis are demonstrated in Table 5-3.

Table 5-2: Associated Storage Volume and Drainage Characteristics of the Wetlands Under the Proposed Condition

WETLAND GROUP / TYPE			HYDROLOGIC REPRESENTATION OF WETLAND GROUP			PROPOSED HYDROLOGIC DRAINAGE CHARACTERISTICS		
WETLAND GROUP REFERENCE ID#	NUMBER OF WETLAND POCKETS IN GROUP (REF. NPCA MAPPING)	IS THE WETLAND GROUP ON-LINE? (WATERCOURSE)	IS THE WETLAND STORAGE LOCATED WITHIN THE SEGMENT 1 ROW?	SURFACE AREA (M^2)	APPROX. MAXIMUM VOLUME (M^3)	CUMULATIVE TOTAL DRAINAGE AREA (HA)	TOTAL IMPERVIOUS DRAINAGE AREA (HA)	AVERAGE IMPERVIOUSNESS (%)
SU01	6	No	No	3552	6098	3.5	0.2	6%
SU02	1	No	No	136	88	0.8	0.0	5%
SU03	1	Yes	No	232	151	18.9	4.3	23%
SU04	1	Yes	No	636	333	19.8	4.4	22%
SU05	2	Yes	Yes	1561	1076	21.6	4.5	21%
SU06	4	No	No	2376	5160	1.1	0.1	9%
SU07	1	Yes	Yes	369	136	89.5	32.2	36%
SU08	1	Yes	No	636	561	6.1	0.3	5%
SU09	2	Yes	No	3716	1240	3.2	0.2	5%
SU10	1	Yes	Yes	184	175	9.7	0.7	7%
SU11	1	Yes	Yes	342	225	27.6	6.1	22%
SU12	3	No	No	884	2209	3.2	0.3	11%
SU13	1	Yes	No	1420	1216	11.0	0.7	7%
SU14	1	Yes	No	848	417	33.4	6.6	20%
SU15	6	No	No	3412	5291	2.7	0.2	6%
SU16	4	No	No	24248	67622	19.6	2.9	15%
SU17	1	No	No	420	234	0.3	0.0	5%
SU18	1	No	No	192	48	0.6	0.0	5%
SU19	1	No	No	344	182	0.8	0.2	25%
SU20	1	No	No	884	690	0.7	0.0	5%
SU21	1	No	No	204	173	0.2	0.0	5%
TOTAL SYSTEM	**41**	-	-	**46597**	**93325**	**292.8**	**69.6**	**24%**

Table 5-3: Summary of the Wetland Risk Analysis Results

WETLAND GROUP / TYPE				HYDROLOGIC REPRESENTATION OF WETLAND GROUP				HYDROLOGIC DRAINAGE CHARACTERISTICS				HYDROLOGIC RISK EVALUATION		
WETLAND GROUP REFERENCE ID#	NUMBER OF WETLAND POCKETS IN GROUP (REF. NPCA MAPPING)	IS THE WETLAND GROUP ON-LINE? (WATERCOURSE)	IS THE WETLAND STORAGE LOCATED WITHIN THE SEGMENT 1 ROW?	CHANGE IN SURFACE AREA (M^2)	CHANGE IN SURFACE AREA (%)	CHANGE IN MAX VOLUME (M^3)	CHANGE IN MAX VOLUME (%)	CHANGE IN DRAINAGE AREA (HA)	CHANGE IN DRAINAGE AREA (%)	CHANGE IN IMPERVIOUS DRAINAGE AREA (HA)	CHANGE IN IMPERVIOUS COVER (%) (= S SCORE)	IMPERVIOUS COVER SCORE	INCREASE OR DECREASE IN CATCHMENT SIZE	RESULTING IMPACT SCORE (WR)
SU01	6	No	No	0	0%	0	0%	0	0%	0	0%	Low	Low	**Low**
SU02	1	No	No	0	0%	0	0%	0	0%	0	0%	Low	Low	**Low**
SU03	1	Yes	No	0	0%	0	0%	0.08	0%	0.17	4%	Low	Low	**Low**
SU04	1	Yes	No	0	0%	0	0%	0.01	0%	0.17	4%	Low	Low	**Low**
SU05	2	Yes	Yes	-150.8	-9%	-104	-9%	1.13	6%	0.28	7%	Low	Low	**Low**
SU06	4	No	No	0	0%	0	0%	-0.27	**-20%**	-0.03	**-20%**	Low	Medium	**Medium**
SU07	1	Yes	Yes	-38.6	-9%	-14	-9%	0.34	0%	0.29	1%	Low	Low	**Low**
SU08	1	Yes	No	0	0%	0	0%	-0.28	-4%	0	0%	Low	Low	**Low**
SU09	2	Yes	No	0	0%	0	0%	0	0%	0	0%	Low	Low	**Low**
SU10	1	Yes	Yes	-331.7	**-64%**	-314	**-64%**	0.15	2%	0.18	**36%**	High	Low	**High**
SU11	1	Yes	Yes	-178.3	**-34%**	-118	**-34%**	0.82	3%	0.66	**12%**	Medium	Low	**Medium**
SU12	3	No	No	0	0%	0	0%	-0.85	**-21%**	-0.09	**-21%**	Low	Medium	**Medium**
SU13	1	Yes	No	0	0%	0	0%	-0.2	-2%	0.16	**28%**	High	Low	**High**
SU14	1	Yes	No	0	0%	0	0%	-0.03	0%	0.57	9.9%	Low	Low	**Low**
SU15	6	No	No	0	0%	0	0%	0	0%	0	0%	Low	Low	**Low**
SU16	4	No	No	0	0%	0	0%	0	0%	0	0%	Low	Low	**Low**
SU17	1	No	No	0	0%	0	0%	0	0%	0	0%	Low	Low	**Low**
SU18	1	No	No	0	0%	0	0%	0	0%	0	0%	Low	Low	**Low**
SU19	1	No	No	0	0%	0	0%	0	0%	0	0%	Low	Low	**Low**
SU20	1	No	No	0	0%	0	0%	0	0%	0	0%	Low	Low	**Low**
SU21	1	No	No	0	0%	0	0%	0	0%	0	0%	Low	Low	**Low**
TOTAL SYSTEM	**41**	-	-	**-699**	**-1.50%**	**-550**	**-0.60%**	**-0.02**	**-0.01%**	**1.15**	**2%**	**Low**	**Low**	**Low**

Note: Yellow Cells = Change < +/- 10%, Red Cells = Change > +/- 25%

Based upon the results demonstrated in Table 5-2, the four (4) wetland groups that undergo a reduction in surface area and associated storage volume include SU05, SU07, SU10 and SU11, which are all located within the proposed ROW of Segment 1. Based upon the ROW limits, these four (4) wetlands would reduce in size by approximately 9% up to 64%, due to the proposed roadway being implemented (notwithstanding any additional works beyond the ROW limits).

In terms of hydrologic changes, a total of eleven (11) wetland groups would experience a change in either total contributing drainage area and/or imperviousness. The majority of these groups are considered on-line systems which receive drainage through the watercourses which both Segment 1 and Segment 4 are contributing to. Out of the eleven (11) wetland groups that would have a hydrologic change, eight (8) would have either an increase in contributing drainage area/imperviousness, and three (3) would have a decrease. Based upon these impacts, the risk assignment in terms of hydrologic change was found to be low (i.e., less than 10%) for the majority of the wetland groups, with the exception of SU10 and SU13, SU6, SU11, and SU12. Wetland groups SU10 and SU13 had a high-risk score associated with their impervious cover, and wetland groups SU6, SU11, and SU12 had a medium risk score associated with either impervious cover or change in contributing catchment sizes. On a system-wide basis, the total PSW system would experience a marginal 0.01% change in total drainage area, and less than a 2% change in total imperviousness as a result of the proposed roadway design.

The results of the magnitude of hydrologic change have been reviewed in conjunction with the ecological assessment for the wetland system, consistent with the Wetland Risk Evaluation Decision Tree (ref. Figure 5-3).

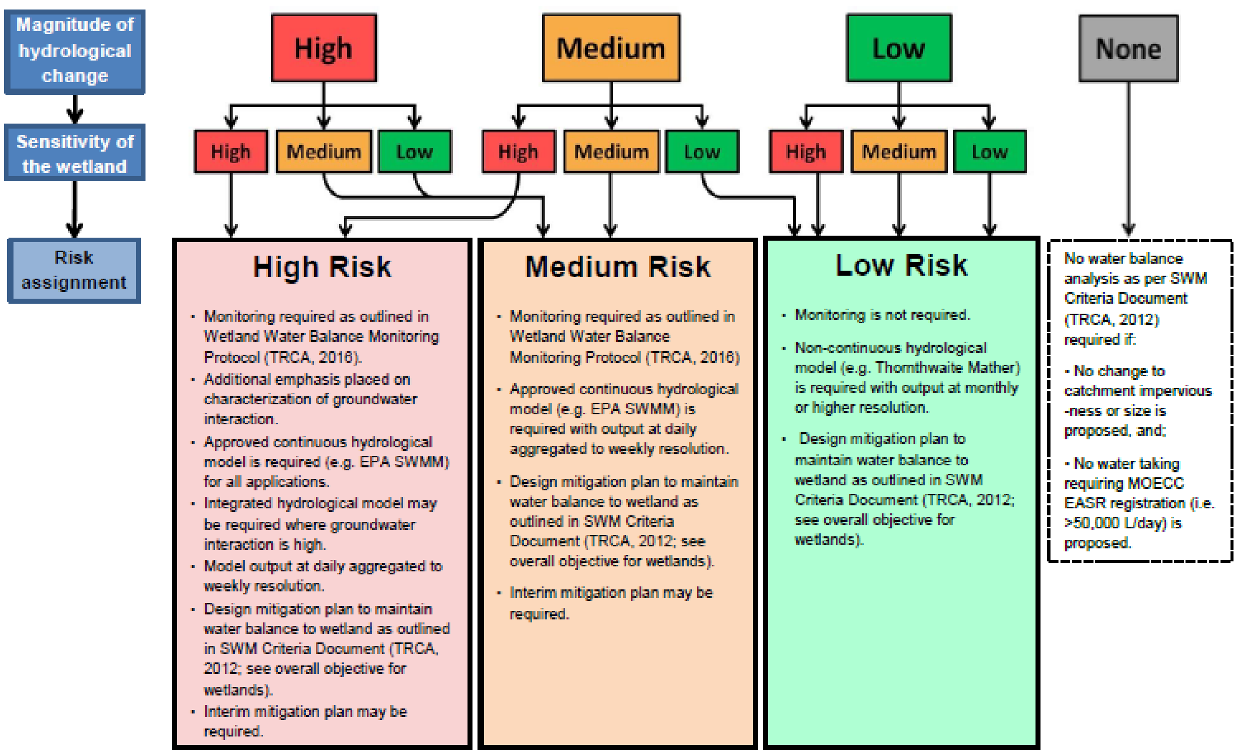


Figure 5-3: Wetland Risk Evaluation Decision Tree (ref. TRCA, 2017)

Further details with respect to the ecological assessment can be found within the EIS (ref. WSP, 2023), which evaluated the wetland groups (and overall system) on the basis of sensitivity of the vegetation community, the flora and fauna species, hydrologically sensitive species, and hydrological classification. The results of this ecological assessment found that in general, the sensitivity of the vegetation community was found to be Low. whereas the sensitivity of all other parameters was found to be High, ultimately resulting in a High Ecological Sensitivity for each of the wetland groups, and for the total PSW system as a whole. The evaluation of the hydrological and ecological integrity of a wetland, as determined using the Magnitude of Hydrological Change and Sensitivity of the Wetland, has been combined to assign risk, as shown in Table 5-4.

Table 5-4: Magnitude of Hydrological Change and Sensitivity of the Wetlands

WETLAND GROUP REFERENCE ID#	MAGNITUDE OF HYDROLOGICAL CHANGE[2]	SENSITIVITY OF THE WETLAND	RISK ASSIGNMENT
SU01	Low	High	**Low**
SU02	Low	High	**Low**
SU03	Low	High	**Low**
SU04	Low	High	**Low**
SU05	Low	High	**Low**
SU06	**Medium**	**High**	**High**
SU07	Low	High	**Low**
SU08	Low	High	**Low**
SU09	Low	High	**Low**
SU10	**High**	**High**	**High**
SU11	**Medium**	**High**	**High**
SU12	**Medium**	**High**	**High**
SU13	**High**	**High**	**High**
SU14	Low	High	**Low**
SU15	Low	High	**Low**
SU16	Low	High	**Low**
SU17	Low	High	**Low**
SU18	Low	High	**Low**
SU19	Low	High	**Low**
SU20	Low	High	**Low**
SU21	Low	High	**Low**
TOTAL SYSTEM	**Low**	**High**	**Low**

As indicated in Table 5-4, based upon the results of the risk assignment, the vast majority of the wetland groups have been identified as a Low-Risk assignment, whereas five (5) wetland groups would result in a High-Risk assignment. These five (5) wetland groups are: SU06, SU10, SU11, SU12 and SU13. These are all located within or directly adjacent to the road ROW. On average across the total PSW system, the magnitude of hydrological change is considered Low Risk, associated with the proposed roadway works. Notwithstanding, seeing as localized sections of the PSW system would experience greater levels of risk based upon local changes, the recommendations of the TRCA wetland impact assessment are to be carried forward. To support the analysis and characterization of potential impacts, the PCSWMM model developed to support the SWM strategy and associated hydraulics component of the project has been used to complete a scoped continuous simulation, in order to further characterize the potential impacts of the hydrologic changes to the wetland system. This is described in further detail in the following section.

5.3 CONTINUOUS SIMULATION MODELLING

5.3.1 BASE MODEL SET-UP

The PCSWMM model which was developed as part of the previous study phases to support both SWM strategy development and the associated hydraulic / floodplain assessment described in preceding sections (ref. Section 3) has been refined for use as part of a continuous simulation modelling exercise focused upon the PSW system within Segment 1. The model used as the existing conditions baseline for this assessment has included the wetland storage nodes developed as described in Section 5.1 (through DEM analysis), as well as the existing culverts and roadway drainage elements / connections which are found under existing conditions.

For the proposed conditions model, the subcatchment imperviousness has been adjusted based upon the proposed roadway design (ref. Section 3.2), and the culverts / roadway drainage elements have been adjusted to represent the preliminary proposed design. In addition to these changes, the storage nodes representing the four (4) wetland groups which would be physically impacted by the construction of the proposed roadway within Segment 1 have been adjusted to reflect this loss of footprint and associated volume (ref. Table 5-2). It should be noted that this area/volume loss is considered high-level / conceptual, as it does not account for any impacts to the systems beyond the road ROW, as details related to grading, staging, etc. are not known at this time.

It should be noted that the representation of the wetland systems within the modelling is based upon the interpretation of the ground surface from the available DEM data. Through analysis of the drainage patterns

5.3.1.1 CLIMATE DATA

Precipitation

In order to complete a continuous simulation analysis, a long-term precipitation dataset is required. Through review of the Niagara Region's Weather Information Systems database, a variety of monitoring stations are available. The continuous precipitation gauge located closest to the study area was found to be the Welland Wastewater Treatment Plant (WWTP) Climate Station, which had data available from 1998-2020. The next closest climate station was found to be the Humberstone Landfill Climate Station, which was used to populate precipitation data for 2021 and 2022. Any gaps in the long-term data set have been filled through the review of other gauge data located within the Region and/or through review of the local Environment Canada gauges to produce a fulsome dataset. The resulting precipitation input file provides a continuous simulation time series of approximately 24 years (+/-).

The resulting precipitation totals for the continuous simulation data set have been compared on a monthly and an average annual basis in comparison to the Climate Normals (1981-2010) produced by Environment Canada at the Niagara Falls NPCSH Climate Station; the results of this comparison are in Table 5-5.

Table 5-5: Comparison of Annual Precipitation Totals

AVERAGE MONTH	NIAGARA FALLS EC GAUGE CLIMATE NORMALS (1981-2010)	M&R CONTINUOUS SIMULATION DATA SET (1998-2022)
January	75.6	38.95
February	61.8	39.25
March	61.7	51.14
April	72.0	81.80

AVERAGE MONTH	NIAGARA FALLS EC GAUGE CLIMATE NORMALS (1981-2010)	M&R CONTINUOUS SIMULATION DATA SET (1998-2022)
May	86.8	66.18
June	80.9	70.80
July	78.9	84.07
August	79.2	75.80
September	98.2	89.25
October	79.7	79.73
November	91.8	68.25
December	81.1	68.08
Average Annual (mm)	947.5	813.3

The trends of the continuous simulation dataset show a generally comparable precipitation depth during the spring to fall, but indicates larger discrepancies during the winter months; this may be due to the limitations of accurately measuring snowfall as part of the precipitation summary. Nonetheless, an average annual precipitation amount of over 800 mm is generally consistent with the climate trends across southern Ontario and is considered adequate to support the current assessment.

EVAPORATION

Evaporation data is required in order to reasonably estimate the moisture loss from soils during warm weather months for the inter-storm event period. A number of different options are available within PCSWMM accordingly:

- A complete time series can be specified:
  - Historic daily pan evaporation data are available from a limited number of sites in Ontario, however no data available for 1997 onwards (Environment Canada stopped collecting these data at that point)
  - Surrogate methods to gap fill beyond this point such as “average day” for previous period of record, or correlation with other parameters
  - Evaporation generally assumed to be zero for winter period (December-March inclusive)
- Monthly averages or constant values can also be assumed
- Alternatively, evaporation can be calculated using an empirical equation (Hargreaves Method) which correlates evaporation with air temperature data and solar radiation as a function of latitude and time of year.

Given the purpose of the current study, the application of monthly averages has been considered a reasonable approach. Average daily lake evaporation Climate Normals (1981 to 2010) is available per month for Environment Canada at select locations. Unfortunately, the Environment Canada Gauges located within the Niagara Region do not have daily lake evaporation data as part of the Climate Normals statistics, therefore the Environment Canada station located at the Royal Botanical Gardens (Climate ID 6153300) has been used for the current assessment as a surrogate approach. These values are summarized in Table 5-6.

Table 5-6: Evaporation Averages (RBG Station) for Continuous Simulation

MONTH	AVERAGE DAILY LAKE EVAPORATION (MM)
January	0
February	0
March	0
April	2.3

MONTH	AVERAGE DAILY LAKE EVAPORATION (MM)
May	3.4
June	4.2
July	4.2
August	3.3
September	1.8
October	0.7
November	0
December	0

These values are considered reasonable for the current simulation, as it is focused upon an existing versus proposed conditions assessment, rather than a diagnostic exercise for the wetland areas. At the detailed design stage, a continuous temperature dataset may be appropriate to develop from local monitoring data and be used as part of future analyses.

SNOWMELT

For a "true" continuous simulation, snowmelt processes should be simulated, which necessitates a number of time series inputs (air temperature and wind speed), as well as snowpack accumulation parameters (including the impact of snowplowing activities). Given the data requirements in this case, and the higher-level focus of the current study, snowmelt processes have been omitted. Given that the same continuous simulation modelling approach is to be applied for both existing and proposed conditions, the modelling will still permit a reasonable assessment of relative changes in the water balance and the resulting characterization of potential impacts.

5.3.2 CONTINUOUS SIMULATION RESULTS

The PCSWMM model for both existing and proposed uncontrolled conditions has been simulated for the period of approximately 24 years based upon the local climate data provided by the NPCA, which has been processed as noted above. The modelling results have been reviewed to assess the potential impacts to each of the wetland groups on the basis of absolute and relative differences for the following parameters:

- Total Inflow Volume (m^3)
- Average Operation Depth (m)
- Average Operating Volume (m^3)

The above parameters have been selected to demonstrate the average changes with respect to the total inflow volume each of the wetland groups are receiving under uncontrolled proposed conditions, as well as how this inflow may impact the operating depth / volume within each of the units. The results from the more than 24-year continuous simulation for both existing and proposed uncontrolled conditions are summarized in Table 5-7, Table 5-8, and Table 5-9; with green cells representing changes less than +/- 10%, yellow cells representing changes between +/- 10% to +/- 25%, and red cells indicating changes over +/-25%.

Table 5-7: Comparison of the Total Inflow Volume of the Wetlands Between the Existing and Proposed Uncontrolled Continuous Simulations

TOTAL INFLOW (M³):	SU01	SU02	SU03	SU04	SU05	SU06	SU07	SU08	SU09	SU10	SU11	SU12	SU13	SU14	SU15	SU16	SU17	SU18	SU19	SU20	SU21
Existing Conditions	549600	82980	387800	284600	348200	63540	3828000	65330	42640	21080	130800	84270	796800	295700	168700	601800	3894	8607	29650	56920	39640
Proposed Uncontrolled	1005000	88680	436400	334700	431600	56410	3460000	62470	47950	67400	258800	70570	769600	338000	177700	638900	3894	8965	29650	65240	39260
Difference (m³)	455400	5700	48600	50100	83400	-7130	-368000	-2860	5310	46320	128000	-13700	-27200	42300	9000	37100	0	358	0	8320	-380
Difference (%)	82.9%	6.9%	12.5%	17.6%	24.0%	-11.2%	-9.6%	-4.4%	12.5%	219.7%	97.9%	-16.3%	-3.4%	14.3%	5.3%	6.2%	0.0%	4.2%	0.0%	14.6%	-1.0%

Table 5-8: Comparison of the Average Operational Depth of the Wetlands Between the Existing and Proposed Uncontrolled Continuous Simulations

AVERAGE OPERATIONAL DEPTH (M):	SU01	SU02	SU03	SU04	SU05	SU06	SU07	SU08	SU09	SU10	SU11	SU12	SU13	SU14	SU15	SU16	SU17	SU18	SU19	SU20	SU21
Existing Conditions	0.57	0.74	0.43	1.3	0.58	0.12	0.73	0.08	0.02	0.02	0.14	0.15	0.6	1.54	0.21	0.58	0.51	0.12	0.04	0.41	2.85
Proposed Uncontrolled	0.83	0.8	0.42	1.3	0.66	0.1	0.73	0.07	0.02	0.28	0.34	0.13	0.57	1.51	0.22	0.59	0.51	0.13	0.04	0.44	2.85
Difference (m)	0.26	0.06	-0.01	0	0.08	-0.02	0	-0.01	0	0.26	0.2	-0.02	-0.03	-0.03	0.01	0.01	0	0.01	0	0.03	0
Difference (%)	45.9%	8.1%	-1.0%	0.2%	13.6%	-11.0%	-0.1%	-2.9%	3.1%	1128.5%	140.5%	-14.4%	-4.9%	-2.0%	3.2%	0.8%	0.0%	4.0%	0.0%	9.1%	0.0%

Table 5-9: Comparison of the Average Operating Volume of the Wetlands Between the Existing and Proposed Uncontrolled Continuous Simulations

AVERAGE OPERATIONAL VOLUME (M³):	SU01	SU02	SU03	SU04	SU05	SU06	SU07	SU08	SU09	SU10	SU11	SU12	SU13	SU14	SU15	SU16	SU17	SU18	SU19	SU20	SU21
Existing Conditions	305.4	49.06	75.92	317.3	126.4	76.37	96.95	12.92	4.989	5.471	19.06	46.98	404.5	391.2	132.6	291.1	19.2	1.34	4.349	22.64	167.3
Proposed Uncontrolled	707.7	55.53	75.08	319	166.4	67.57	86.96	12.37	6.232	14.35	58.85	41.06	379.2	377.1	142	332.8	19.2	1.39	4.35	25.89	167.3
Difference (m³)	402.3	6.47	-0.84	1.7	40	-8.8	-9.99	-0.55	1.24	8.88	39.79	-5.92	-25.3	-14.1	9.4	41.7	0	0.05	0	3.25	0
Difference (%)	131.7%	13.2%	-1.1%	0.5%	31.6%	-11.5%	-10.3%	-4.3%	24.9%	162.3%	208.8%	-12.6%	-6.3%	-3.6%	7.1%	14.3%	0.0%	3.9%	0.0%	14.4%	0.0%

Note: Green cells = < +/- 10%
Yellow Cells = > +/- 10% and < +/- 25%
Red Cells = > +/- 25%

As demonstrated within Table 5-7 to Table 5-9, there is a range in the predicted potential impacts within the wetland groups under the proposed uncontrolled condition. Of the predicted changes in total inflow volume (m^3), the majority of the wetland groups would experience minor changes, ranging between no change to +/- 10% change in total inflow throughout the 24-year simulation period. For the wetland groups which experience changes in total inflow of greater than +/- 10%, these changes primarily result in a change in operational depth of less than 0.06 m (+/-), indicating relatively minor changes in terms of the operational storage of the wetland groups based upon the existing footprints.

In review of all three (3) result trends for changes in total inflow volume and the respective operational depth / volume of the wetland groups, there are four (4) wetland groups that have a change greater than +/- 25% in at least one of the categories, these include SU01, SU05, SU10 and SU11. The wetland groups which have a footprint both directly impacted by the proposed Segment 1 ROW as well as are expected to receive additional drainage from the impervious portions of the ROW include SU05, SU10 and SU11. The combination of these changes in the local hydrologic and functional conditions of the wetland groups contributes to the results determined through the continuous simulation.

The wetland group SU01 is an off-line wetland group, which should not be receiving any additional drainage from the proposed ROW. The results of the continuous simulation indicate that the total inflow volume would result in an increase under proposed conditions, which equates to increases in both operational volume and depth. This demonstrates that even the wetlands which do not receive direct runoff from the proposed ROW can still be impacted through backwater conditions and the interconnectedness of the wetland pockets. This should be reviewed further as part of the future detailed design to better understand the connections and functional relationships of the wetland units.

5.3.3 MITIGATION OPTIONS

As demonstrated through the continuous simulation analysis presented above, there are a range of potential hydrologic impacts to the wetland groups and the PSW system as a result of the proposed roadway design if left uncontrolled, including:

- Additional runoff volume to certain wetland units receiving roadway drainage / act as on-line wetland storage features.
- Wetland footprint reductions due to the development of the Segment 1 ROW (notwithstanding potential additional grading / construction impacts beyond the ROW).
- Impacts to both operational volume and depth within the wetland units for both on-line and off-line wetland groups.

The majority of these impacts are focused on the portions of the wetlands which receive direct drainage from both the Rice Road and Merritt Road ROW. However due to the flat topography of the Segment 1 area, impacts would occur for other wetland pockets of the PSW through backwater impacts and hydrologic surface connections between the various units.

The primary option to mitigate the hydrologic impacts of the proposed design include maintaining the runoff volume to the wetland features, which for the purpose of this study would be controlling the runoff volume at the limits of the road ROW. As summarized in Section 3.2, there are a variety of SWM controls that are being proposed as solutions to meet the necessary SWM control criteria for the proposed roadway design, these include the combination of stormwater detention within the roadside ditches for quantity control purposes, as well as the recommendation for infiltrating the runoff volume control target for the 90th percentile rainfall event as identified by the MECP through infiltration trenches beneath the roadside ditches.

The implementation of infiltration trenches designed to capture and retain the increased runoff associated with the increased impervious area under frequent events not only helps to satisfy the Niagara Region's erosion control criteria, but also promotes water quality improvements and helps to maintain the local hydrologic cycle. By implementing these or other infiltrative LID BMPs, this would allow the retention and infiltration of 90% of average annual rainfall, which for the Niagara Region would equate storms under 28-29 mm. On a long-term basis, the implementation of these LID BMPs would help to mitigate the impacts to the receiving wetland features associated with higher runoff volumes occurring from the road ROW, which will in turn help to reduce the impacts on the operational depth and volume of the PSW system.

For the portions of the wetland units which are directly physically impacted by the Segment 1 ROW, the loss of footprints and associated operational volume / storage should be mitigated. As indicated in the EIS (separate cover), from an ecological perspective the detailed design must include a restoration and compensation plan to offset the negative impacts of the habitat loss. This is also true from a hydrologic / hydraulic perspective, to ensure that the storage available within this PSW is maintained to ensure no impacts further downstream, as the PSW provides storage / attenuation prior to discharging at Cataract Road. This should be assessed further as part of the detailed design efforts to ensure that the functionality of the wetland is maintained both upstream and downstream of the proposed roadway, and that the key hydrologic connections are maintained through culvert crossings.

In order to inform the future detailed design phase, additional long-term monitoring is recommended within the study area. This includes additional surface water monitoring gauges both upstream, downstream as well as within the PSW system. The additional monitoring will allow for a better understanding of the local functions of the wetland system. The details of surface water monitoring will need to be confirmed with NPCA, following completion of the Class EA Study / during detailed design phase. This understanding of wetland functions can help to refine the modelling developed as part of the current study, and help to refine the impact assessment based upon the detailed design of the roadway and further develop mitigation opportunities. Additional monitoring requirements from an ecological / ecohydrology perspective are outlined in the EIS completed under separate cover.

6 CONCLUSIONS & RECOMMENDATIONS

6.1 CONCLUSIONS

The following can be concluded from the current study and associated hydrologic and hydraulic assessments:

- The study area of Merritt Road and Rice Road is located within three (3) local are municipalities (Thorold, Pelham, Welland) and contributes to two (2) subwatershed systems, namely Singers Drain and Towpath Drain, which both outlet to the Welland Canal. The existing roadway segments are primarily rurally serviced through roadside ditches and cross-culverts.
- The proposed roadway design of Merritt Road and Rice Road includes roadway widening, extension and active transportation facilities. These improvements will result in a total increase in impervious area of approximately 2.1 (ha) (+/-), equating approximately a 2% (+/-) increase within the study area subwatershed systems. Segments 1, 2 and 4 are proposed to be hybrid cross-sections (rural / urban) with ditches, and Segment 3 is proposed to be urban with storm sewers.
- A hydrologic model has been developed for the study area under both existing and proposed conditions. The hydrologic assessment has been completed using PCSWMM, which is an integrated hydrologic / hydraulic model, allowing for a characterization of both hydrologic changes associated with increased impervious coverage and potential drainage area boundary changes, as well as impacts of the local conveyance system.
- Due to the increased impervious area associated with the proposed design, SWM controls are required to mitigate the impacts to the downstream receivers.
- A hydraulic impact assessment has been completed for the Segment 1 ROW. As part of this assessment, a new HEC-RAS model has been developed based upon provincial LiDAR data and local survey data to assess the potential flood risks associated with the development of the unopened road allowance within Segment 1. The results of this analysis found the following:
  - The existing floodplain within the Segment 1 study area is very shallow and very wide, due to the flat nature of the local topography. Majority of the existing hydraulic structures within the area are found to overtop during frequent events, indicating that the ditches are undersized with respect to current design standards.
- A wetland impact assessment has been completed in consultation with the EIS/ecology study team to characterize the potential impacts to the PSW located within the Segment 1 ROW, which consists of several wetland pockets forming the greater system. The wetland impact assessment has followed the TRCA guidelines, and has found the following:
  - The PSW system located within Segment 1 is made up of several localized wetland pockets, which includes features acting as on-line features, as well as off-line / isolated features. The existing subcatchments contributing to each wetland and the associated storage and footprints of the wetland pockets have been determined through a terrain analysis using the provincial DEM.

- The results of the wetland impact assessment identified five (5) local wetland groups with either a Medium or High-risk score associated with changes in each total drainage area or contributing imperviousness. These findings coupled with the ecological assessment (which identified all as High Risk), resulted in these groups being a High Risk. The total PSW system resulted in Low Risk from a hydrologic perspective, with only a 2% increase in impervious area associated with the proposed roadway design.
- Due to the localized High-Risk assessment, a continuous simulation has been completed utilizing the PCSWMM modelling developed for informing SWM control requirements. The models have been simulated for a 24-year period of record, using climate data sourced from the Niagara Region / NPCA's long-term monitoring network.
- The results of the results of the continuous simulation quantified the potential impacts associated with a proposed uncontrolled scenario, which resulted in varying impacts to total inflow volume and operational depth / volume throughout the numerous wetland groups. This demonstrates the interconnectedness of the wetland groups and how the potential impacts may extend beyond the areas of most change.

- Notwithstanding the above conclusions, there are some limitations to the current assessment; these include:
  - Surface water monitoring data was collection from June 15th to October 24th, 2022. Only four (4) significant storm events with hydrologic responses took place during this period. This represents a short season of surface water monitoring. Surface water monitoring data from this short monitoring period was used for calibration of the PCSWMM modelling. Due to the lack of formative events as well as the highly flat nature of the study area, a strong calibration was difficult to achieve. Best efforts have been made to refine the modelling as part of this exercise, however with longer monitoring period data a better fit may be achieved.
  - The PCSWMM modelling developed as part of the current study is an integrated hydrologic and hydraulic model, incorporating the drainage system via conduits representing both watercourse features as well as ditches / culverts. Due to the highly flat nature of the study area, the modelling was found to be highly sensitive to backwater conditions and hydraulic influences, which impacted the peak flow responses at key comparative nodes. Best efforts have been made to eliminate some of these influences. However, in future it may benefit from assessing the hydrologic impacts separately (i.e., hydrologic model only) and size the necessary quantity controls, which can then be validated through a hydrologic/hydraulic model as for the operational concerns of the drainage network.

6.2 RECOMMENDATIONS & REQUIREMENTS FOR FUTURE STUDY

The following represents the recommendations resulting from the outcomes of the current study:

- The proposed SWM strategy for the roadway includes the following elements:
  - Water quantity controls are required for all individual outlets within the road ROW to control post-development flows to pre-development conditions. The recommended strategies to provide water quantity control include temporary storage through the roadside ditches, through the implementation of rock check dams / orifice controls for the hybrid Segments 1, 2 and 4, and through the application of underground storage (i.e., super pipe or cellular tank storage, etc.) as part of the proposed storm sewer within Segment 3. Storm sewers for Segment 3 shall be designed as part of detailed design phase.

- Erosion control is to be provided through the application of LID BMPs designed to retain the Runoff Volume Control Target as identified through the MECP's Draft LID Guidance (i.e., 28-29 mm) for the increased impervious area within each roadway segment. The LID BMPs may include infiltration trenches beneath the roadside ditches (hybrid segments), or Silva Cells / Bioretention features within the urban segment. The subsurface soil and groundwater conditions are required to be confirmed through detailed design phase throughout the project area to confirm that the LID BMPs can be designed to provide the required infiltration / retention.
- The Runoff Volume Control Target of 28-29 mm is to be provided to the extent feasible based on physical and site constraints with a flexible approach to both surface and subsurface storage systems, acknowledging that the target may not be feasible in some locations due to local constraints.
- Enhanced Level of water quality control is to be provided for the increased impervious area within each roadway Segment through the implementation of LID BMPs such as enhanced grass swales within the hybrid roadway segments, or the combination of conventional practices (i.e., OGS units, CB shields, etc.) acting as pre-treatment with LID BMPs as part of the urban segments.
- The water balance criteria of 5 mm retention can be achieved through the implementation of the infiltration trenches identified for the erosion control criteria.

- Under proposed conditions, preliminary structure upgrades have been recommended including open bottom concrete box culverts ranging in size from 3 m up to 15 m span, and 0.6 m to 0.9 m rise. The preliminary sizes are all capable of conveying storms up to and including the 100-year storm without overtopping and achieve a minimum 0.30 m freeboard. Additional iterations of the proposed roadway profile may be required to achieve the minimum 1 m freeboard under the 25-year design event.
- The development of the Segment 1 ROW would result in impacts to the 100-year flood risk. Based upon the analysis completed, wide and shallow cross culverts would be required to mitigate any impacts to the upstream WSEs and minimize increases to the local floodplain associated with the proposed roadway, as well as maintain hydrologic connections within the PSW.
- Mitigation measures are required to ensure water balance and wetland functionality is maintained as part of the detailed design strategy. LID BMPs are considered required to retain the additional surface runoff associated with the additional impervious areas; this strategy is consistent with those identified for SWM, which demonstrate multi-benefits to incorporating LID BMPs designed to the MECP's runoff volume control target. Restoration and compensation are required for the footprints / volume of the wetland areas which will be physically impacted by the Segment 1 ROW.

The following is required / recommended for future studies as it relates to the future detailed design of Merritt Road and Rice Road:

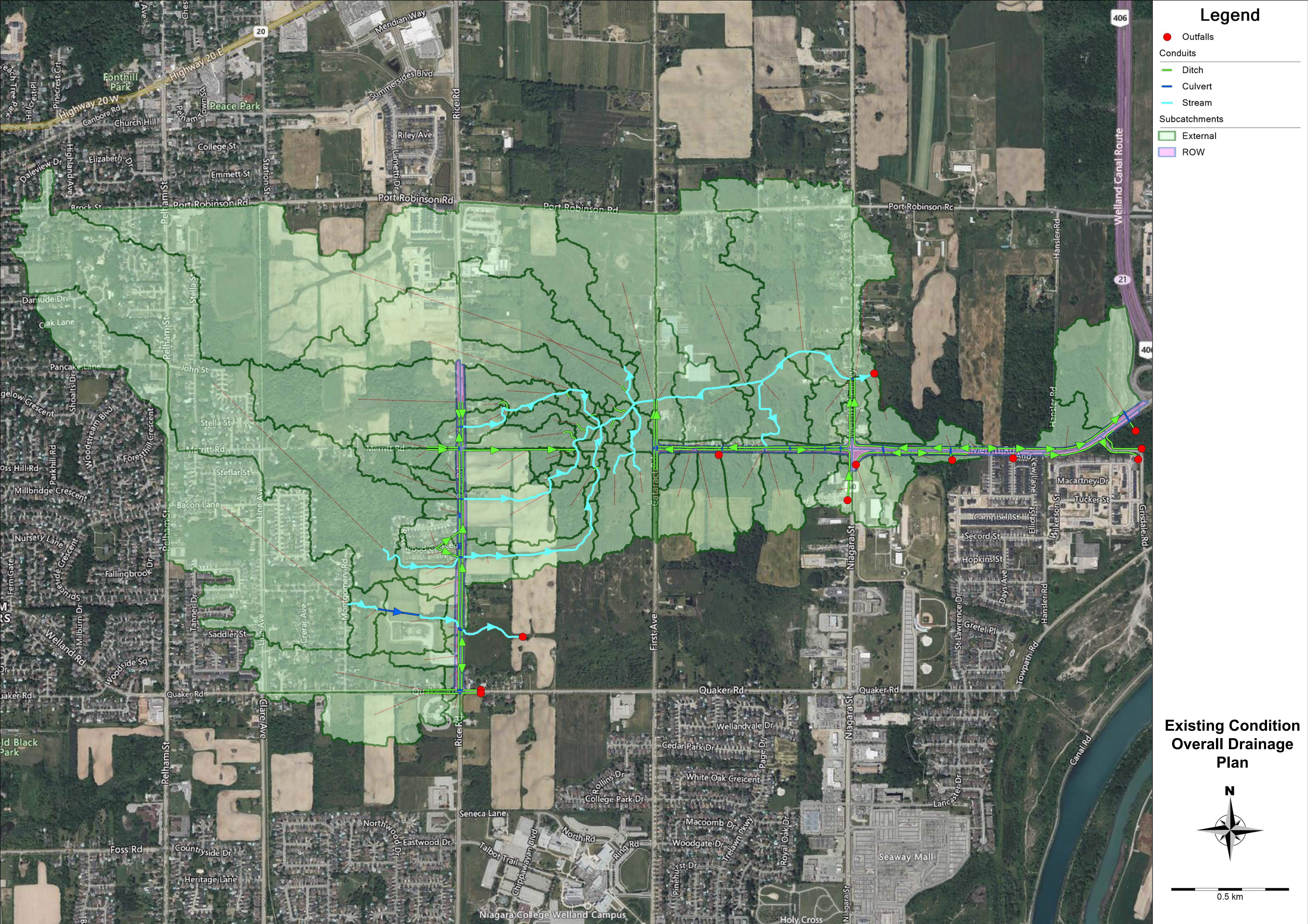
- Topographic / bathymetric survey is to be completed within the Segment 1 ROW and adjacent wetland systems to validate the LiDAR data available for the area.
- Additional long-term surface water monitoring should be undertaken upstream, downstream and within the wetland systems located within the Segment 1 ROW to better characterize and understand the performance and functionality of the wetland units. The details of the monitoring program will need to be determined in consultation with the NPCA.

- Hydrologic and hydraulic modelling should be updated based upon the results of additional background data (external drainage areas) as well as new monitoring / data collection to support a detailed calibration and the final roadway designs. The final roadway designs should aim to maintain contributing drainage areas to existing drainage outlets to the best extent possible through localized ditch grading to minimize potential impacts.
- A 2D hydraulic modelling exercise is recommended for the floodplain area within Segment 1, due to the flat terrain and highly interconnected stream / wetland systems in this area, 1D computations are not capable of accurately represent the flooding conditions.
- Hydraulic structure sizing is to be updated based upon the results of the updated hydrologic (steady flow input) and 2D hydraulic modelling. The updated hydraulic model should incorporate the revised road profile and any associated ROW grading and should verify the structures adhere to the necessary MTO design criteria and mitigate any additional WSE increases to the 100-year floodplain within Segment 1. The cross culverts within the ROW will need to be reviewed for capacity and minimum cover requirements as part of the updated roadway design.
- Preliminary SWM strategies should be verified as part of the detailed design of the ROW. This includes confirming the erosion sensitivity of downstream receivers through local geomorphological assessment, confirming there is sufficient space for LID BMPs in the roadway cross-sections and that the subsurface soil conditions and bedrock and seasonally high groundwater elevations are conducive to infiltration. Geotechnical investigation / infiltration testing is to be completed throughout each segment once the preferred locations for the LID BMPs are identified during detailed design.
- The final design footprint for Merritt Road across Highway 406 Overpass (between Grisdale Road and Kottmeier Road) will be determined during detailed design phase. The need for SWM controls will need to be determined at that time. Other elements to be confirmed through detailed design include the drainage / conveyance system. It's understood that under existing conditions, this area is rurally serviced through roadside ditches and cross-culverts. Therefore, the drainage infrastructure will be required to be confirmed during detailed design to be of adequate capacity and condition to support the changes proposed within the interchange area.
- As a part of the detailed design of Segment 3, external minor and major systems peak flows resulting from the MTO's ROW and associated external drainage areas, should be assessed under both the existing and proposed roadway and drainage conditions to confirm that there is no impact on drainage conveyance from the MTO's ROW based on the proposed Merritt Road drainage system (incl. catch basins and storm sewer system).
- During the detailed design stage, the roadway's flow spread for Segment 3 should be assessed to confirm that it meets the MTO's Highway Drainage Standards (2008).
- At the detail design stage, the MTO shall review design and assessment of recommended stormwater management measures and drainage systems to confirm that proposed road improvements do not impact the MTO's drainage system.
- As unconventional underground storm storage systems such as chambers and infiltration systems are not permitted by the MTO, unconventional storm storage systems will not be considered by the MTO in the determination of controlled post development peak flows and ponding limits. As such, calculations and assessment of peak flows and ponding limits without the unconventional storm storage systems will be required in the detailed design by the MTO to confirm that the proposed development will not impact the MTO's drainage system. (Ref. Appendix G).

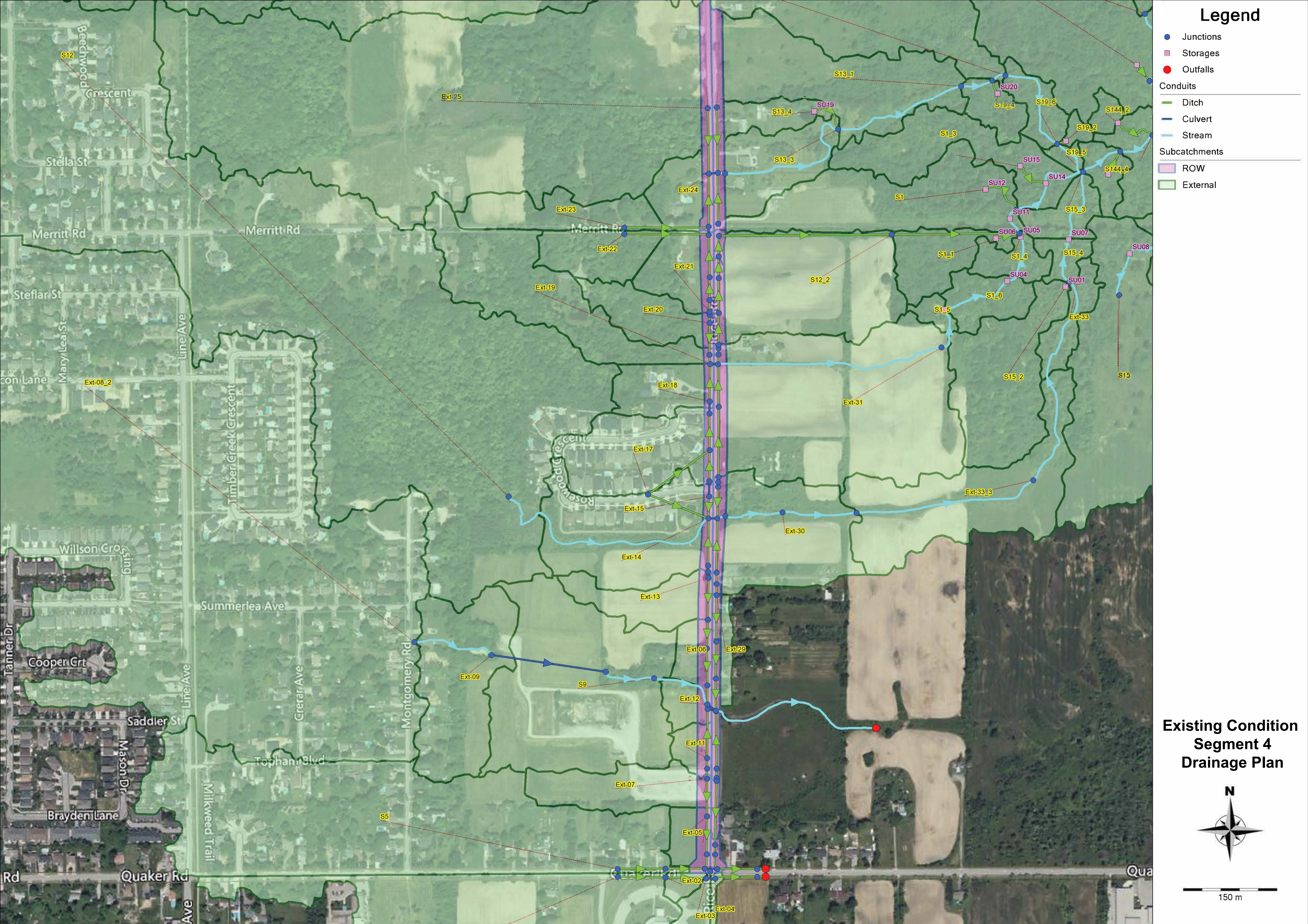
- During detailed design, the MTO will require all culverts located within the MTO's right-of-way to meet MTO's standards as per the Highway Drainage Standards (2008).
- The wetland impact assessment should be refined as further details become available at the detailed design stage, these include updated continuous simulation and assessment of the potential impacts associated with local grading refinements, construction impacts, etc. Any updates to the wetland impact assessment and associated mitigation measures should be completed in consultation with the ecologists assigned to the detailed design, in adherence to the recommendations of the EIS (under separate cover).
- The NPCA has been consulted throughout this project and is in agreement with the recommendations. The NPCA should be consulted throughout the detailed design stage (ref. Appendix G).

Appendix A

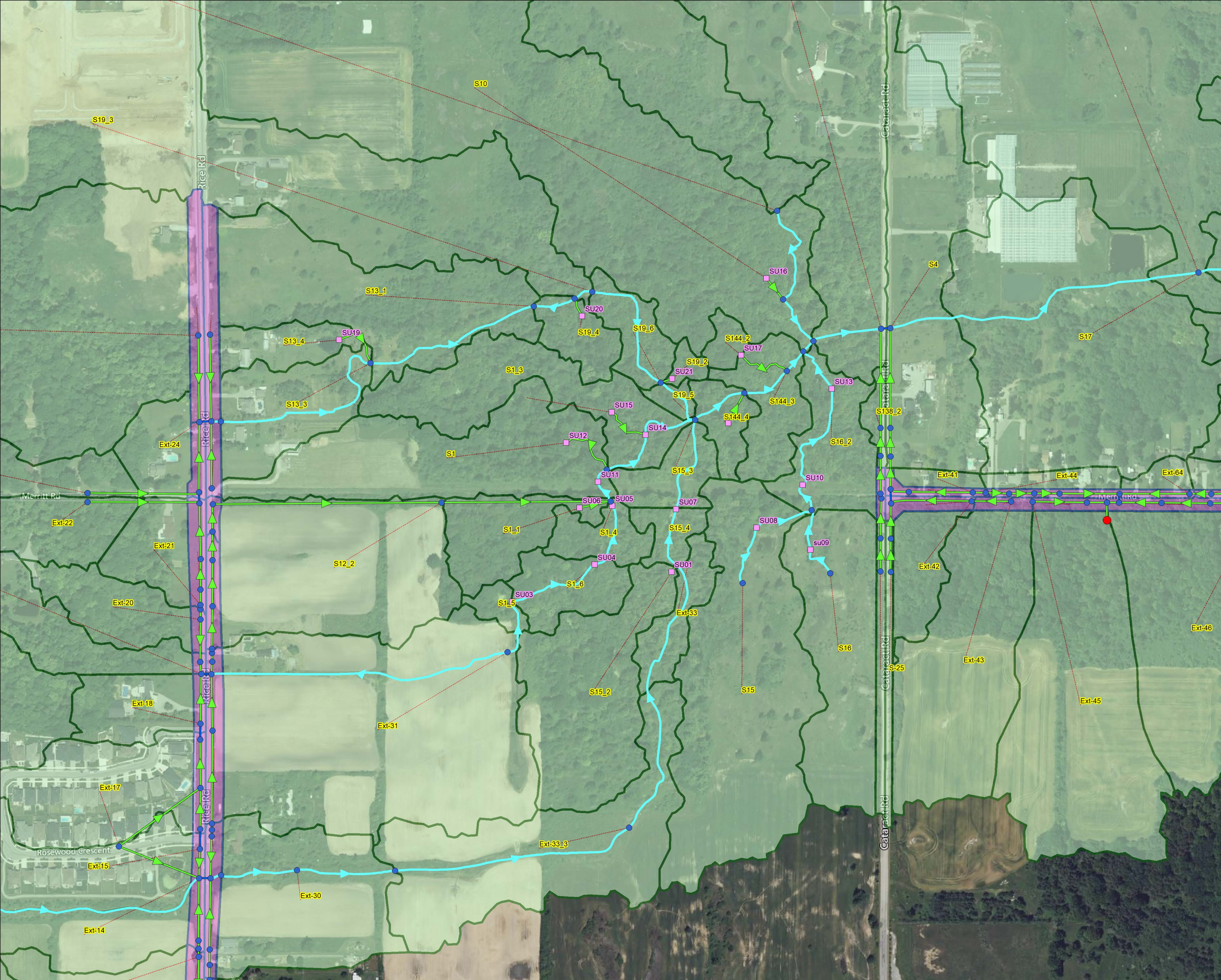
Existing Conditions Subcatchment Drainage Plans



Legend
Outfalls
Conduits
Ditch
Culvert
Stream
Subcatchments
External
ROW
Existing Condition Overall Drainage Plan
N
0.5 km
Port Robinson Rd
Merritt Rd
Quaker Rd
Rice Rd
Pelham St
First Ave
Niagara St
Welland Canal Route
Highway 20 W
Highway 20 E
Seaway Mall
Niagara College Welland Campus



Legend
Junctions
Storages
Outfalls
Conduits
Ditch
Culvert
Stream
Subcatchments
ROW
External
Existing Condition
Segment 4
Drainage Plan
N
150 m
Merritt Rd
Quaker Rd
Line Ave
Montgomery Rd
Summerlea Ave
Willson Crossing
Cooper Crt
Saddler St
Mason Dr
Brayden Lane
Tanner Dr
Topham Blvd
Milkweed Trail
Grerar Ave
Timber Creek Crescent
Rosewood Crescent
Stella St
Steflar St
Mary Lea St
Beechwood Crescent



Legend

- Junctions
- Storages
- Outfalls

Conduits

- Ditch
- Culvert
- Stream

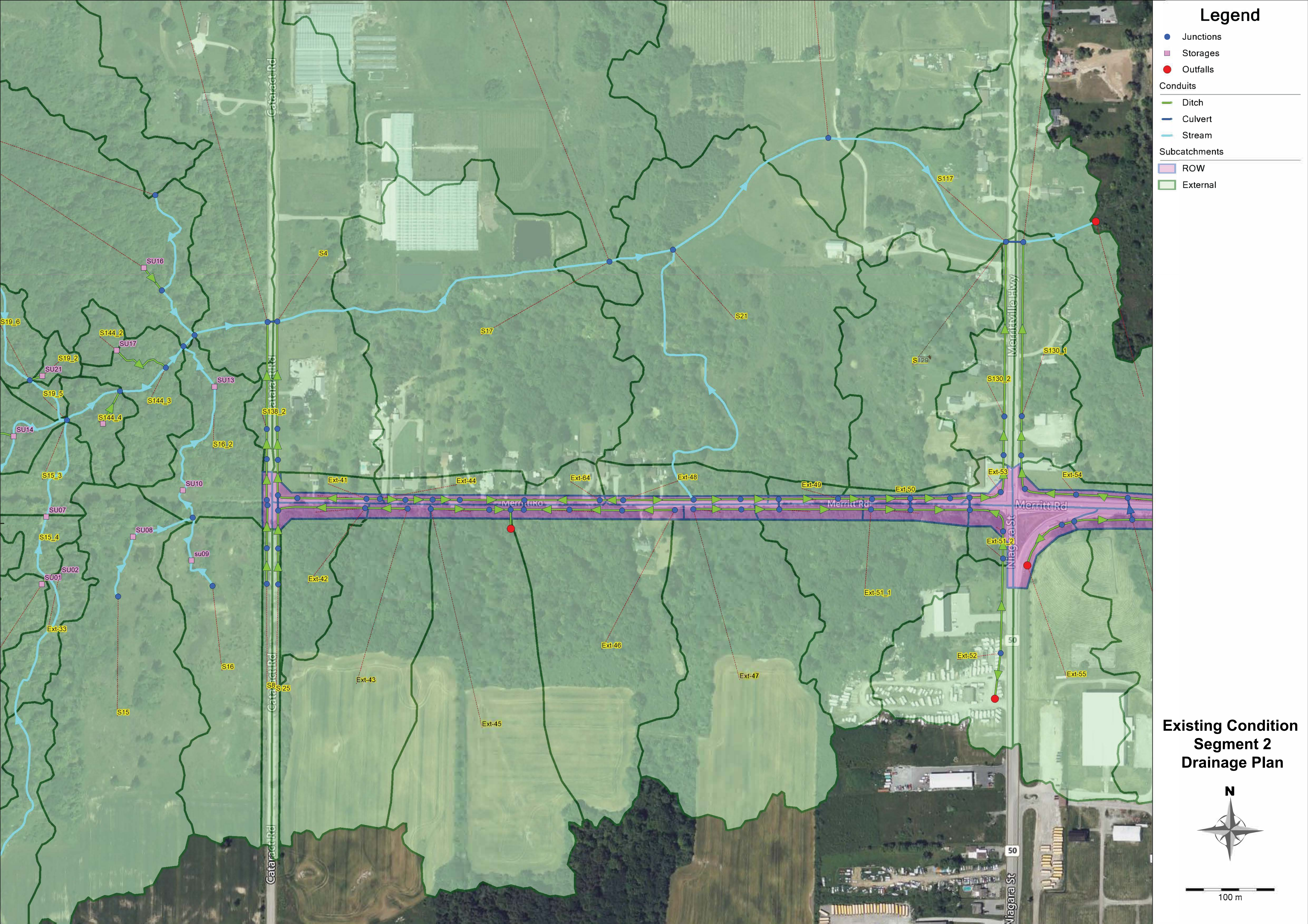
Subcatchments

- ROW
- External

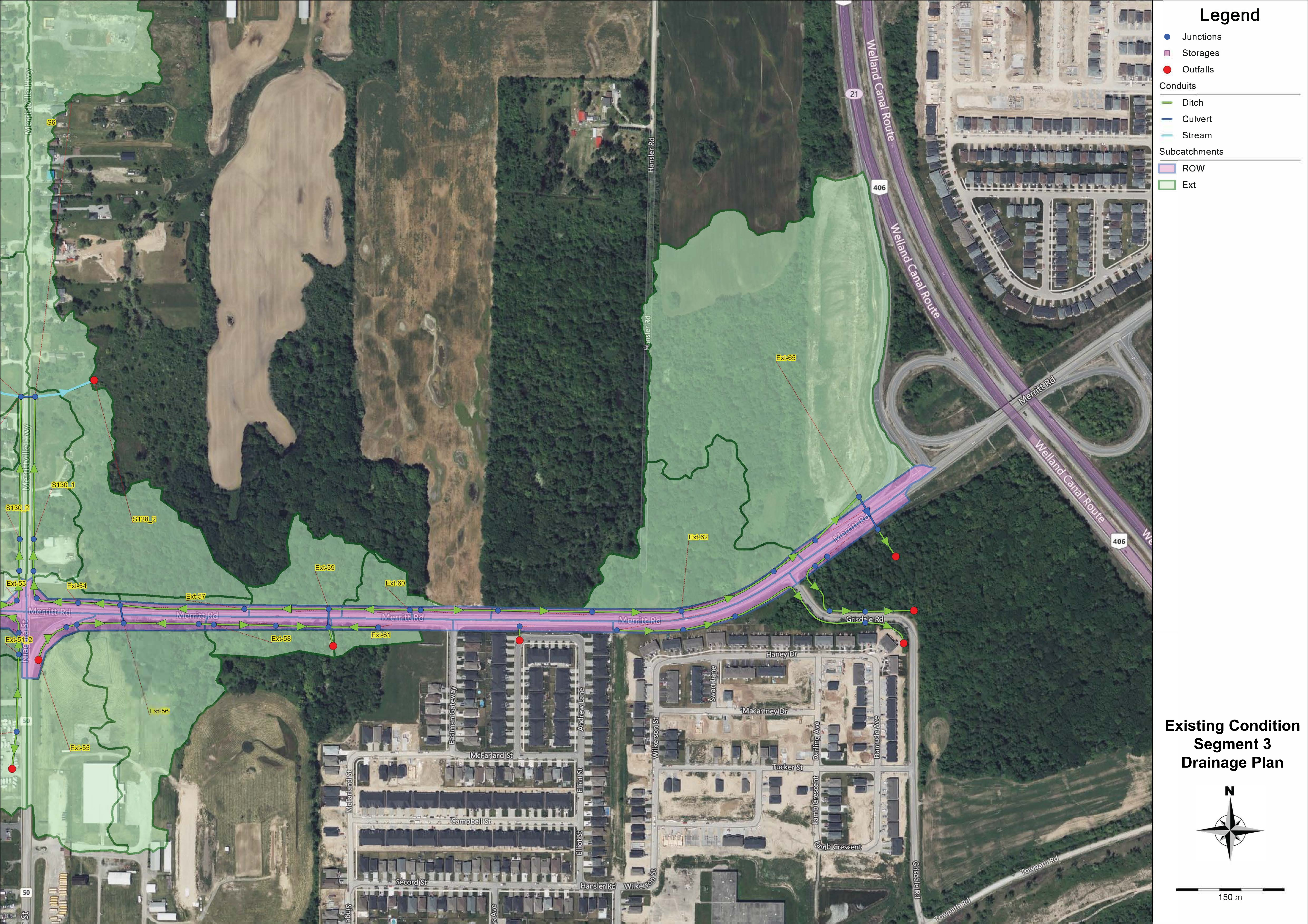
Existing Condition Segment 1 Drainage Plan

N

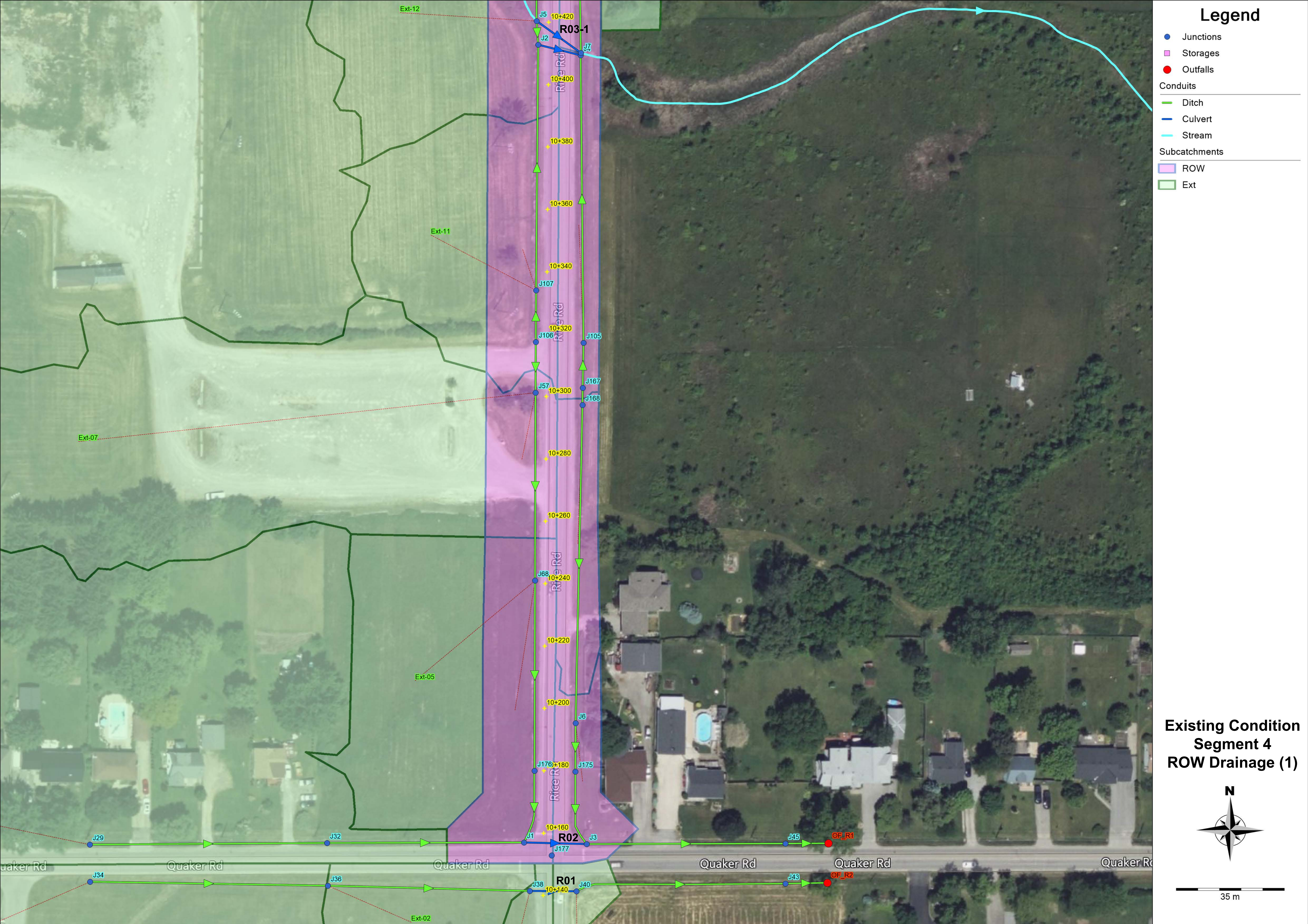
150 m



Existing Condition Segment 2 Drainage Plan

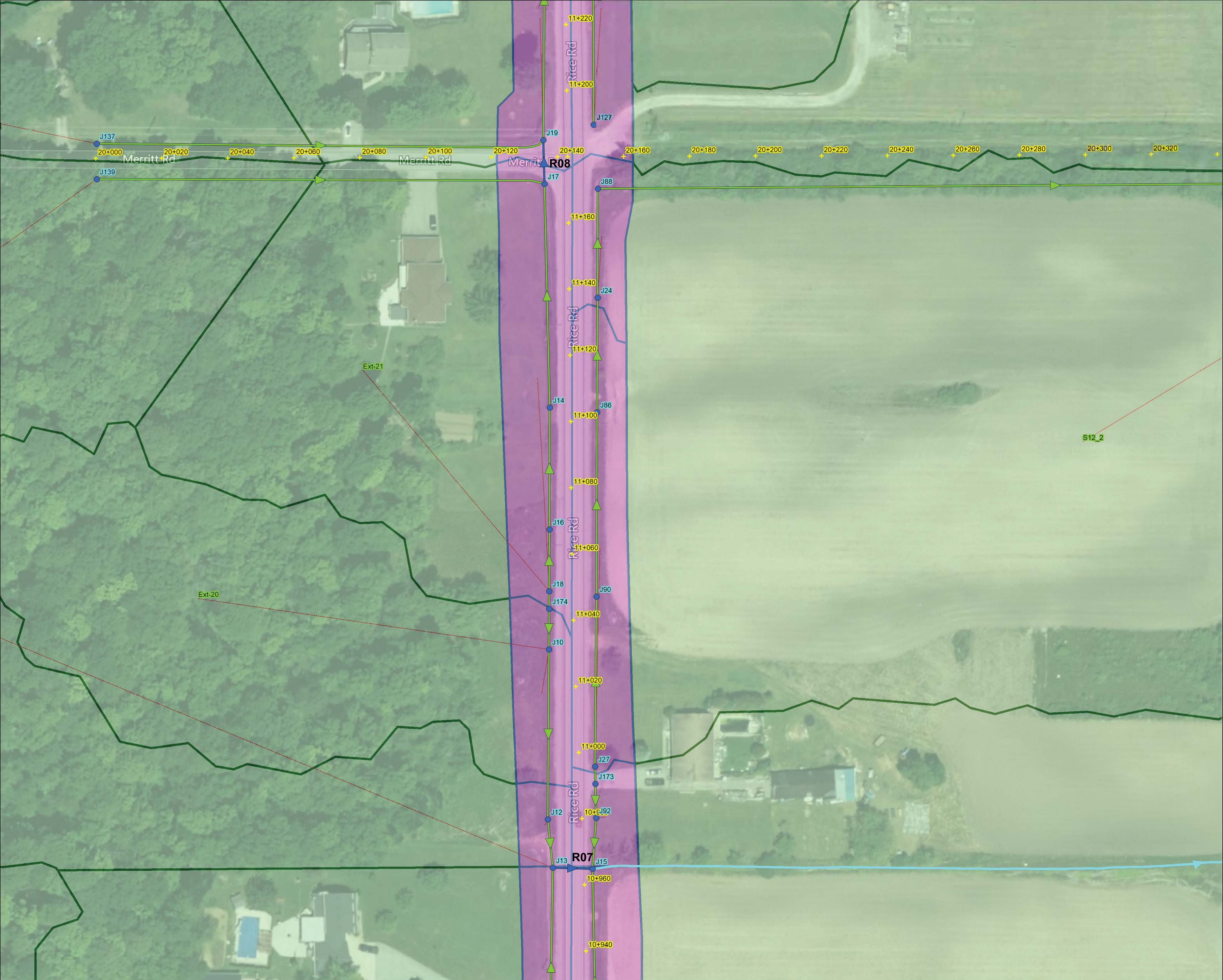


Legend
Junctions
Storages
Outfalls
Conduits
Ditch
Culvert
Stream
Subcatchments
ROW
Ext
Existing Condition
Segment 3
Drainage Plan
N
150 m
Merritt Rd
Welland Canal Route
Hansler Rd
Grisdale Rd
Haney Dr
Macartney Dr
Tucker St
McFarland St
Campbell St
Secord St
Wilkerson St
Towpath Rd
Ext-65
Ext-62
Ext-59
Ext-60
Ext-61
Ext-58
Ext-57
Ext-54
Ext-53
Ext-56
Ext-55
S128_2
S130_1
S130_2
S6


Legend
Junctions
Storages
Outfalls
Conduits
Ditch
Culvert
Stream
Subcatchments
ROW
Ext
Existing Condition
Segment 4
ROW Drainage (1)
N
35 m
R03-1
R02
R01
Rice Rd
Quaker Rd
Ext-12
Ext-11
Ext-07
Ext-05
Ext-02
OF_R1
OF_R2
10+420
10+400
10+380
10+360
10+340
10+320
10+300
10+280
10+260
10+240
10+220
10+200
10+180
10+160
10+140


Legend
Junctions
Storages
Outfalls
Conduits
Ditch
Culvert
Stream
Subcatchments
ROW
Ext
Existing Condition
Segment 4
ROW Drainage (2)
N
35 m
R03-1
Rice Rd
Ext-14
Ext-13
Ext-06
Ext-29
Ext-12
J8
J169
J98
J99
J171
J109
J108
J101
J103
J22
J20
J5
J2
J7
J165
J-3
10+660
10+640
10+620
10+600
10+580
10+560
10+540
10+520
10+500
10+480
10+460
10+440
10+420
10+400


Rice Rd
Rosewood Crescent
R04
R05
R06
J37
J39
J93
J95
J33
J97
J172
J148
J35
J9
J11
J163
J-6
Ext-18
Ext-17
Ext-15
Ext-30
10+940
10+920
10+900
10+880
10+860
10+840
10+820
10+800
10+780
10+760
10+740
10+720
10+700
10+680
Legend
Junctions
Storages
Outfalls
Conduits
Ditch
Culvert
Stream
Subcatchments
ROW
Ext
Existing Condition
Segment 4
ROW Drainage (3)
N
35 m



Legend

- Junctions
- Storages
- Outfalls

Conduits

- Ditch
- Culvert
- Stream

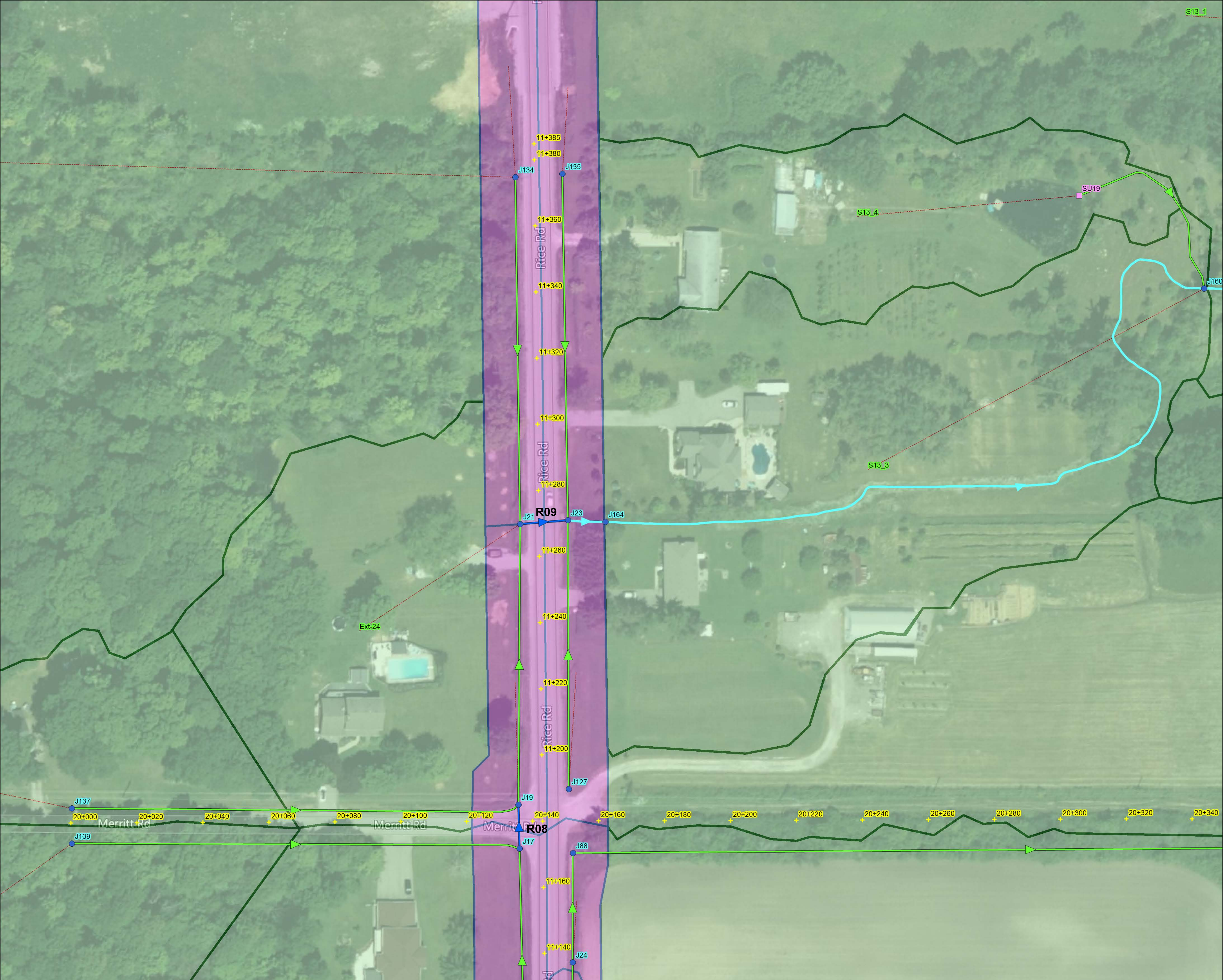
Subcatchments

- ROW
- Ext

Existing Condition
Segment 4
ROW Drainage (4)

N

35 m



Legend

- Junctions
- Storages
- Outfalls

Conduits

- Ditch
- Culvert
- Stream

Subcatchments

- ROW
- Ext

Existing Condition
Segment 4
ROW Drainage (5)

N

35 m

Legend

- Junctions
- Storages
- Outfalls

Conduits

- Ditch
- Culvert
- Stream

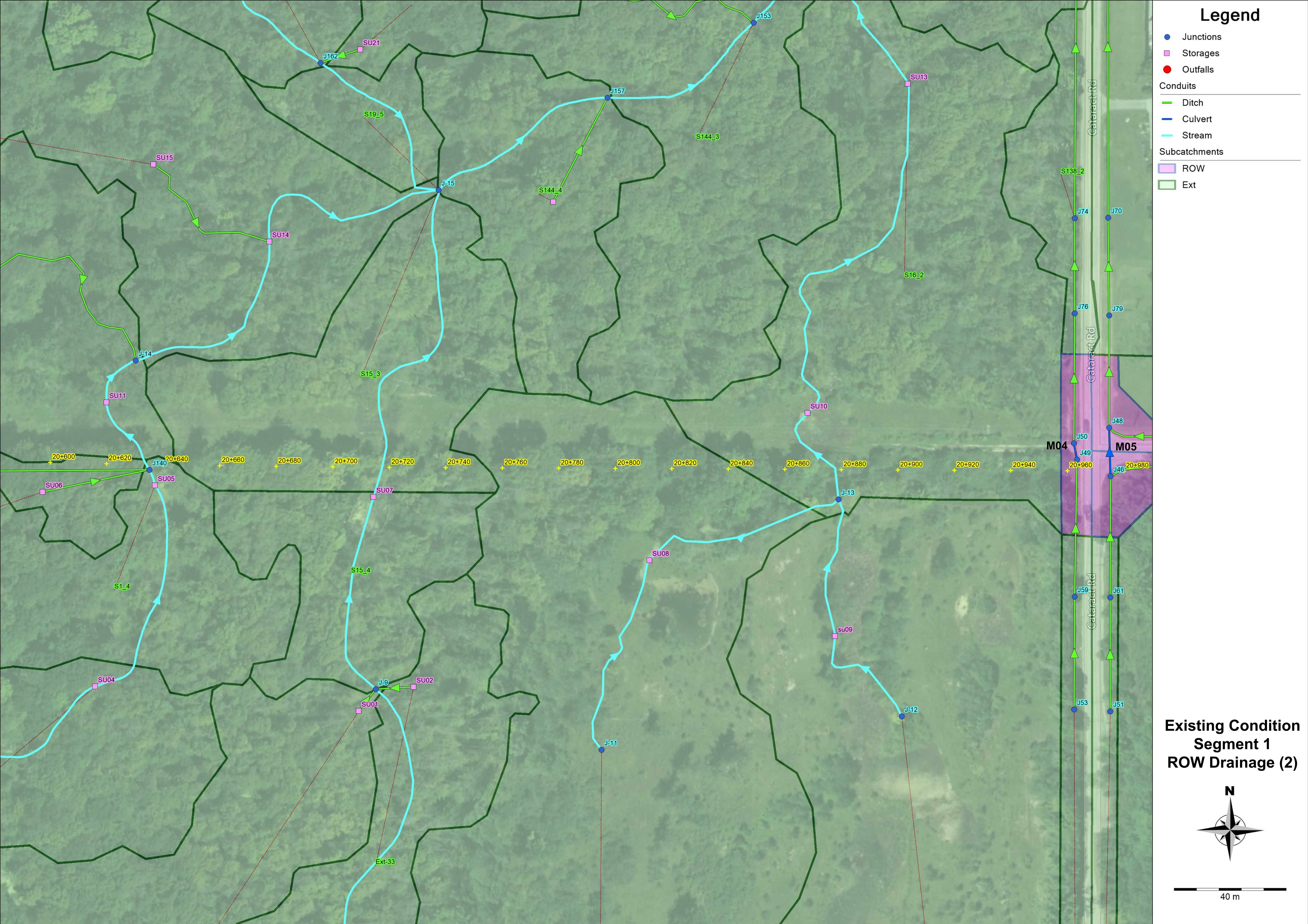
Subcatchments

- ROW
- Ext

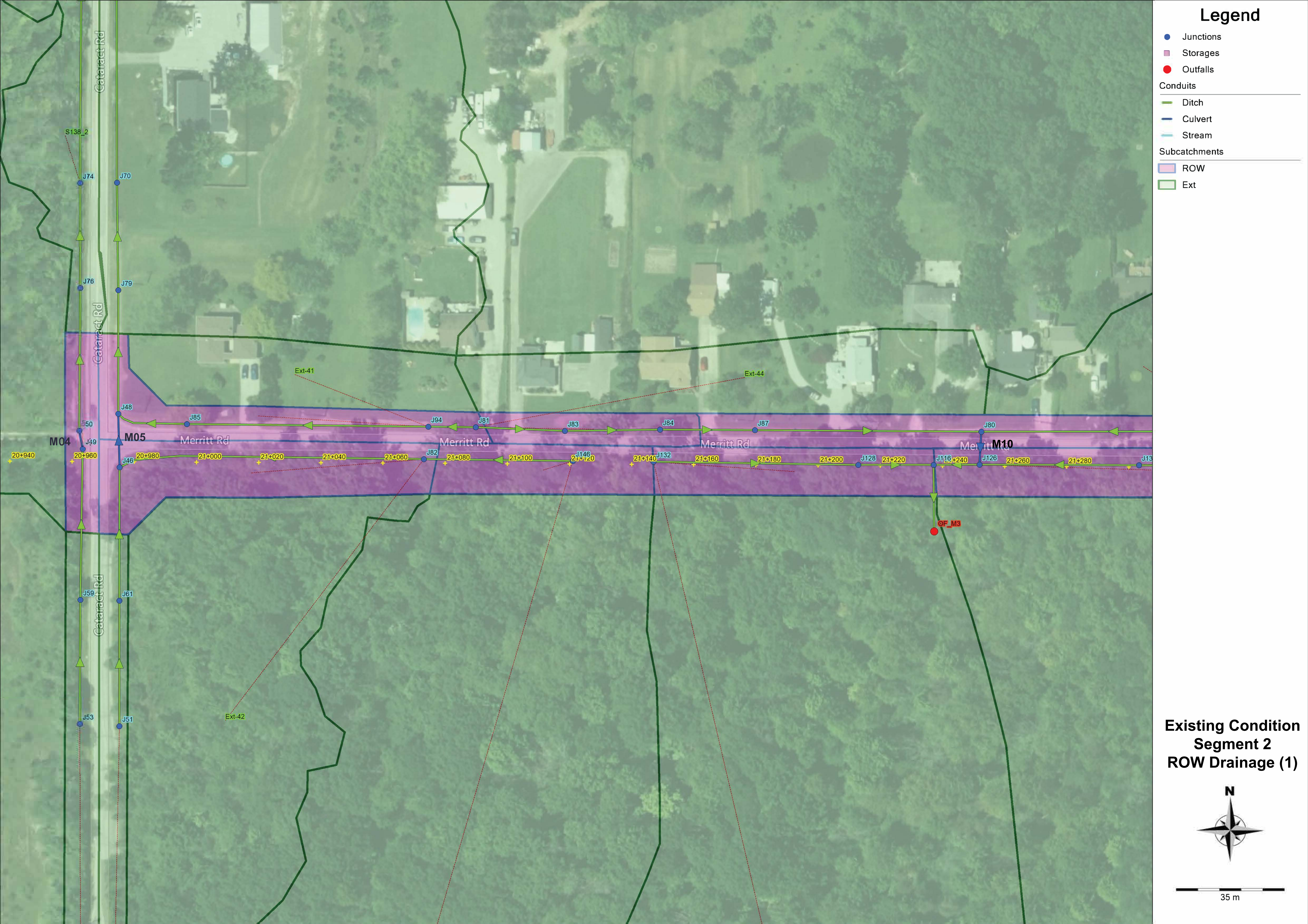
Existing Condition
Segment 1
ROW Drainage (1)

N

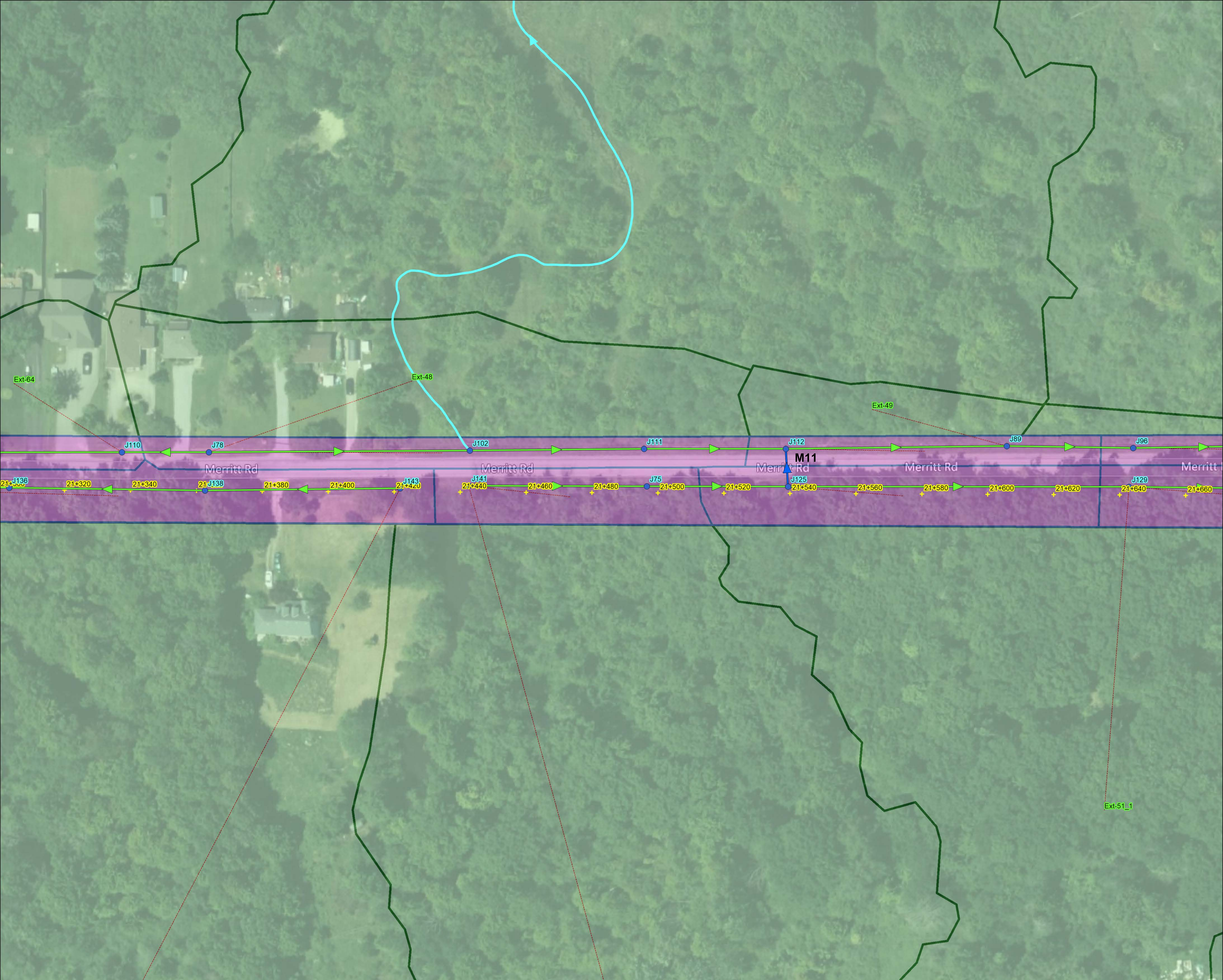
35 m



Existing Condition
Segment 1
ROW Drainage (2)



Legend
Junctions
Storages
Outfalls
Conduits
Ditch
Culvert
Stream
Subcatchments
ROW
Ext
Existing Condition
Segment 2
ROW Drainage (1)
N
35 m
Merritt Rd
Cataract Rd
M04
M05
M10
Ext-41
Ext-42
Ext-44
OF_M3



Legend

- Junctions
- Storages
- Outfalls

Conduits

- Ditch
- Culvert
- Stream

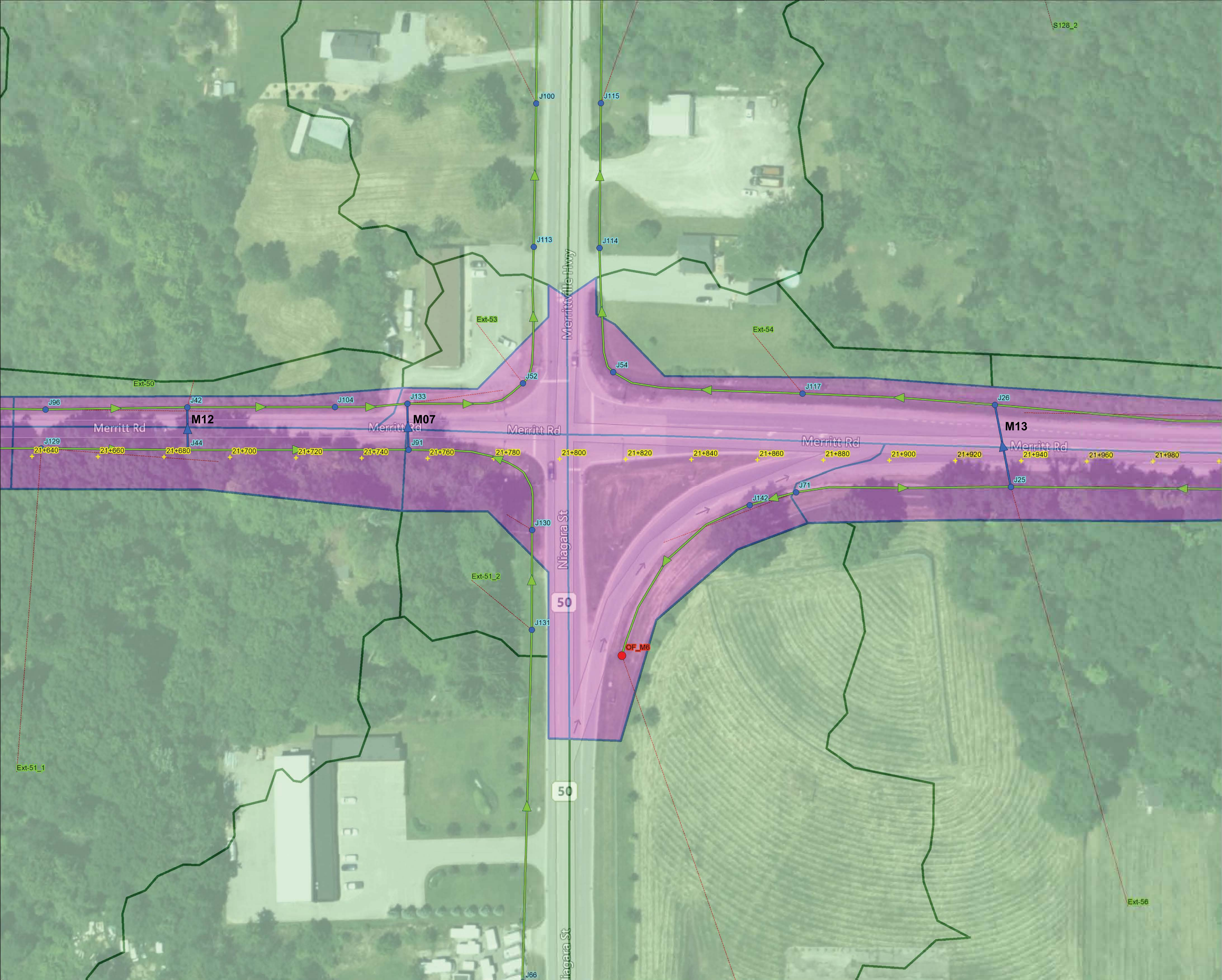
Subcatchments

- ROW
- Ext

Existing Condition
Segment 2
ROW Drainage (2)

N

35 m



Legend

- Junctions
- Storages
- Outfalls

Conduits

- Ditch
- Culvert
- Stream

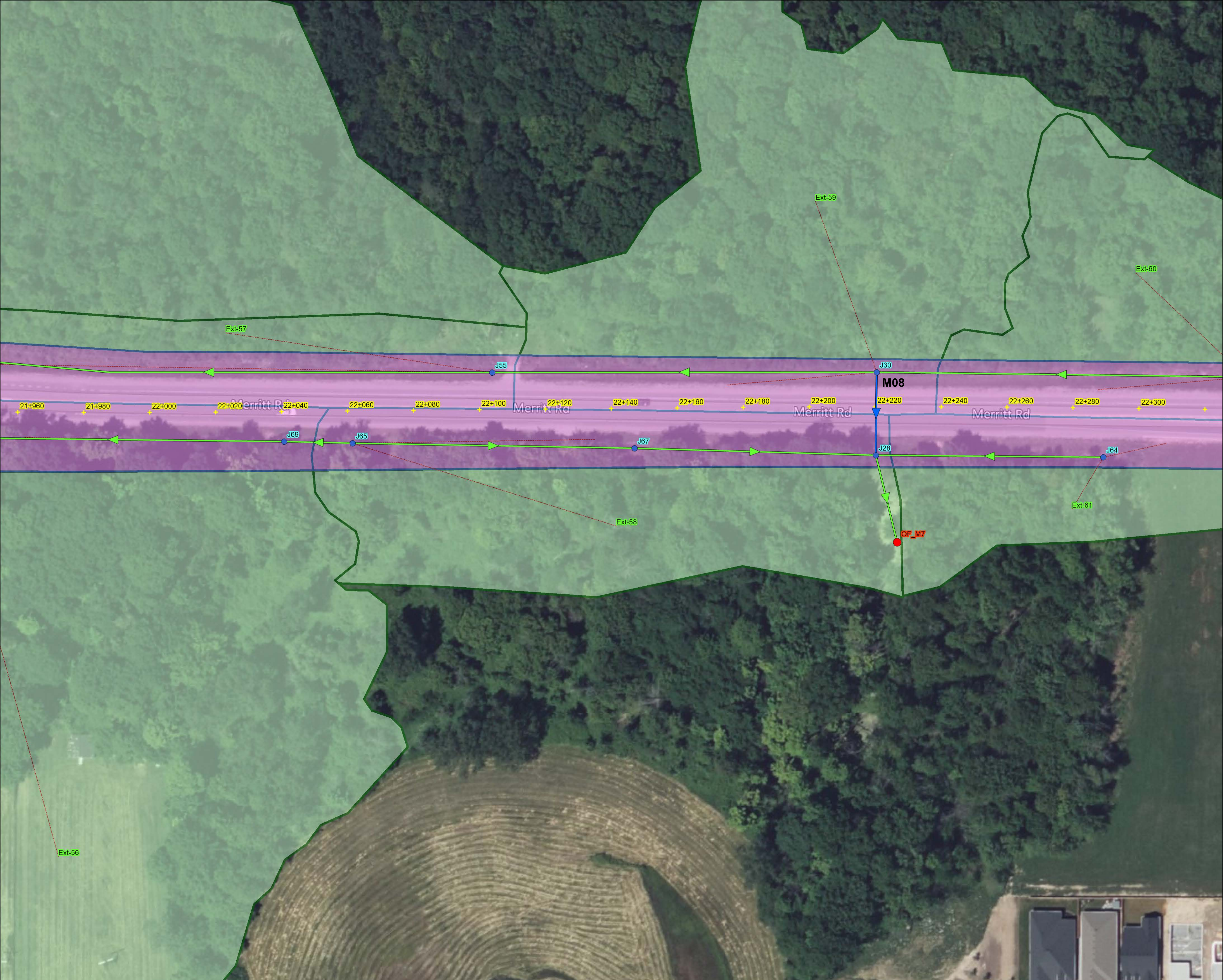
Subcatchments

- ROW
- Ext

Existing Condition
Segment 2
ROW Drainage (3)

N

35 m



Legend

- Junctions
- Storages
- Outfalls

Conduits

- Ditch
- Culvert
- Stream

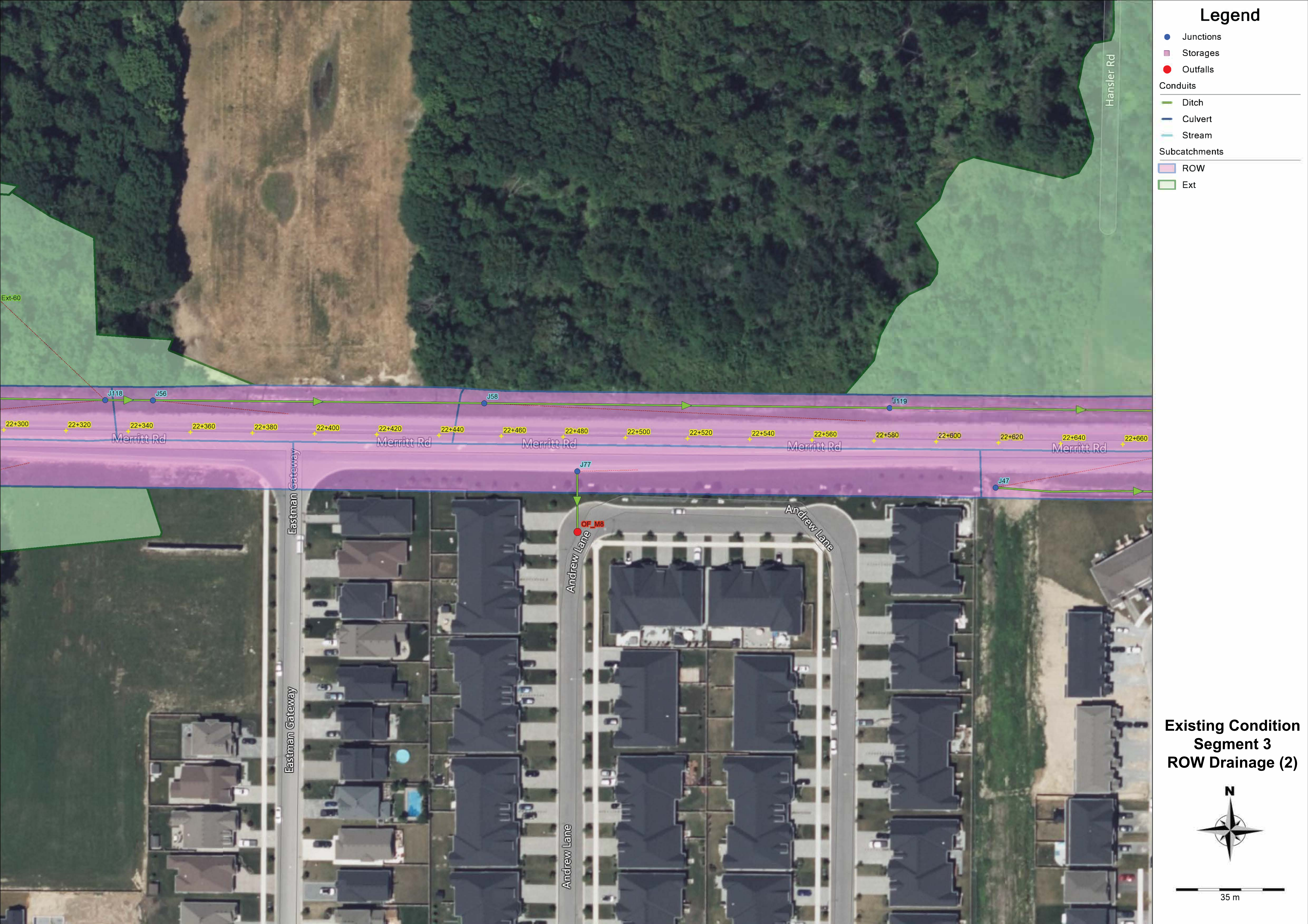
Subcatchments

- ROW
- Ext

Existing Condition
Segment 3
ROW Drainage (1)

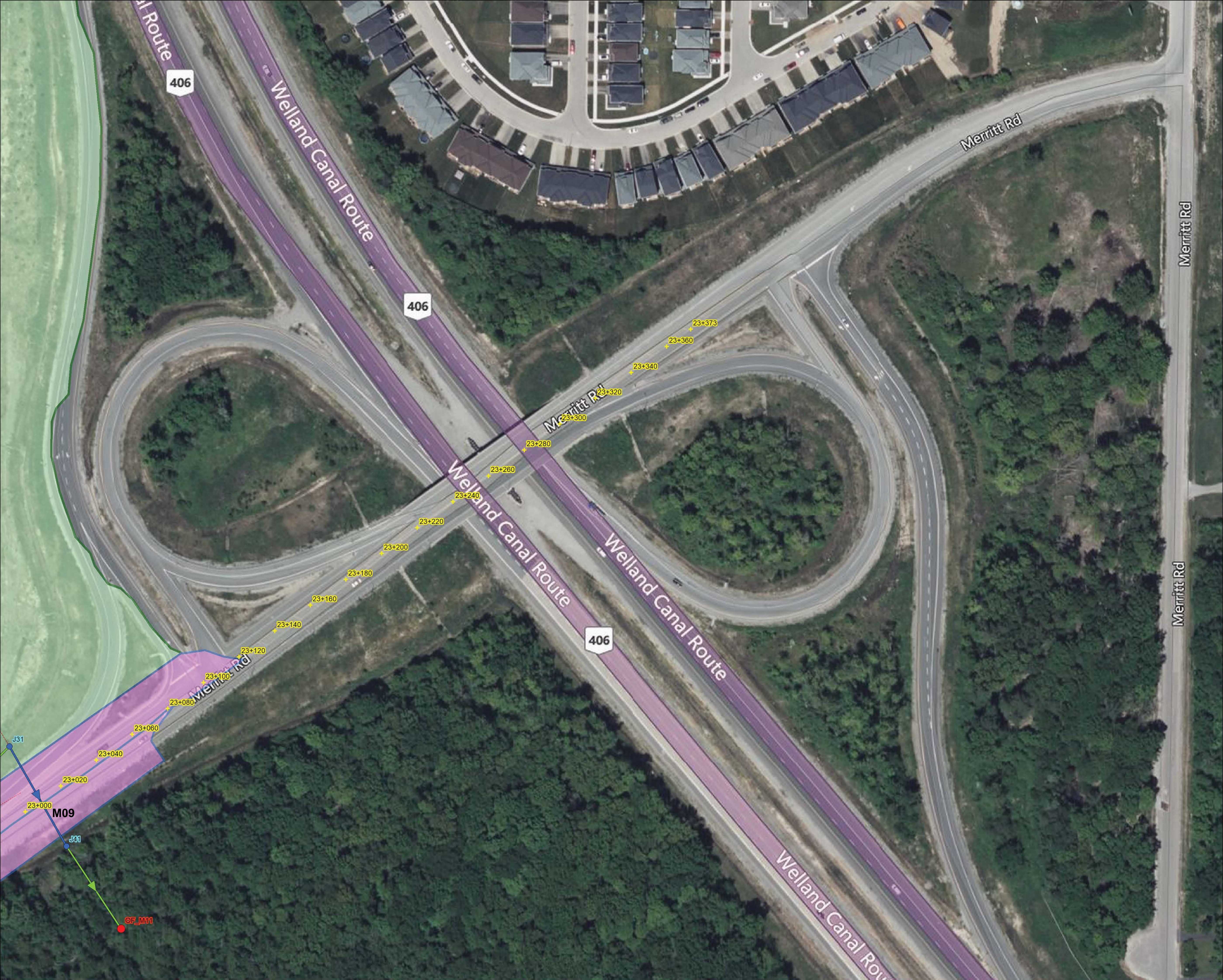
N

35 m



Existing Condition Segment 3 ROW Drainage (2)

Existing Condition
Segment 3
ROW Drainage (3)



Legend

- Junctions
- Storages
- Outfalls

Conduits

- Ditch
- Culvert
- Stream

Subcatchments

- ROW
- Ext

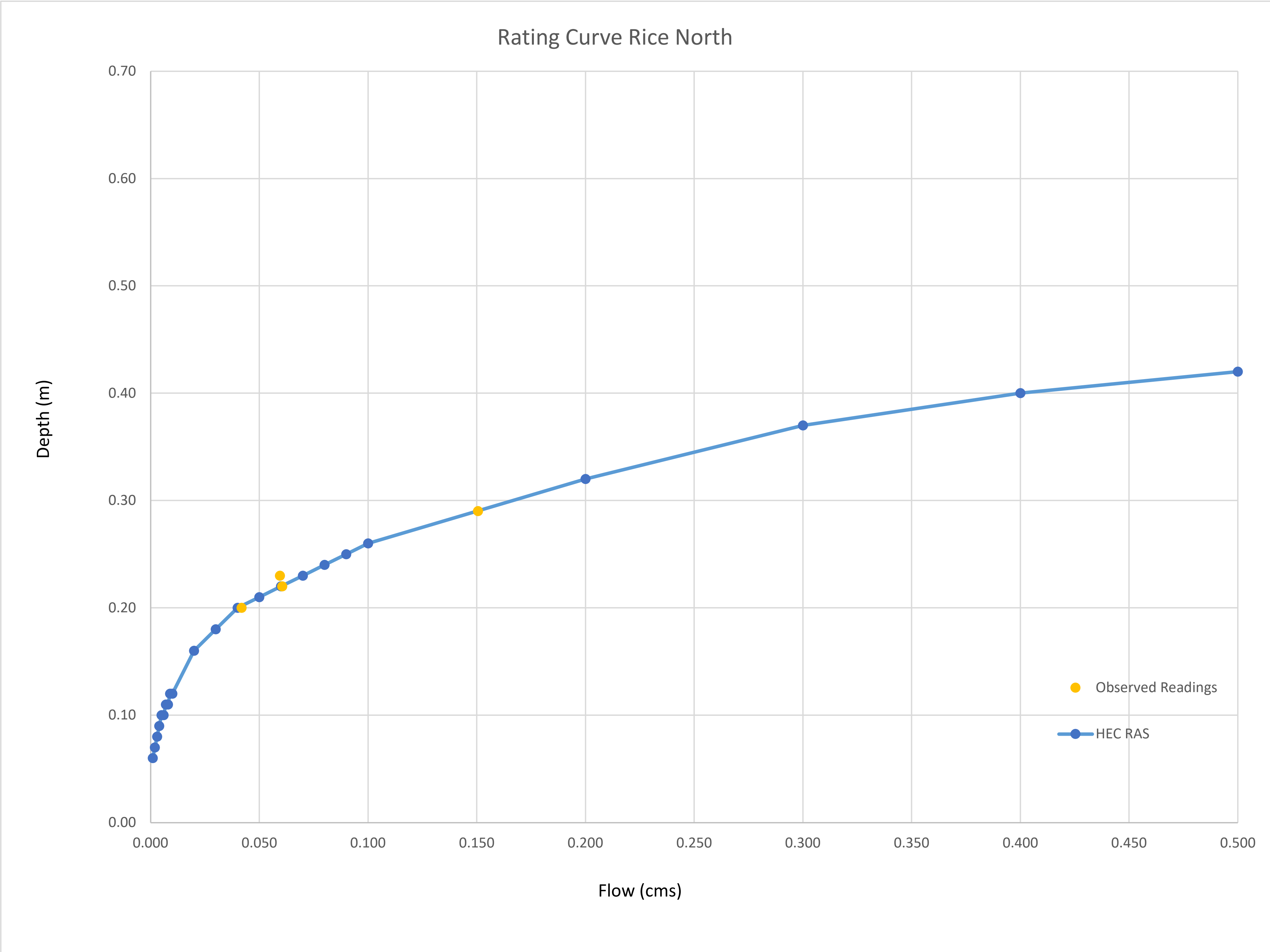
Existing Condition
Segment 3
ROW Drainage (4)

N

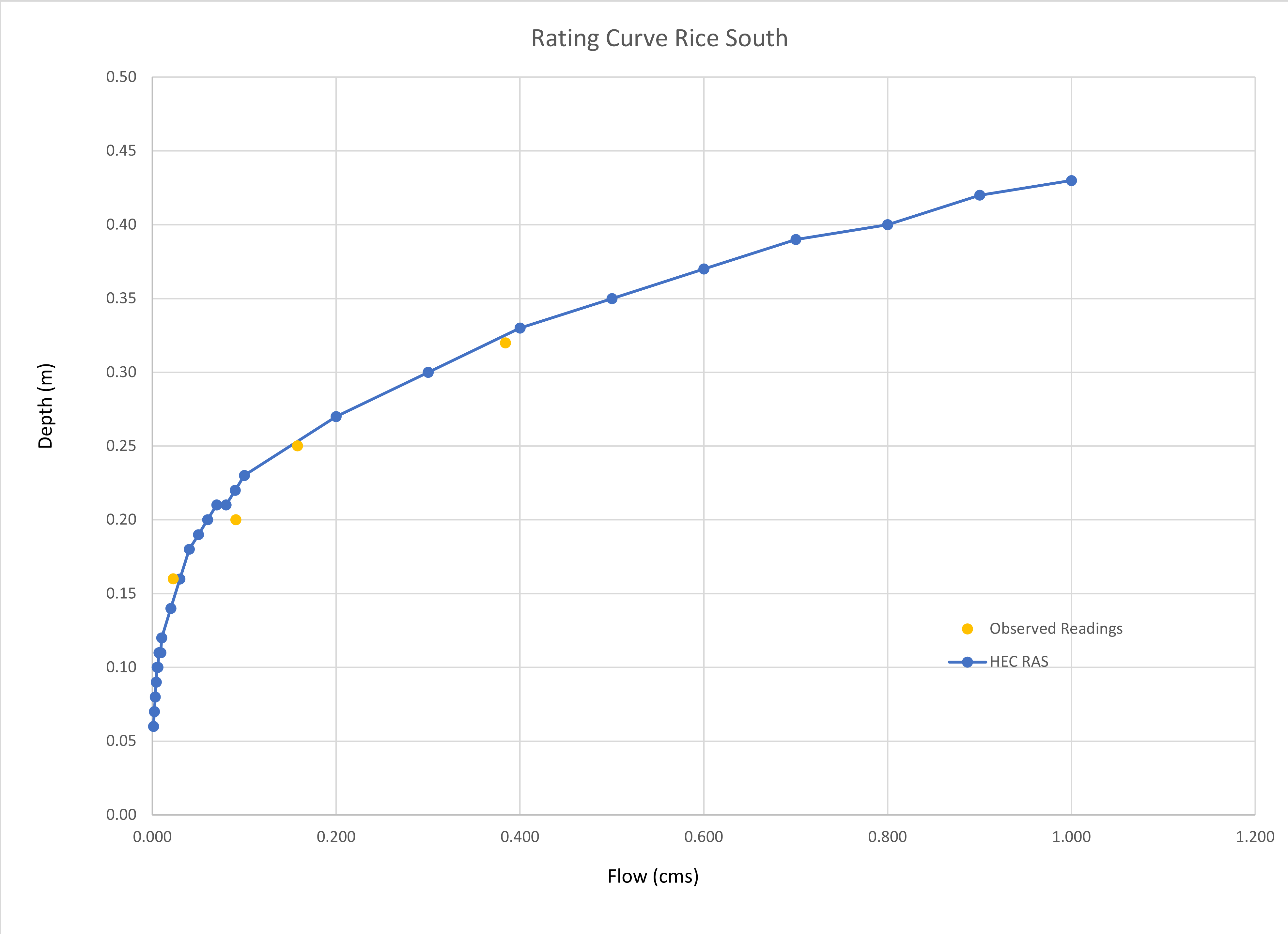
50 m

Appendix B

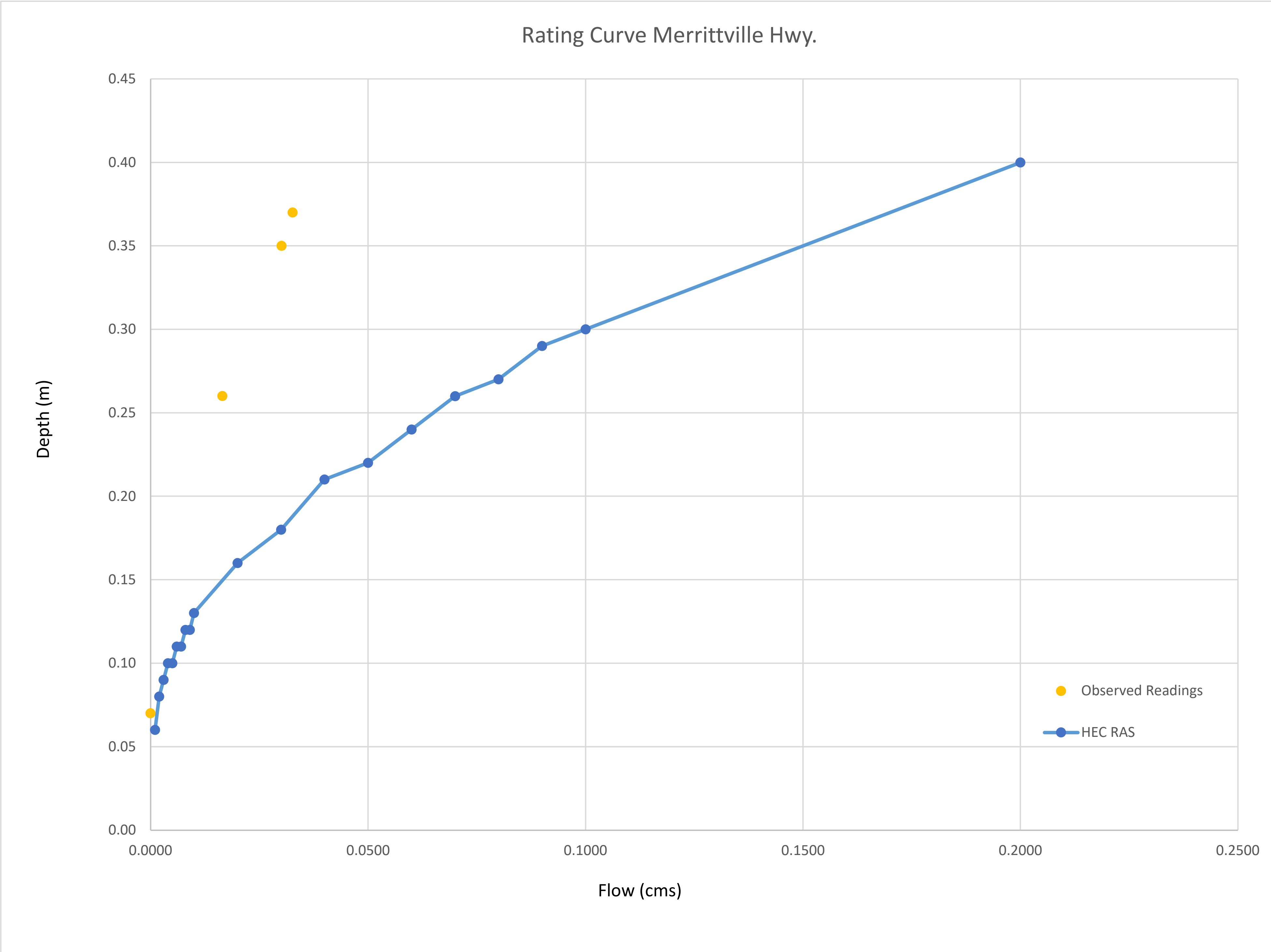
Surface Water Monitoring Data



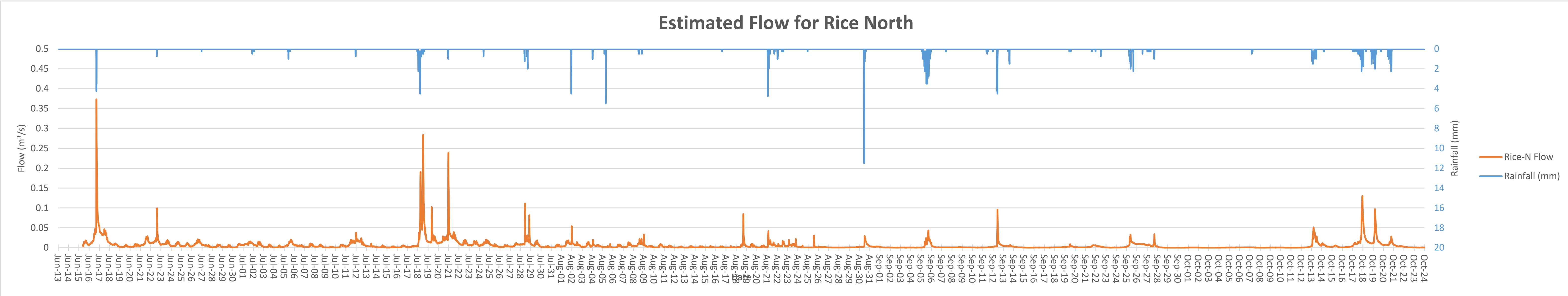
Rating Curve Rice North
Depth (m)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.000
0.050
0.100
0.150
0.200
0.250
0.300
0.350
0.400
0.450
0.500
Flow (cms)
Observed Readings
HEC RAS

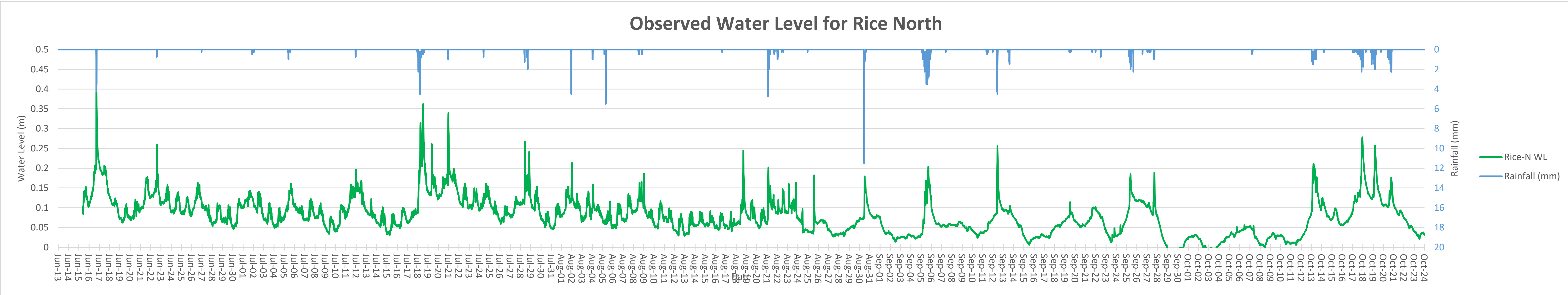


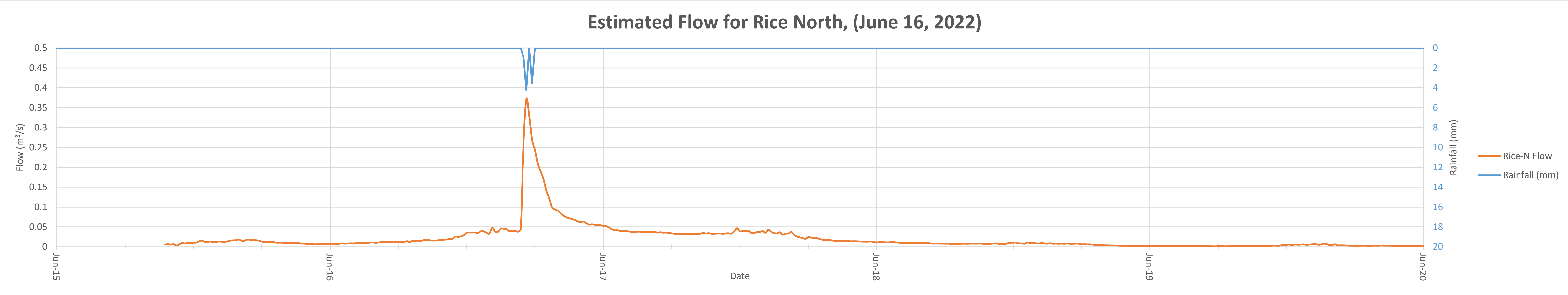
Rating Curve Rice South
Depth (m)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.000
0.200
0.400
0.600
0.800
1.000
1.200
Flow (cms)
Observed Readings
HEC RAS

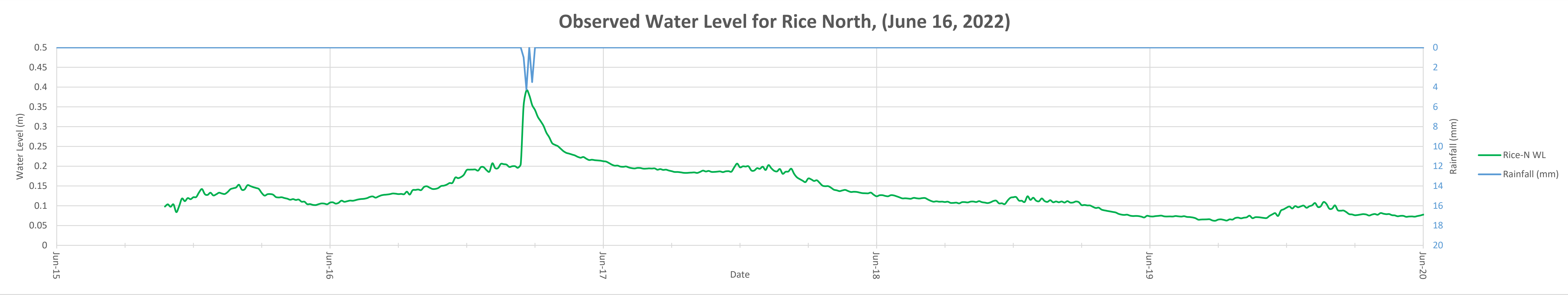


Rating Curve Merrittville Hwy.
Depth (m)
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.0000
0.0500
0.1000
0.1500
0.2000
0.2500
Flow (cms)
Observed Readings
HEC RAS

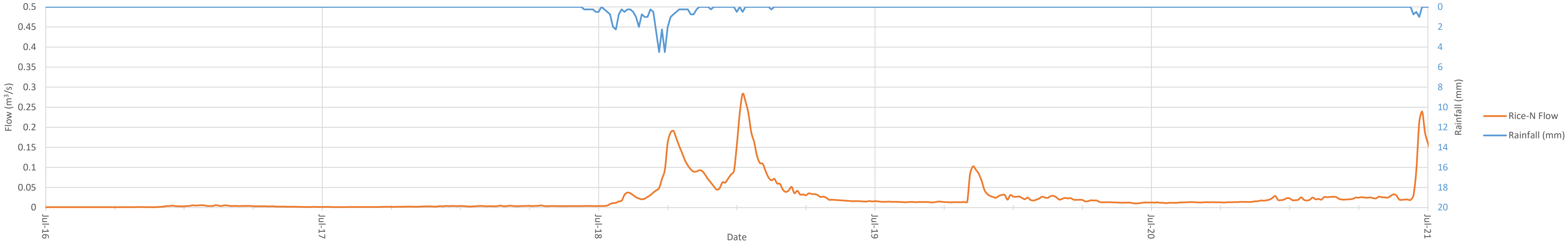

Estimated Flow for Rice North
Flow (m³/s)
Rainfall (mm)
Date
Rice-N Flow
Rainfall (mm)


Observed Water Level for Rice North
Water Level (m)
Rainfall (mm)
Date
Rice-N WL
Rainfall (mm)

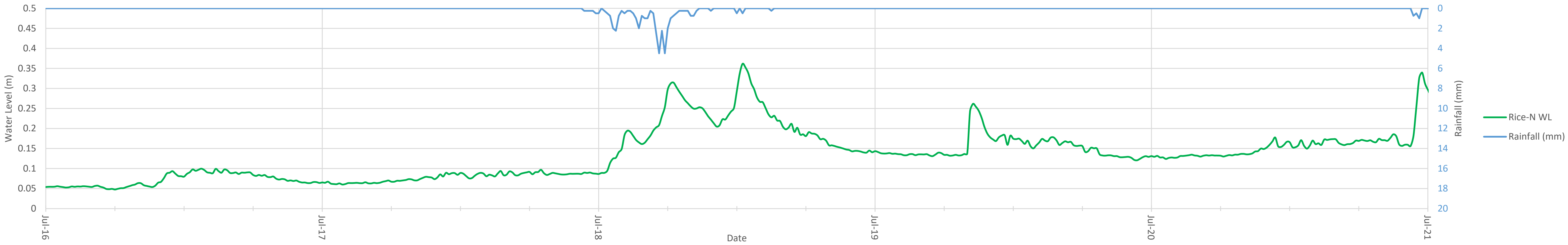

Estimated Flow for Rice North, (June 16, 2022)
Flow (m³/s)
Rainfall (mm)
Date
Jun-15
Jun-16
Jun-17
Jun-18
Jun-19
Jun-20
Rice-N Flow
Rainfall (mm)

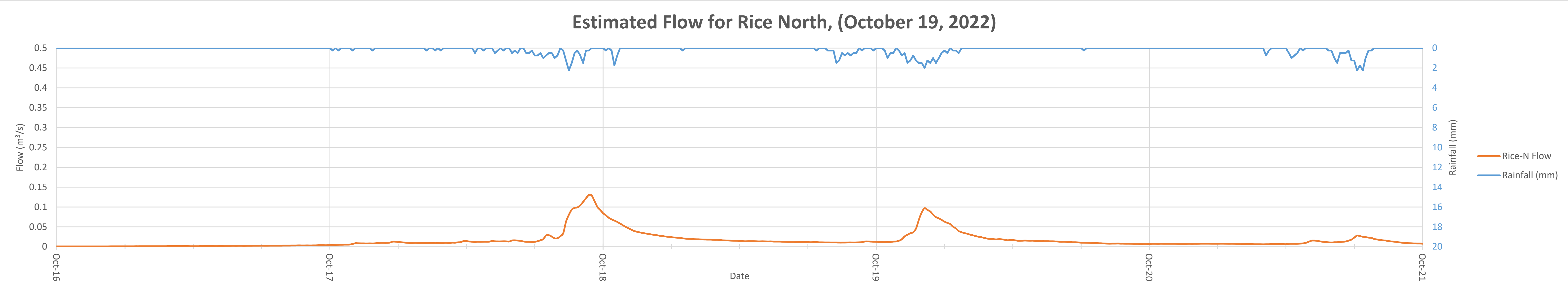

Observed Water Level for Rice North, (June 16, 2022)
Water Level (m)
Rainfall (mm)
Date
Jun-15
Jun-16
Jun-17
Jun-18
Jun-19
Jun-20
Rice-N WL
Rainfall (mm)

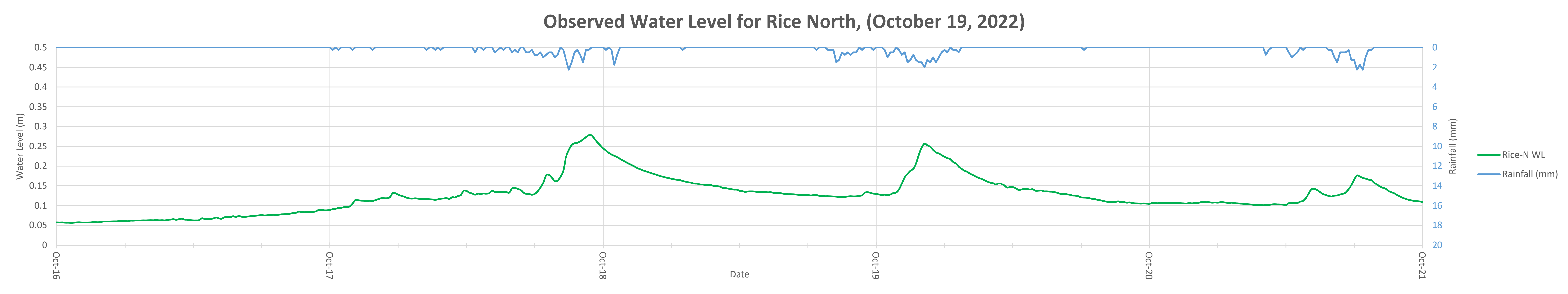
Estimated Flow for Rice North, (July 18, 2022)



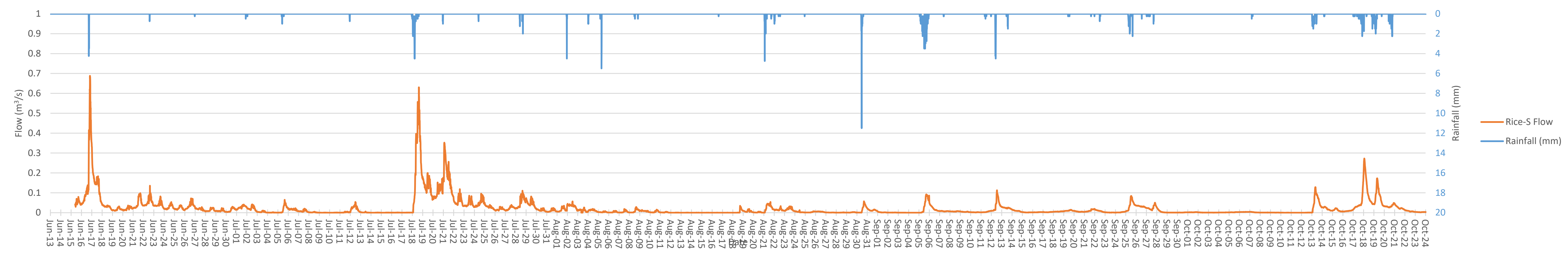
Observed Water Level for Rice North, (July 18, 2022)



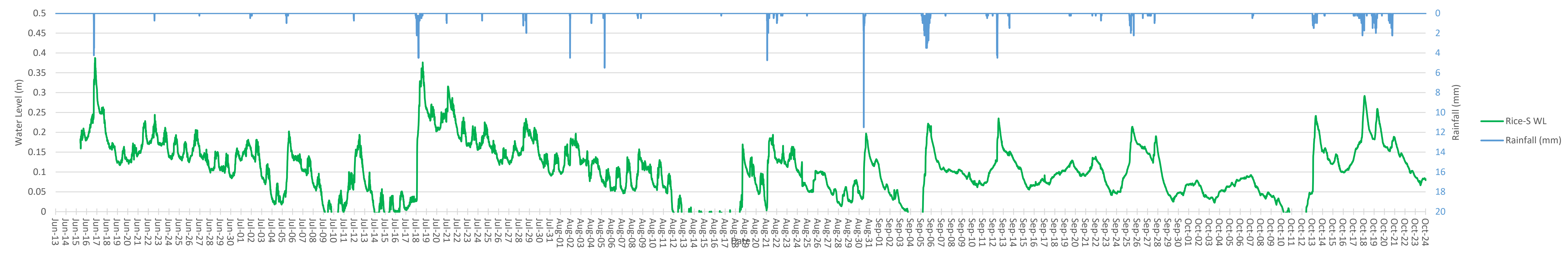

Estimated Flow for Rice North, (October 19, 2022)
Flow (m³/s)
Rainfall (mm)
Date
Oct-16
Oct-17
Oct-18
Oct-19
Oct-20
Oct-21
Rice-N Flow
Rainfall (mm)

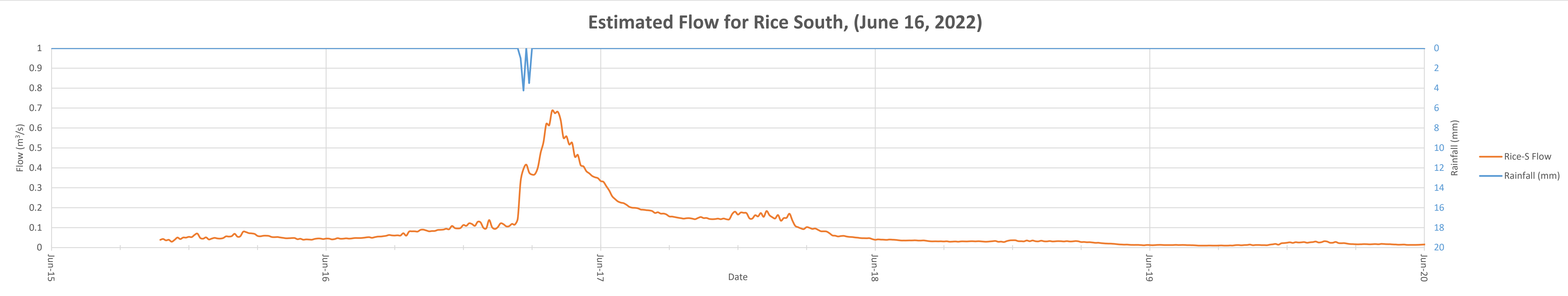

Observed Water Level for Rice North, (October 19, 2022)
Water Level (m)
Rainfall (mm)
Date
Oct-16
Oct-17
Oct-18
Oct-19
Oct-20
Oct-21
Rice-N WL
Rainfall (mm)

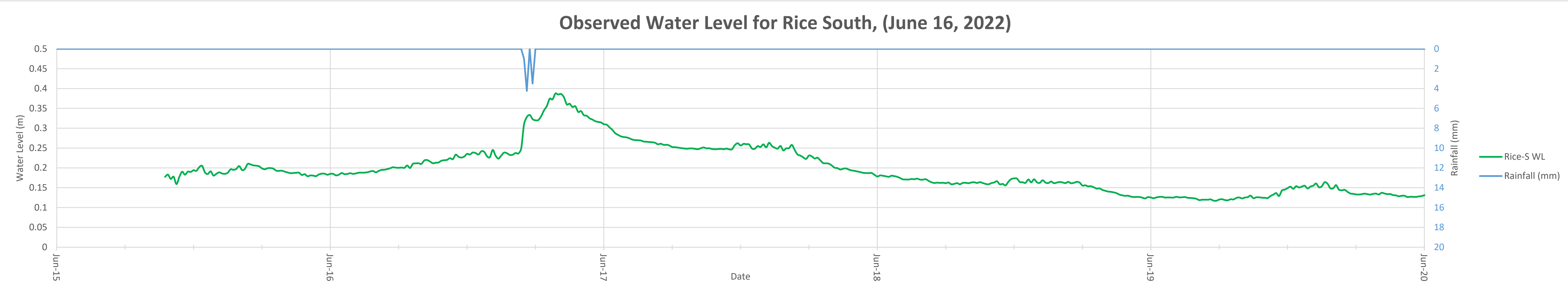
Estimated Flow for Rice South

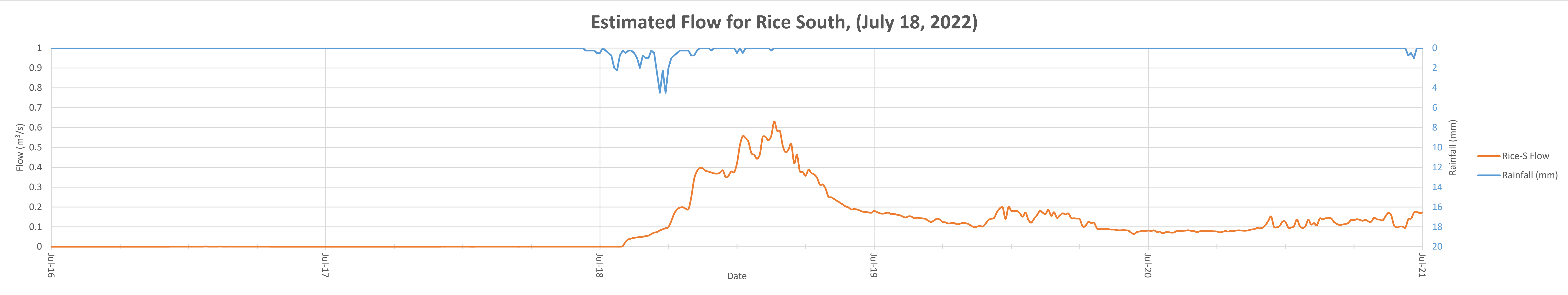


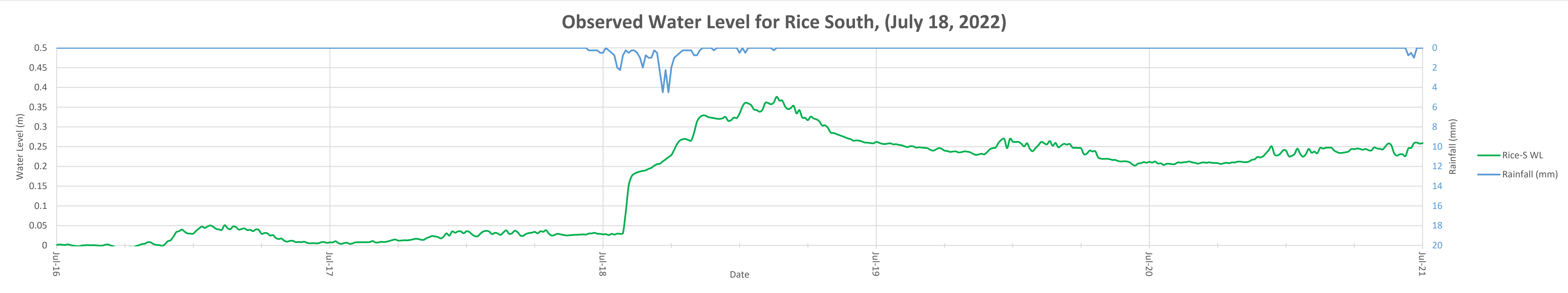
Observed Water Level for Rice South

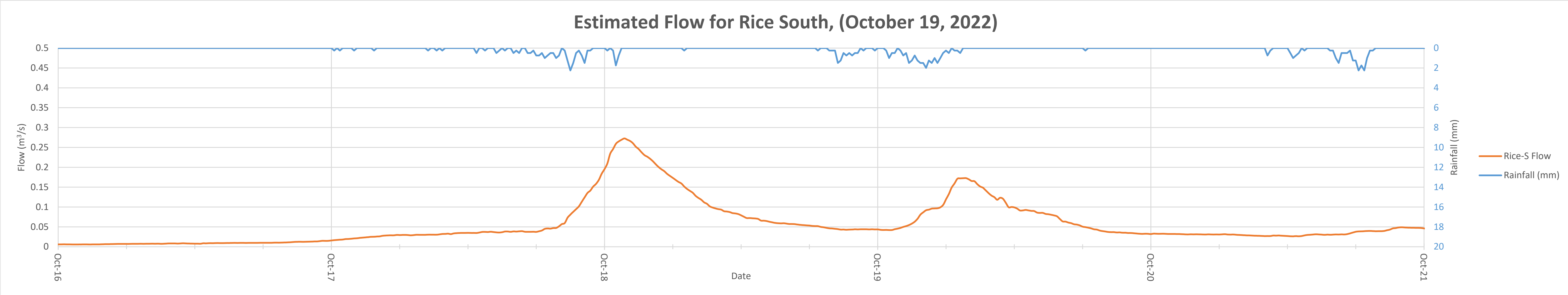


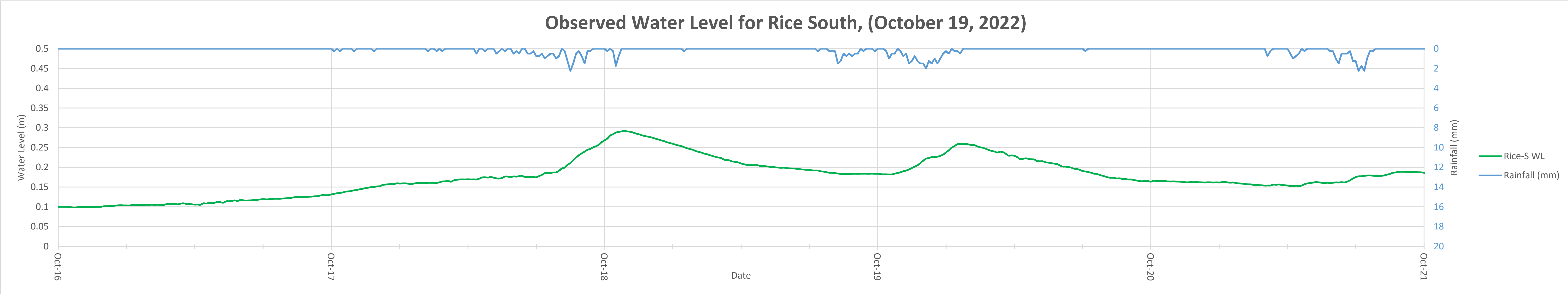

Estimated Flow for Rice South, (June 16, 2022)
Flow (m³/s)
Rainfall (mm)
Date
Rice-S Flow
Rainfall (mm)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
14
16
18
20
Jun-15
Jun-16
Jun-17
Jun-18
Jun-19
Jun-20


Observed Water Level for Rice South, (June 16, 2022)
Water Level (m)
Rainfall (mm)
Date
Rice-S WL
Rainfall (mm)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
2
4
6
8
10
12
14
16
18
20
Jun-15
Jun-16
Jun-17
Jun-18
Jun-19
Jun-20


Estimated Flow for Rice South, (July 18, 2022)
Flow (m³/s)
Rainfall (mm)
Date
Jul-16
Jul-17
Jul-18
Jul-19
Jul-20
Jul-21
Rice-S Flow
Rainfall (mm)

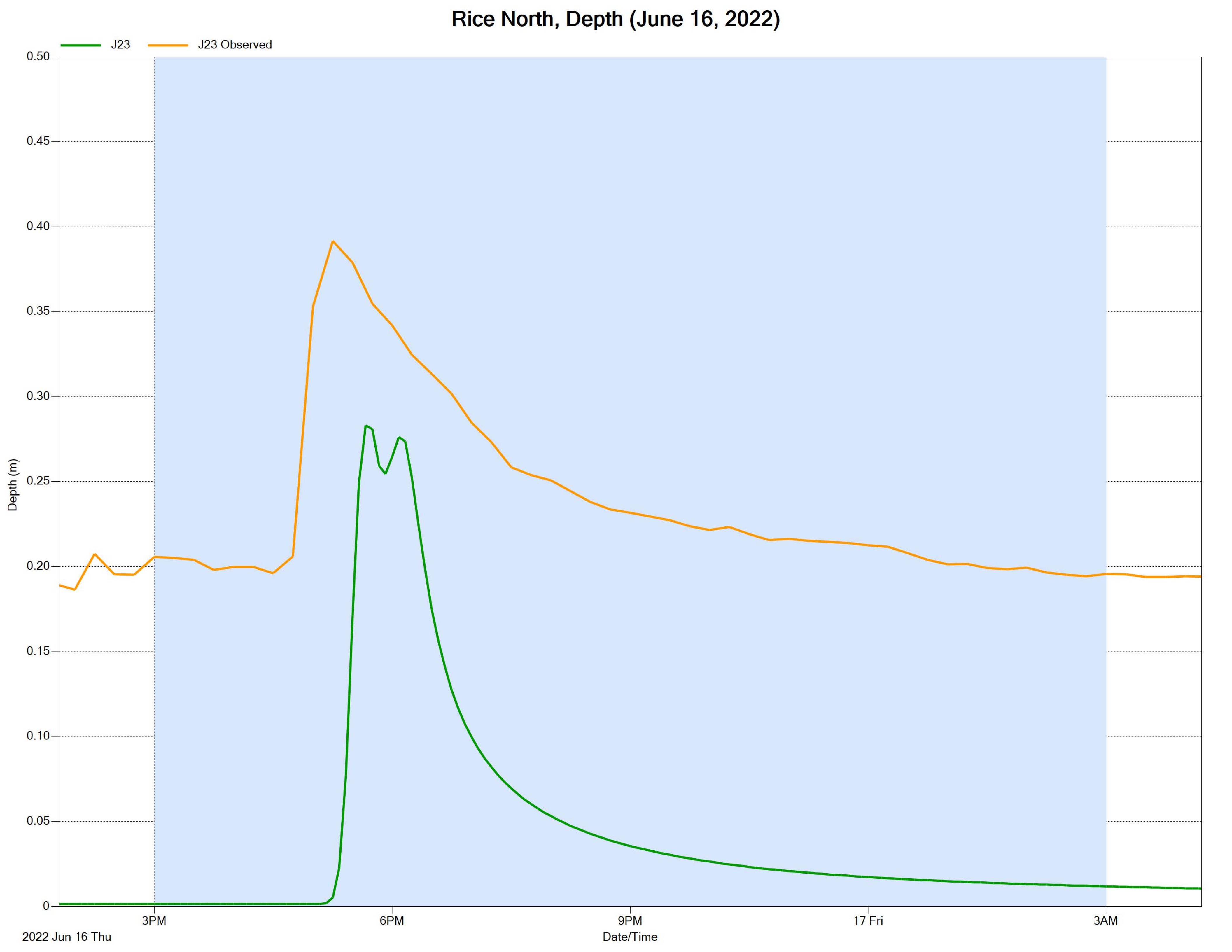

Observed Water Level for Rice South, (July 18, 2022)
Water Level (m)
Rainfall (mm)
Date
Jul-16
Jul-17
Jul-18
Jul-19
Jul-20
Jul-21
Rice-S WL
Rainfall (mm)


Estimated Flow for Rice South, (October 19, 2022)
Flow (m³/s)
Rainfall (mm)
Date
Oct-16
Oct-17
Oct-18
Oct-19
Oct-20
Oct-21
Rice-S Flow
Rainfall (mm)

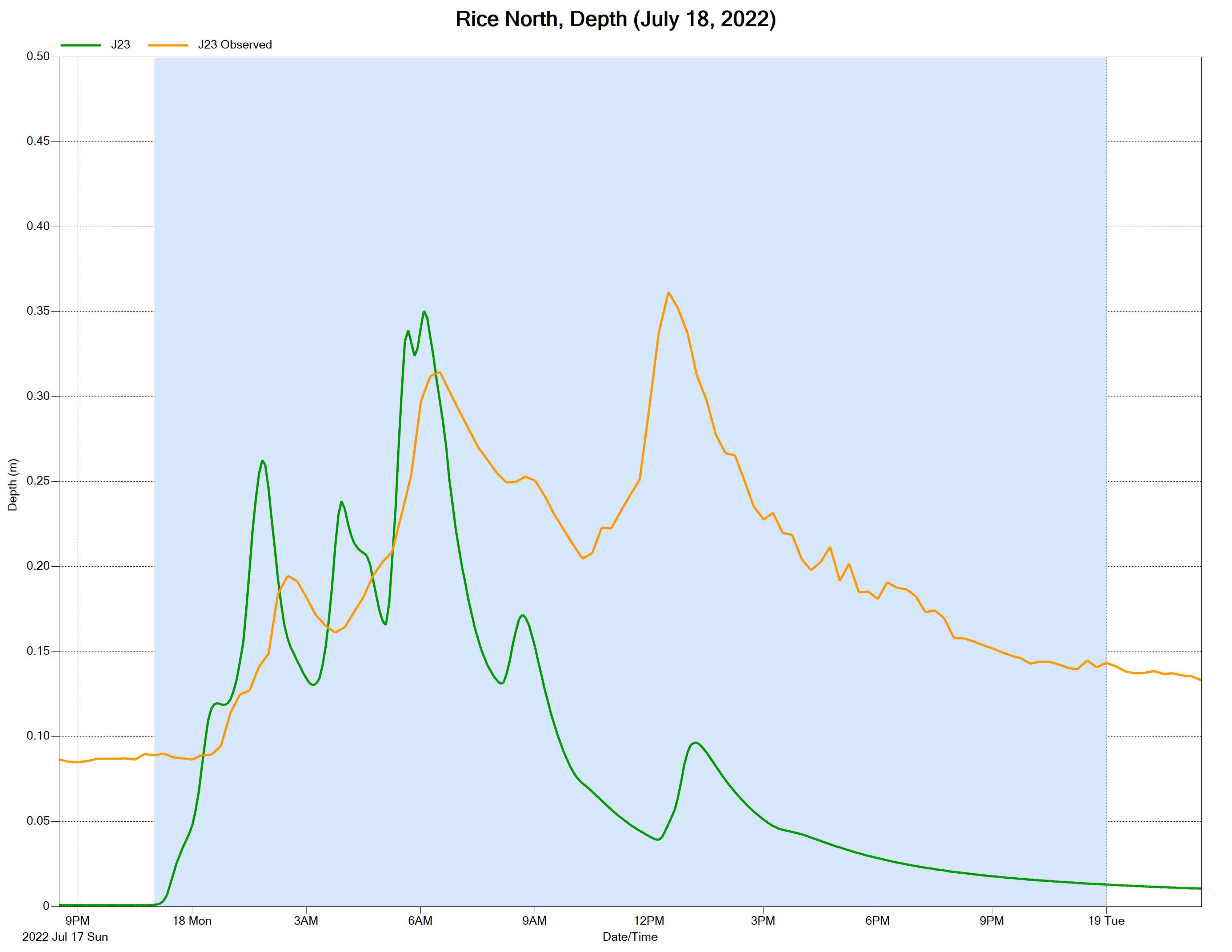

Observed Water Level for Rice South, (October 19, 2022)
Water Level (m)
Rainfall (mm)
Date
Oct-16
Oct-17
Oct-18
Oct-19
Oct-20
Oct-21
Rice-S WL
Rainfall (mm)

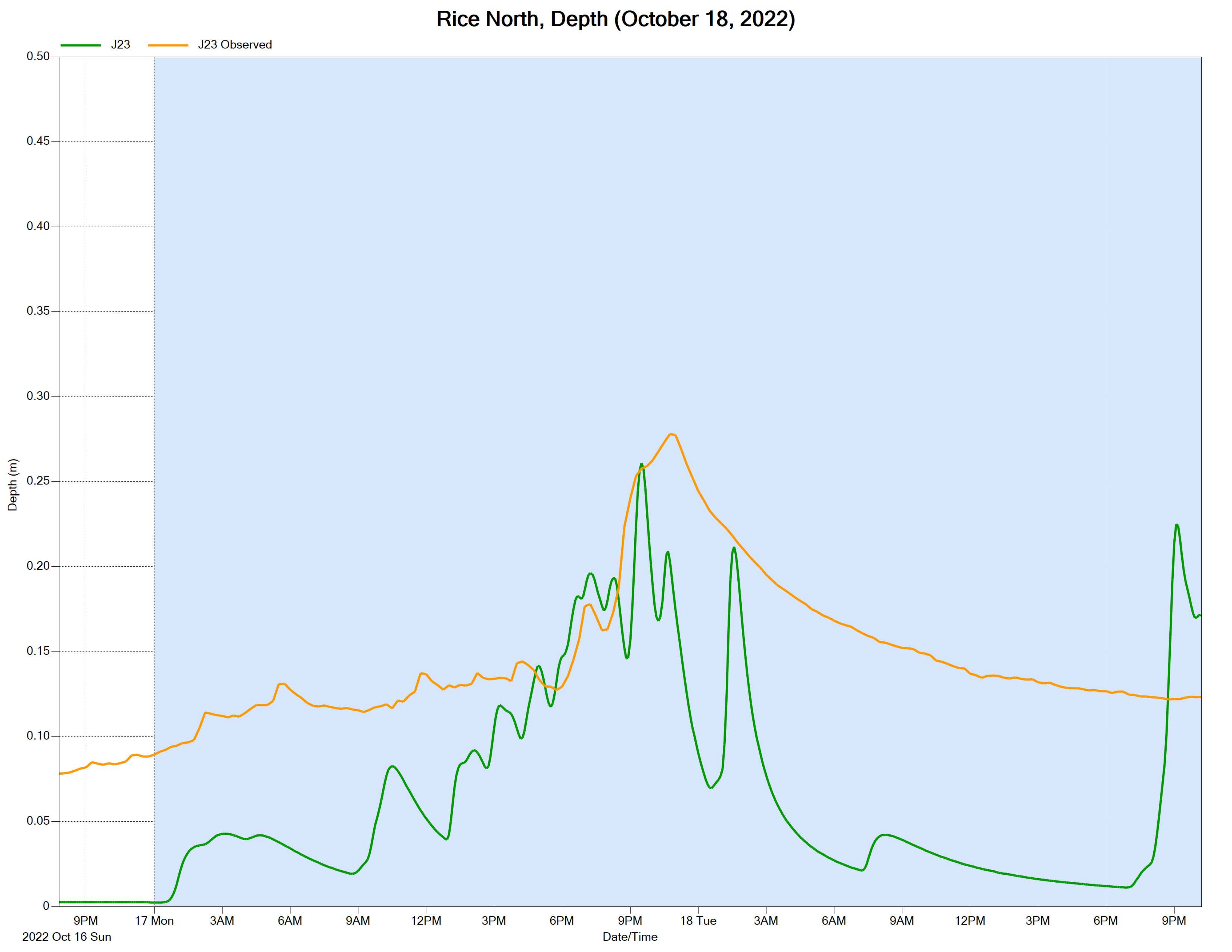
Appendix C

Calibration Results

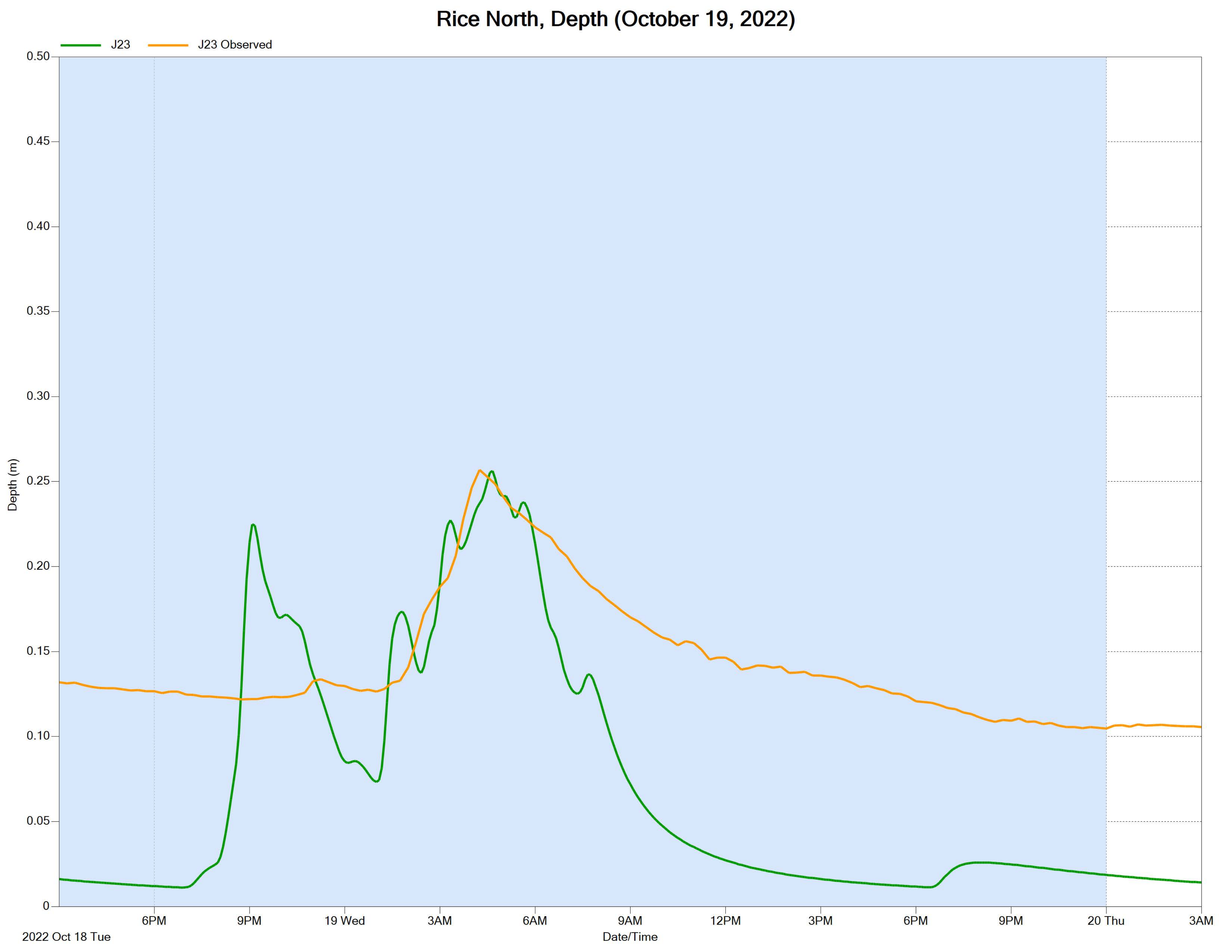


Rice North, Depth (June 16, 2022)
J23
J23 Observed
Depth (m)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
3PM
6PM
9PM
17 Fri
3AM
2022 Jun 16 Thu
Date/Time

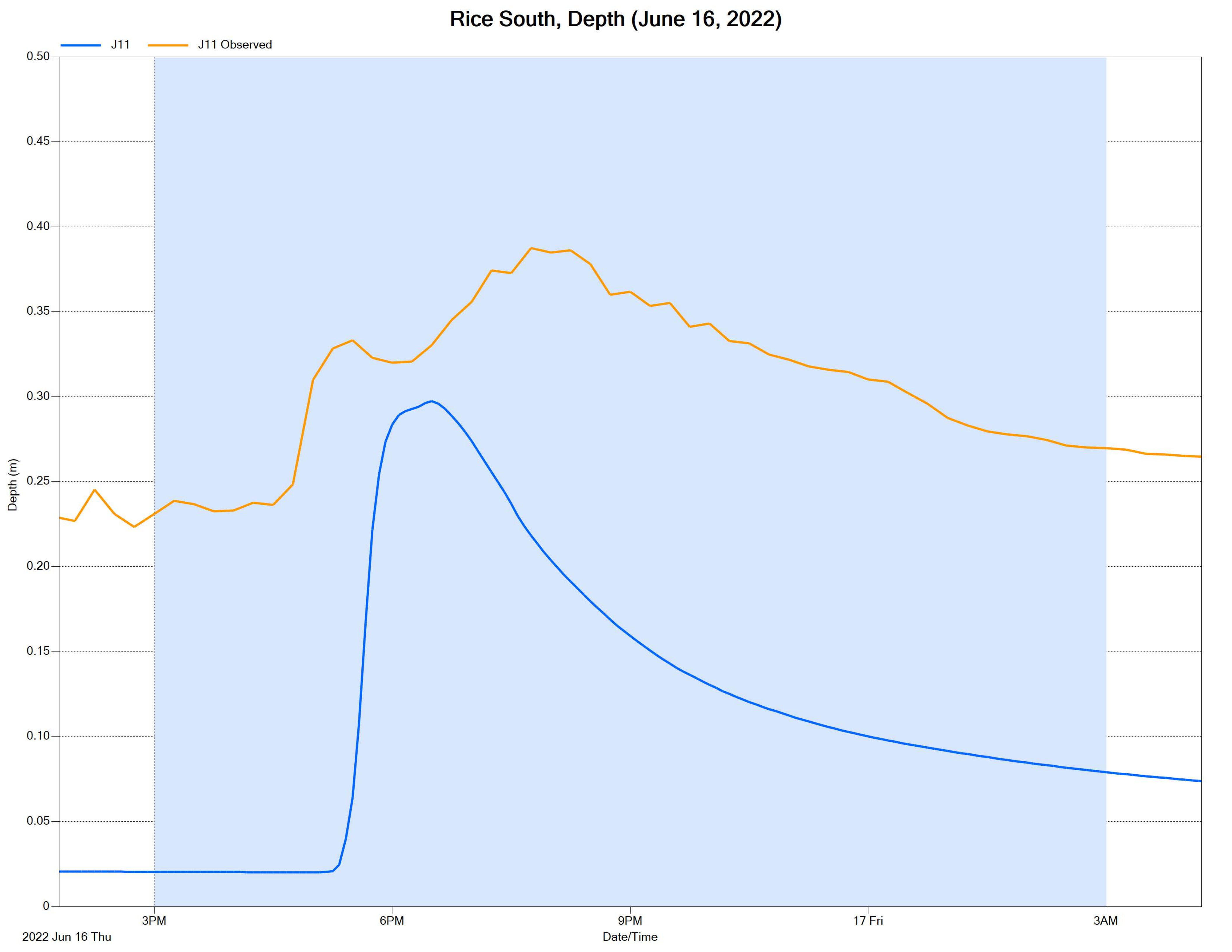

Rice North, Depth (July 18, 2022)
J23
J23 Observed
Depth (m)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
9PM
18 Mon
3AM
6AM
9AM
12PM
3PM
6PM
9PM
19 Tue
2022 Jul 17 Sun
Date/Time



Rice North, Depth (October 18, 2022)
J23
J23 Observed
Depth (m)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
9PM
17 Mon
3AM
6AM
9AM
12PM
3PM
6PM
9PM
18 Tue
3AM
6AM
9AM
12PM
3PM
6PM
9PM
2022 Oct 16 Sun
Date/Time

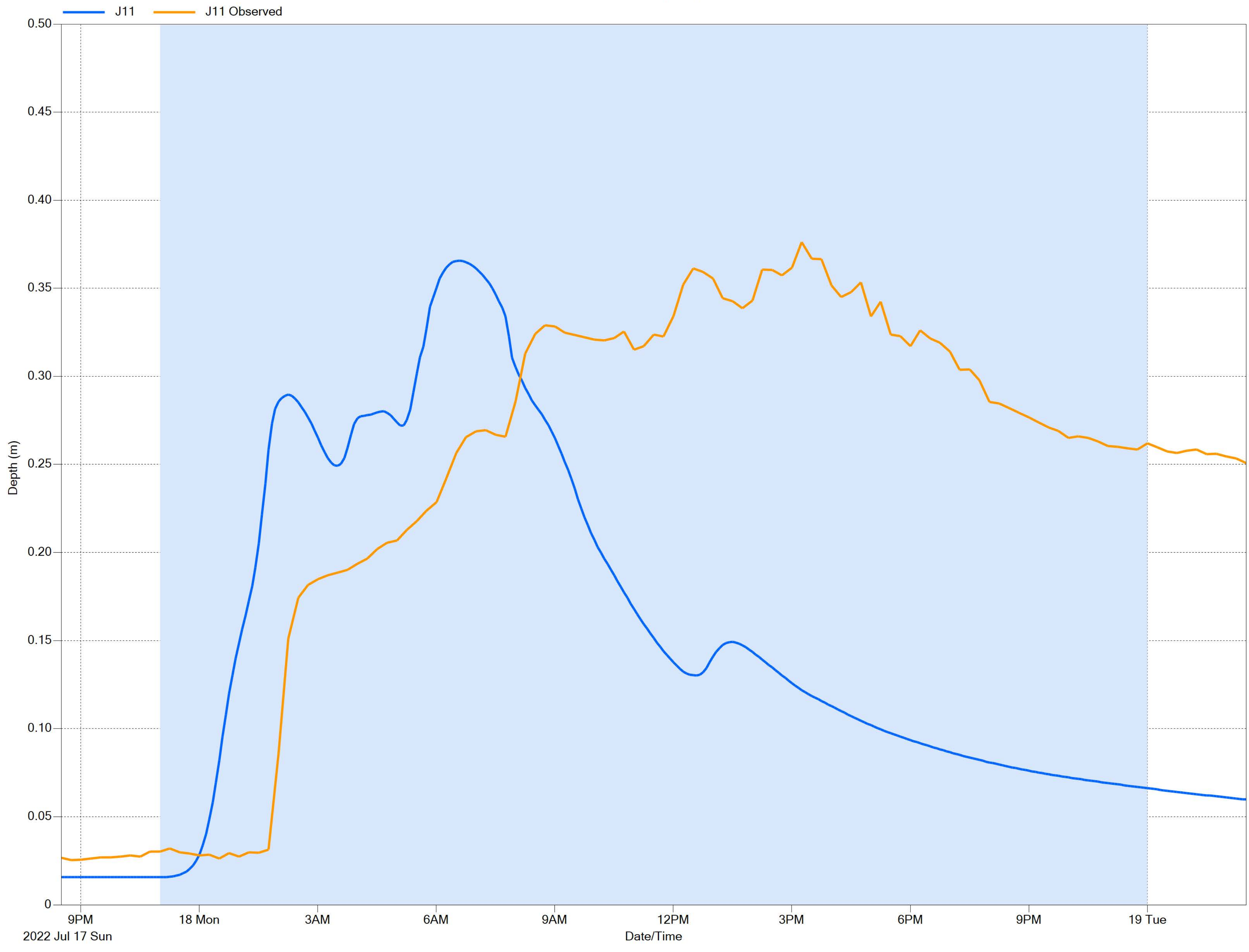


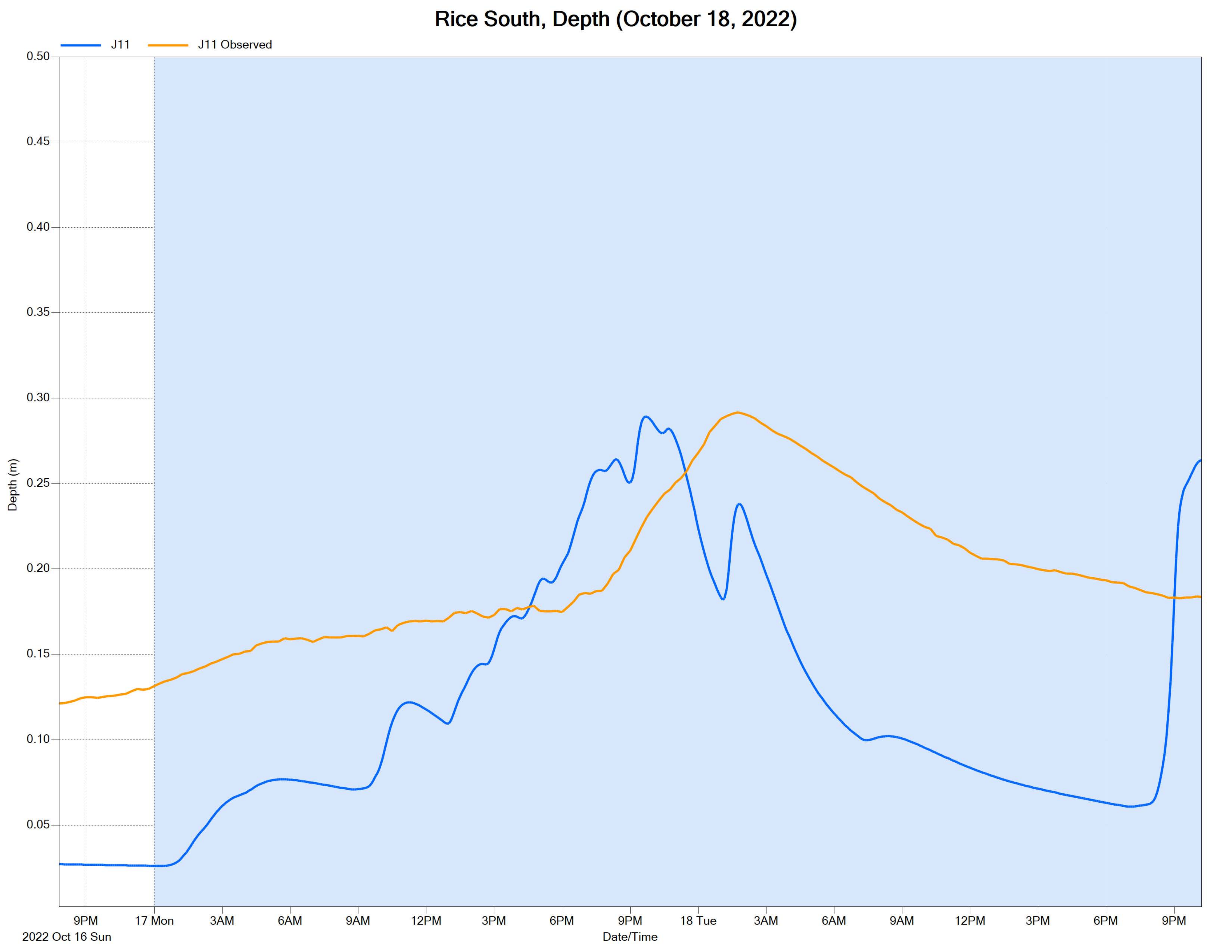
Rice North, Depth (October 19, 2022)
J23
J23 Observed
Depth (m)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
6PM
9PM
19 Wed
3AM
6AM
9AM
12PM
3PM
6PM
9PM
20 Thu
3AM
2022 Oct 18 Tue
Date/Time



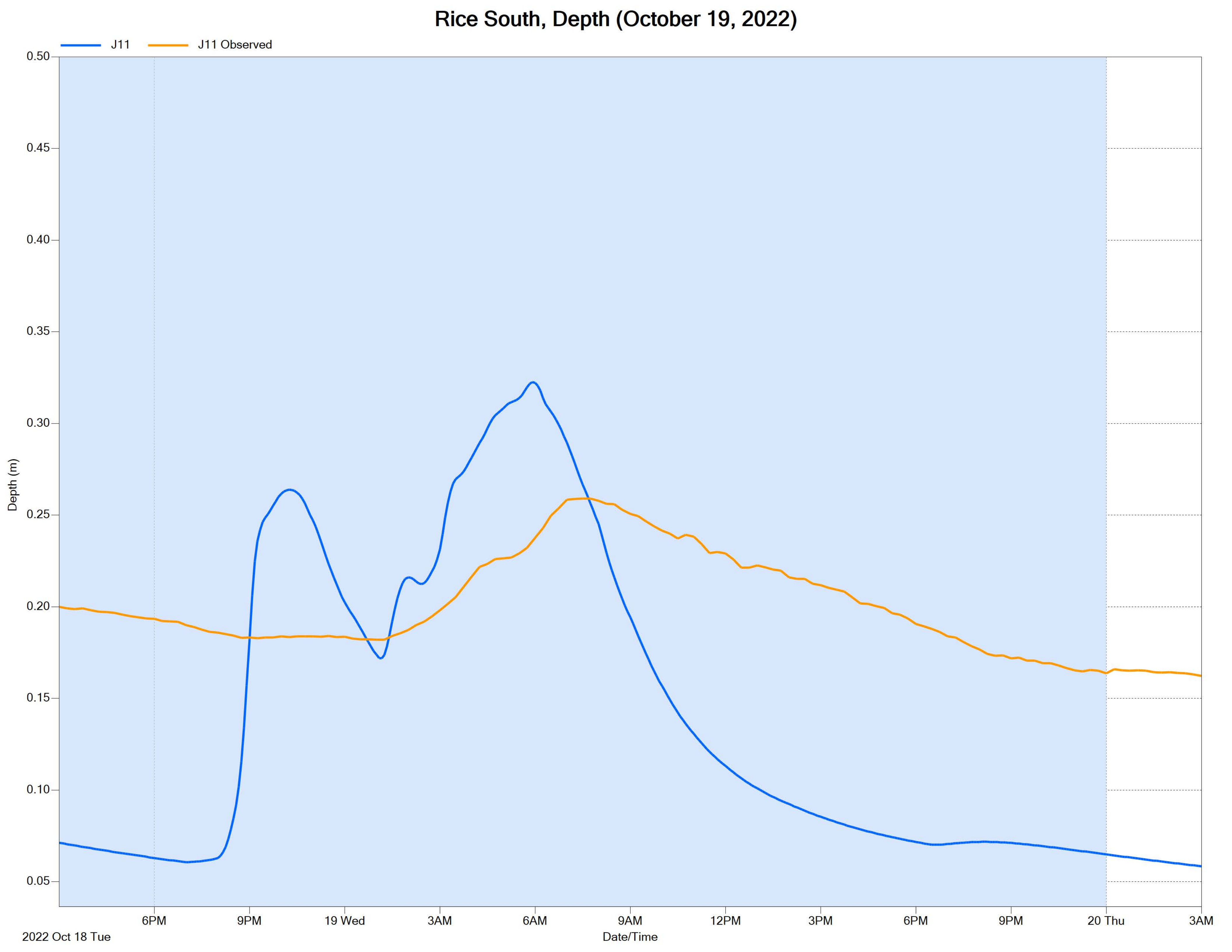
Rice South, Depth (June 16, 2022)
J11
J11 Observed
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
Depth (m)
3PM
6PM
9PM
17 Fri
3AM
2022 Jun 16 Thu
Date/Time

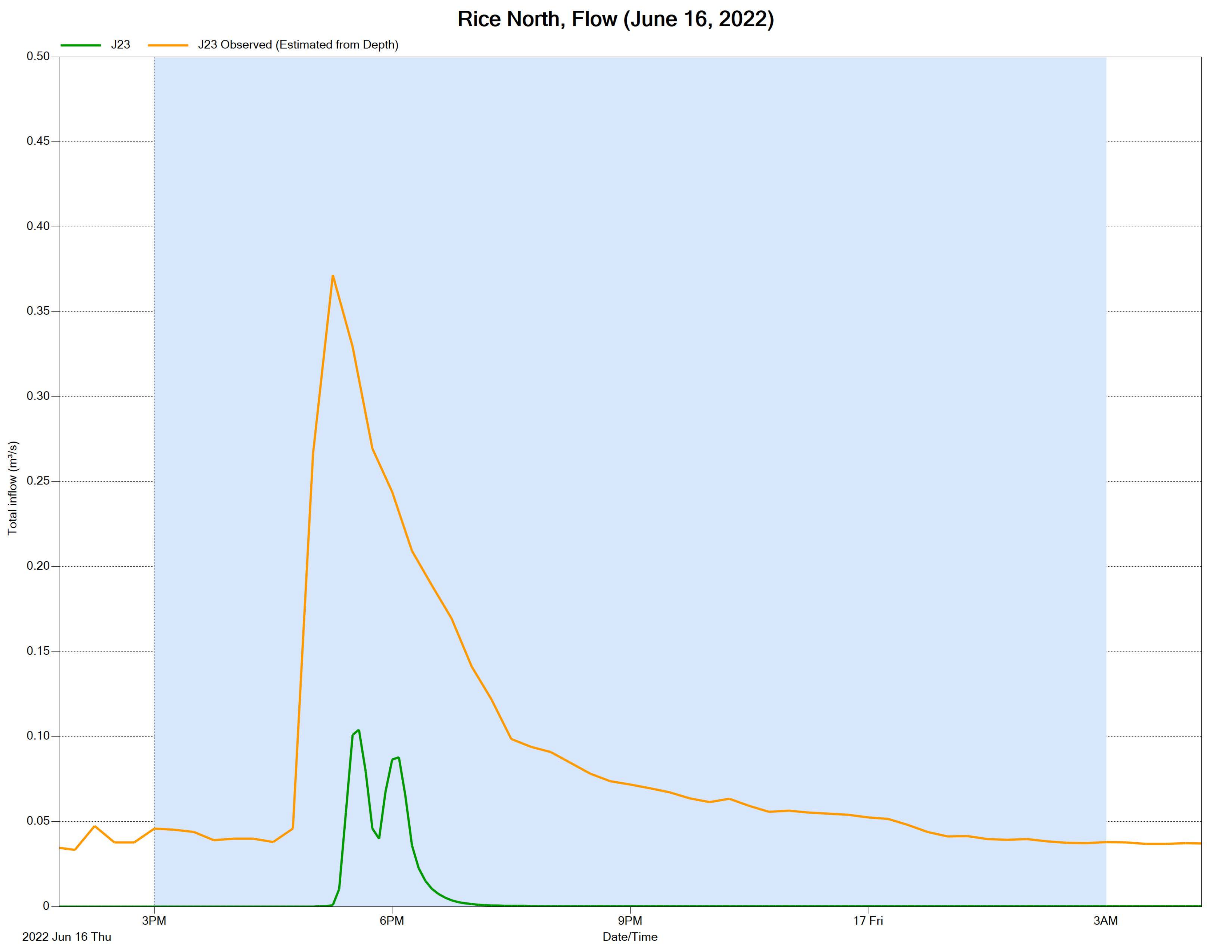
Rice South, Depth (July 18, 2022)





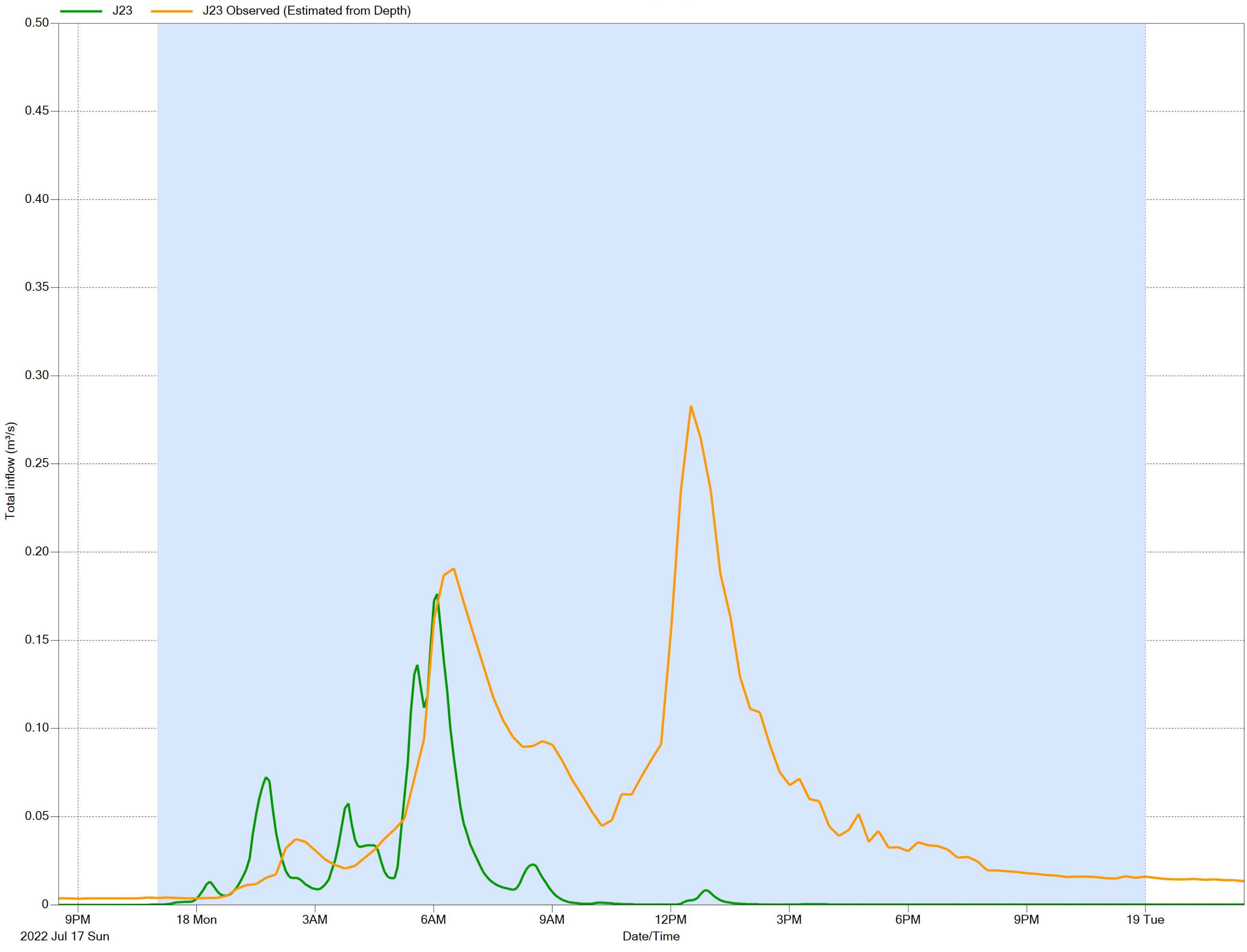
Rice South, Depth (October 18, 2022)
J11
J11 Observed
Depth (m)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
9PM
17 Mon
3AM
6AM
9AM
12PM
3PM
6PM
9PM
18 Tue
3AM
6AM
9AM
12PM
3PM
6PM
9PM
2022 Oct 16 Sun
Date/Time

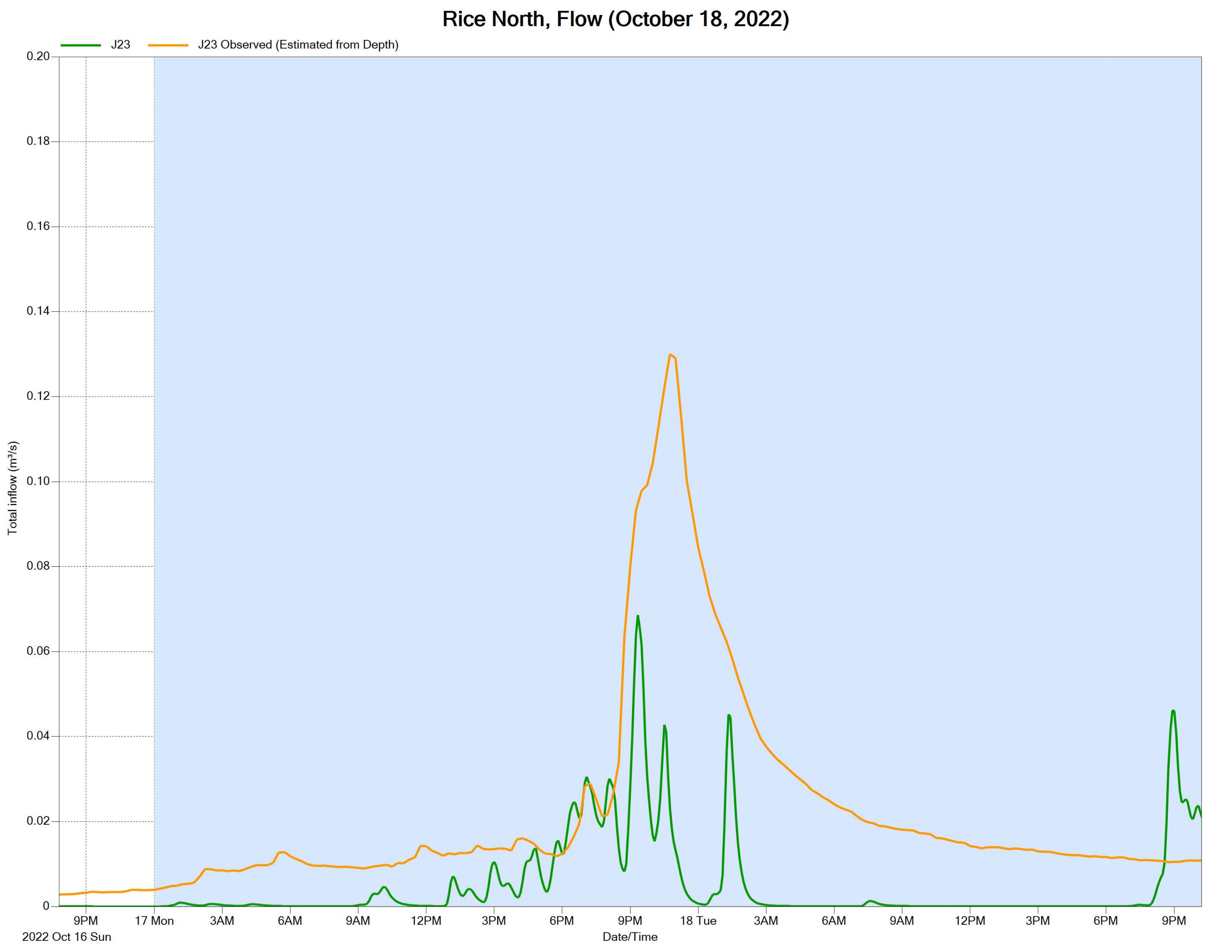

Rice South, Depth (October 19, 2022)
J11
J11 Observed
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
Depth (m)
6PM
9PM
19 Wed
3AM
6AM
9AM
12PM
3PM
6PM
9PM
20 Thu
3AM
2022 Oct 18 Tue
Date/Time



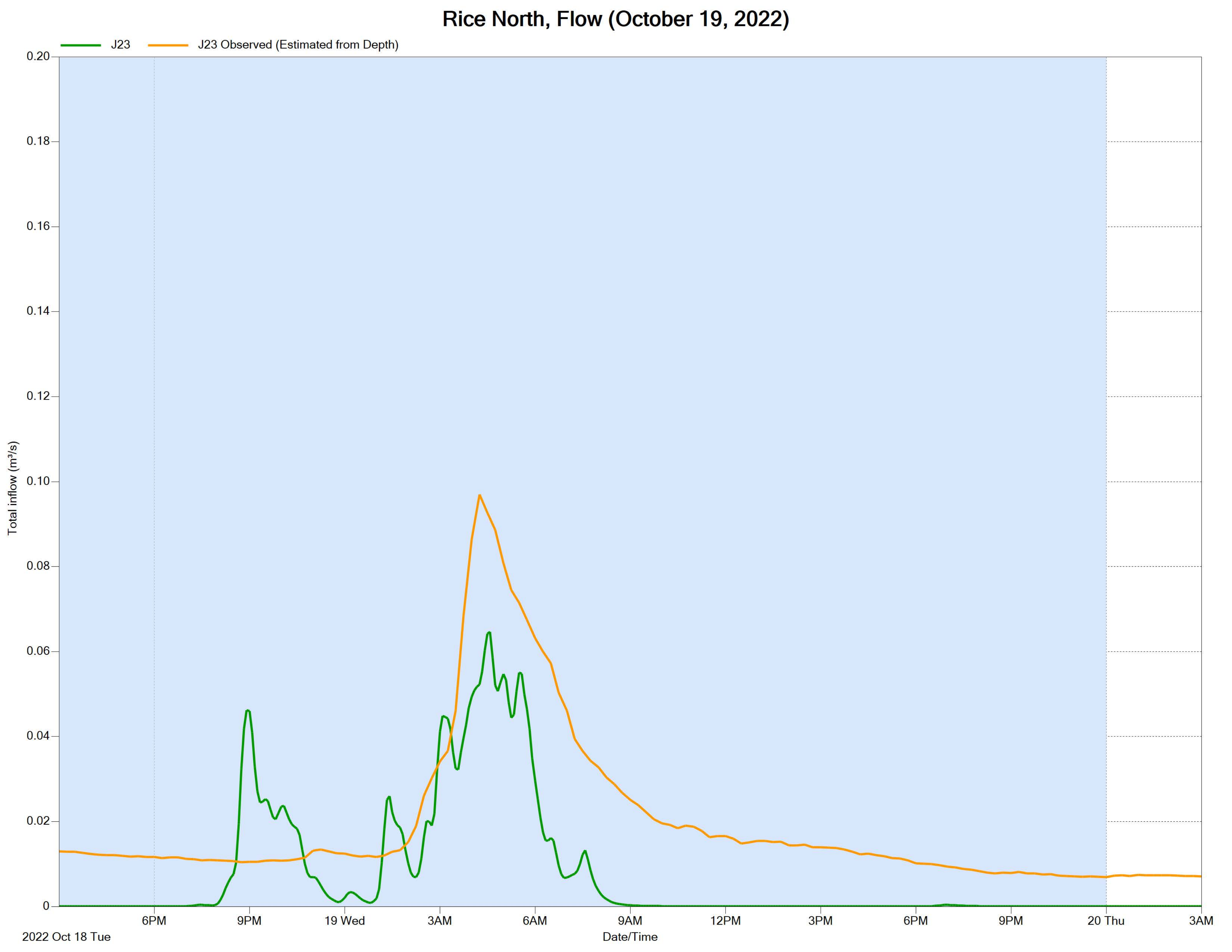
Rice North, Flow (June 16, 2022)
J23
J23 Observed (Estimated from Depth)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
Total inflow (m³/s)
3PM
6PM
9PM
17 Fri
3AM
2022 Jun 16 Thu
Date/Time

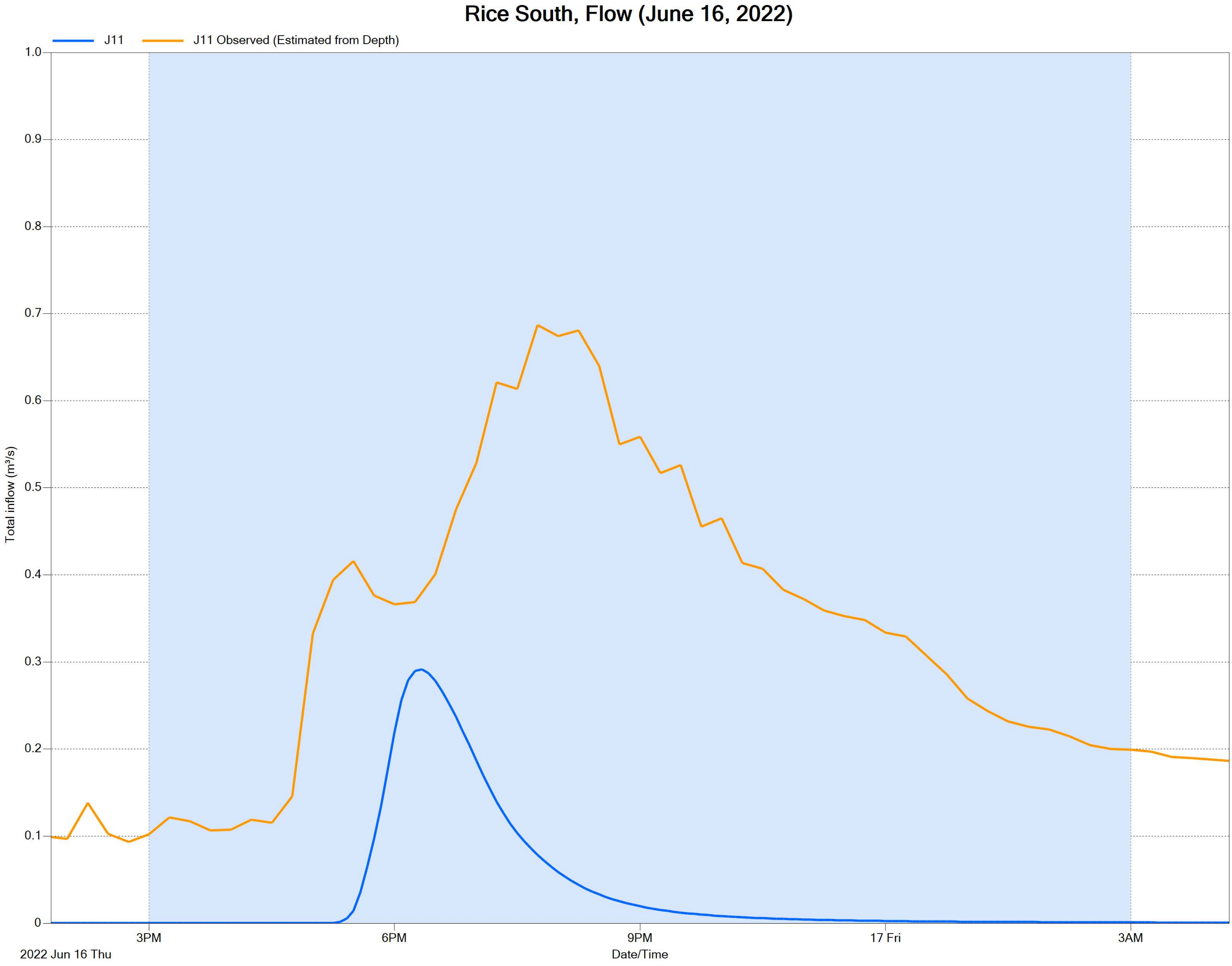
Rice North, Flow (July 18, 2022)



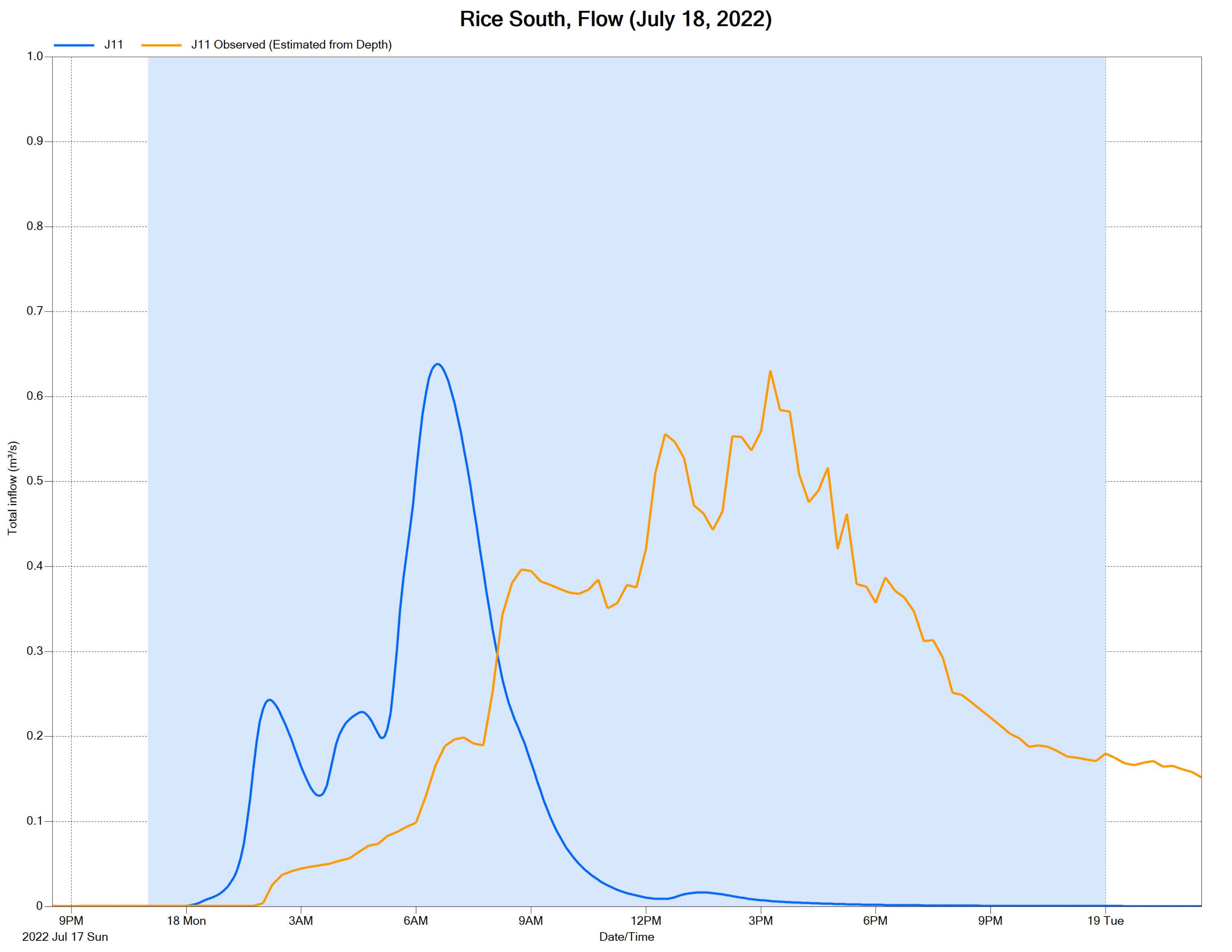


Rice North, Flow (October 18, 2022)
J23
J23 Observed (Estimated from Depth)
Total inflow (m³/s)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0
9PM
17 Mon
3AM
6AM
9AM
12PM
3PM
6PM
9PM
18 Tue
3AM
6AM
9AM
12PM
3PM
6PM
9PM
2022 Oct 16 Sun
Date/Time

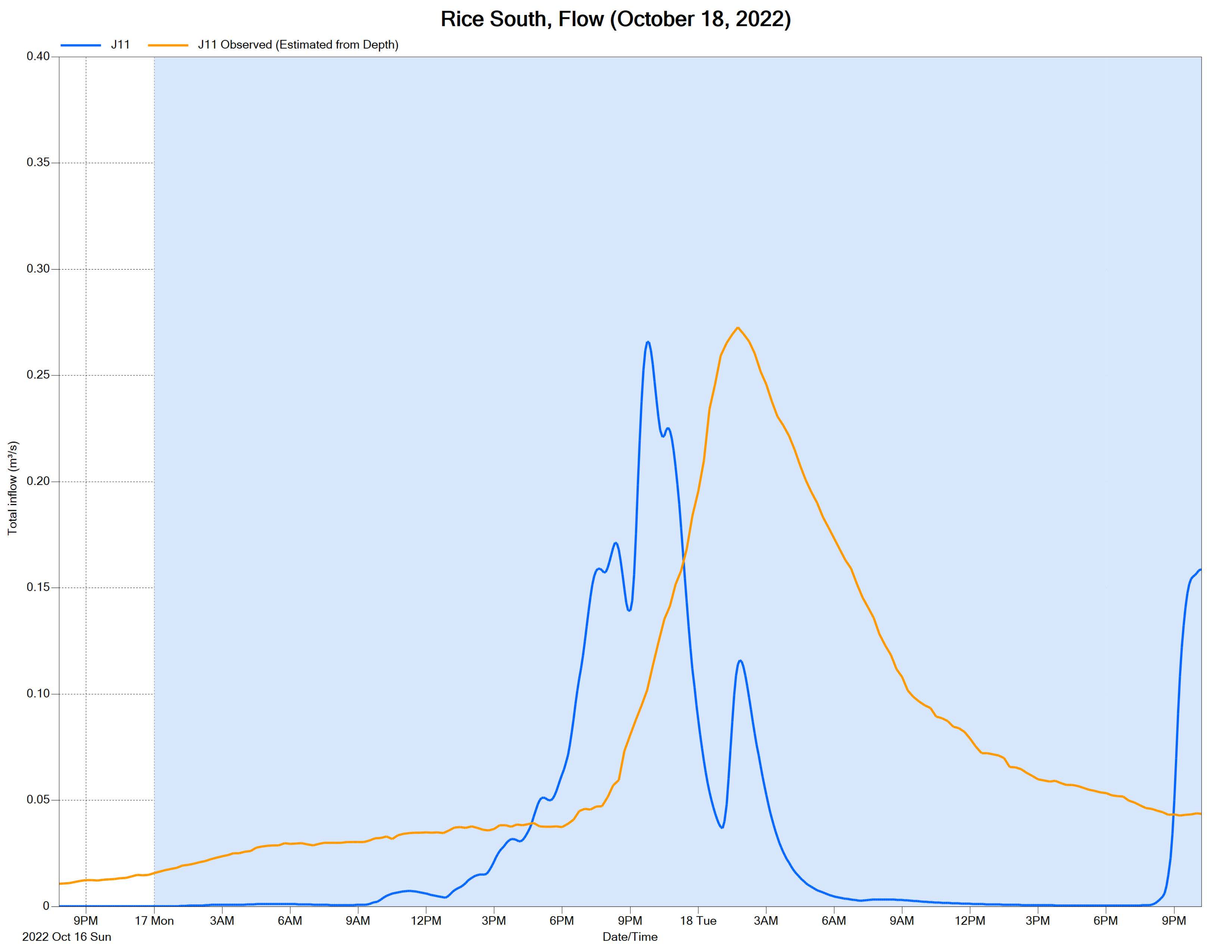

Rice North, Flow (October 19, 2022)
J23
J23 Observed (Estimated from Depth)
Total inflow (m³/s)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0
6PM
9PM
19 Wed
3AM
6AM
9AM
12PM
3PM
6PM
9PM
20 Thu
3AM
2022 Oct 18 Tue
Date/Time



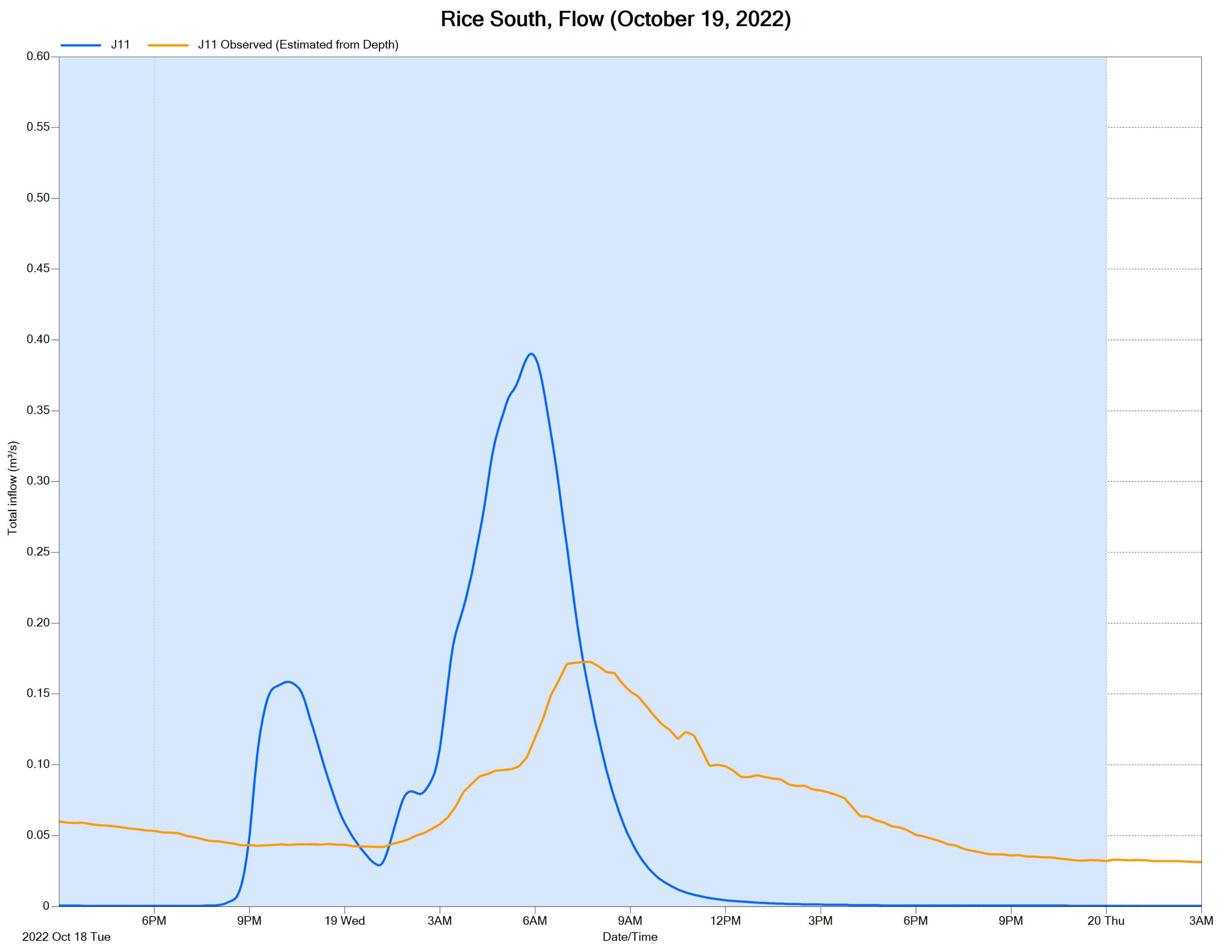
Rice South, Flow (June 16, 2022)
J11
J11 Observed (Estimated from Depth)
Total inflow (m³/s)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
3PM
6PM
9PM
17 Fri
3AM
2022 Jun 16 Thu
Date/Time



Rice South, Flow (July 18, 2022)
J11
J11 Observed (Estimated from Depth)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Total inflow (m³/s)
9PM
18 Mon
3AM
6AM
9AM
12PM
3PM
6PM
9PM
19 Tue
2022 Jul 17 Sun
Date/Time



Rice South, Flow (October 18, 2022)
J11
J11 Observed (Estimated from Depth)
Total inflow (m³/s)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
9PM
17 Mon
3AM
6AM
9AM
12PM
3PM
6PM
9PM
18 Tue
3AM
6AM
9AM
12PM
3PM
6PM
9PM
2022 Oct 16 Sun
Date/Time



Rice South, Flow (October 19, 2022)
J11
J11 Observed (Estimated from Depth)
Total inflow (m³/s)
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
6PM
9PM
19 Wed
3AM
6AM
9AM
12PM
3PM
6PM
9PM
20 Thu
3AM
2022 Oct 18 Tue
Date/Time

Appendix D

Proposed Roadway Designs

PLAN LEGEND

- EXISTING PROPERTY LINE
- PROPOSED PROPERTY LINE
- PROPERTY TAKING
- PROPOSED BIKE PATH CROSSING
- PROPOSED MULTI USE PATH
- PROPOSED SIDEWALK
- PROPOSED BOULEVARD
- PROPOSED ROAD
- PROPOSED MEDIAN
- PROPOSED DITCH

PROFILE LEGEND

- EXISTING GROUND
- PROPOSED CENTERLINE OF ROAD
- DITCH PROFILE

RICE ROAD (SEGMENT 4)

REGION OF NIAGARA

PLAN AND PROFILE

Scale 1:500

Consultant File No. IM20103036

Drawing No. 4

PLAN LEGEND

EXISTING PROPERTY LINE
PROPOSED PROPERTY LINE
PROPERTY TAKING
PROPOSED BIKE PATH CROSSING
PROPOSED MULTI USE PATH
PROPOSED SIDEWALK
PROPOSED BOULEVARD
PROPOSED ROAD
PROPOSED MEDIAN
PROPOSED DITCH

PROFILE LEGEND

EXISTING GROUND
PROPOSED CENTERLINE OF ROAD
DITCH PROFILE
EXISTING MERRITT RD CENTERLINE

MERRITT ROAD (SEGMENT 1)

REGION OF NIAGARA

PLAN AND PROFILE

Scale 1:500

Consultant File No. IM20103036

Drawing No. 1

Plotted: 2023-07-04
Last Saved: 2023-07-04

PLAN LEGEND

- EXISTING PROPERTY LINE
- PROPOSED PROPERTY LINE
- PROPERTY TAKING
- PROPOSED BIKE PATH CROSSING
- PROPOSED MULTI USE PATH
- PROPOSED SIDEWALK
- PROPOSED CYCLE TRACK
- PROPOSED BOULEVARD
- PROPOSED ROAD
- PROPOSED MEDIAN
- PROPOSED DITCH

PROFILE LEGEND

- EXISTING GROUND
- PROPOSED CENTERLINE OF ROAD
- DITCH PROFILE
- EXISTING MERRITT RD CENTERLINE

MERRITT ROAD (SEGMENT 2)

REGION OF NIAGARA

PLAN AND PROFILE

wsp

Scale 1:500

Consultant File No. IM20103036

Drawing No. 2

PLAN LEGEND

EXISTING PROPERTY LINE	PROPOSED BIKE PATH
PROPOSED PROPERTY LINE	PROPOSED MULTI USE PATH
PROPERTY TAKING	PROPOSED SIDEWALK
PROPOSED CYCLE TRACK	PROPOSED MEDIAN
PROPOSED BOULEVARD	PROPOSED DITCH
PROPOSED ROAD	

PROFILE LEGEND

- EXISTING GROUND
- PROPOSED CENTERLINE OF ROAD
- DITCH PROFILE
- EXISTING MERRITT RD CENTERLINE

MERRITT ROAD (SEGMENT 3)

REGION OF NIAGARA

PLAN AND PROFILE

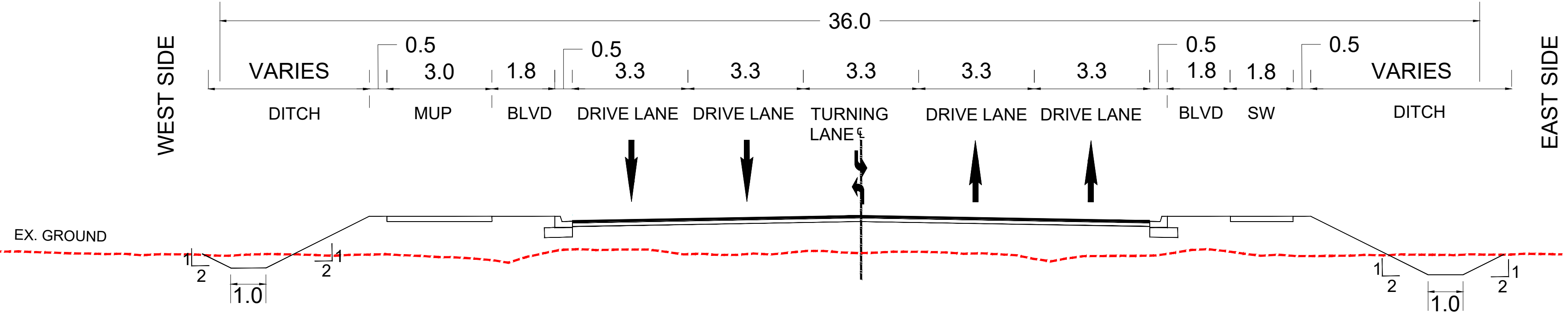
wsp

Scale 1:500

Consultant File No. IM20103036

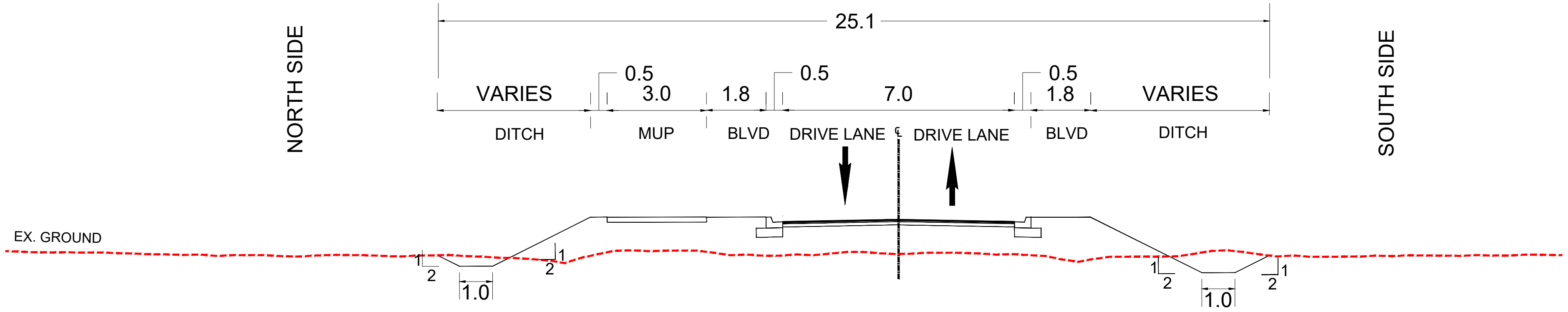
Drawing No. 3

RICE ROAD (SEGMENT 4)



FILENAME: S:\PLANNING DWGS\CA0002253.5346 - Merritt Road\Plan\Typical Sections.dwg
DATE: 5 June 2023

MERRITT ROAD (SEGMENT 1&2)



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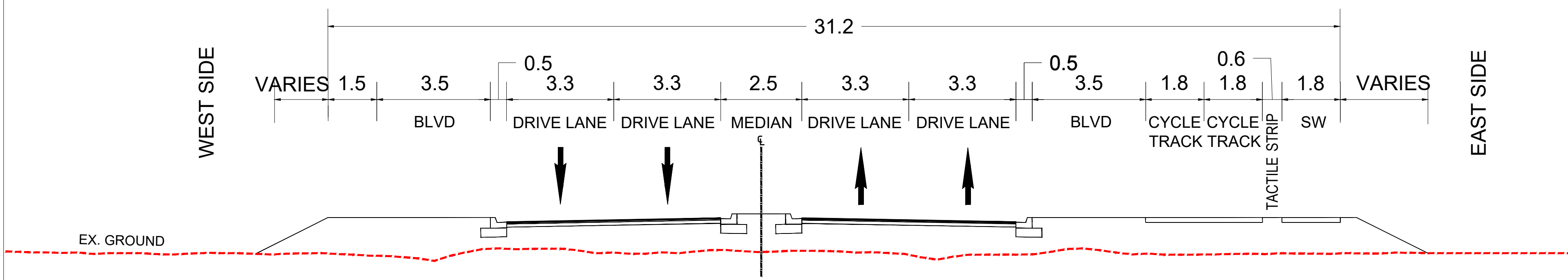
DATE: 5 June 2023

MERRITT ROAD (SEGMENT 3)



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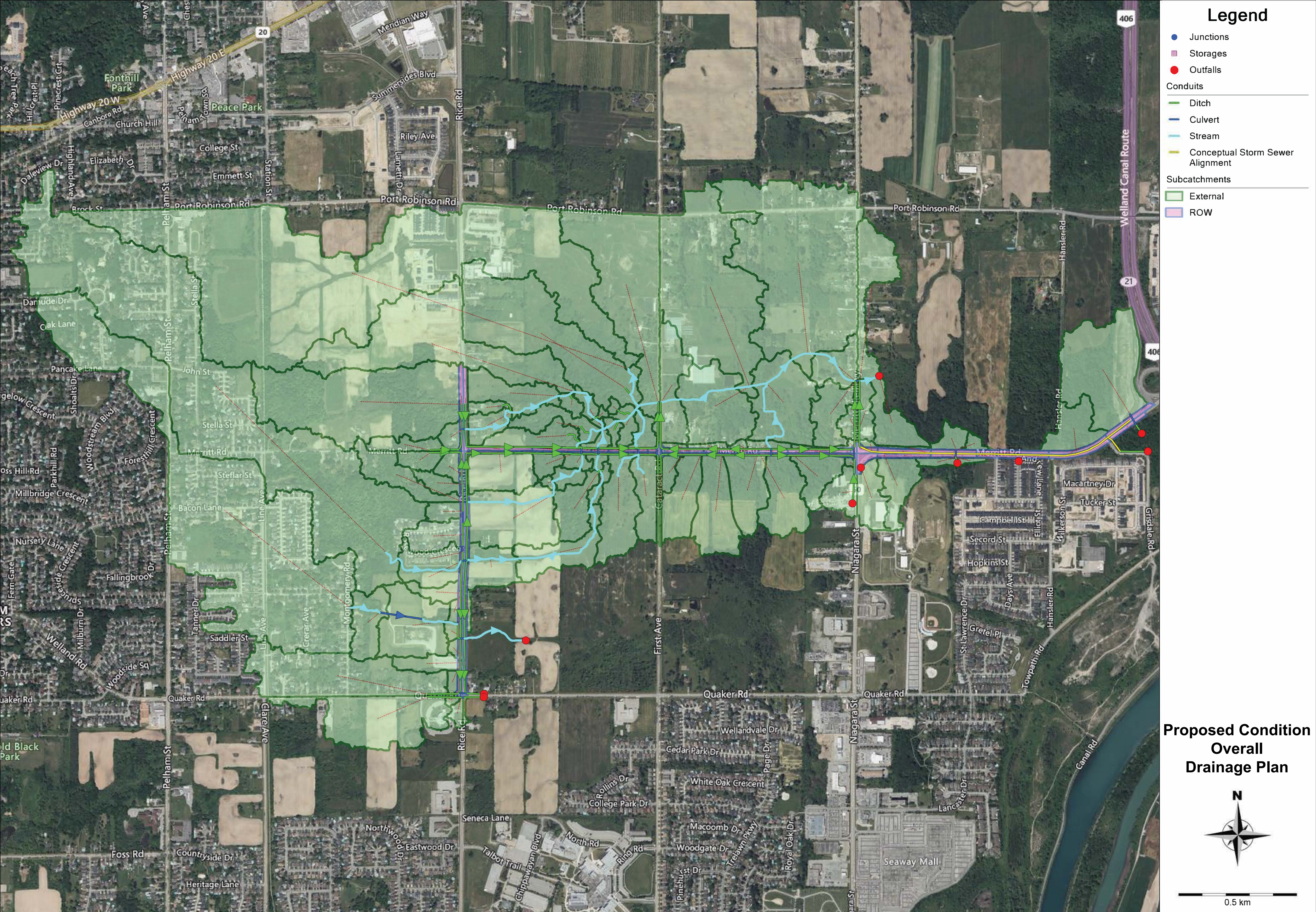
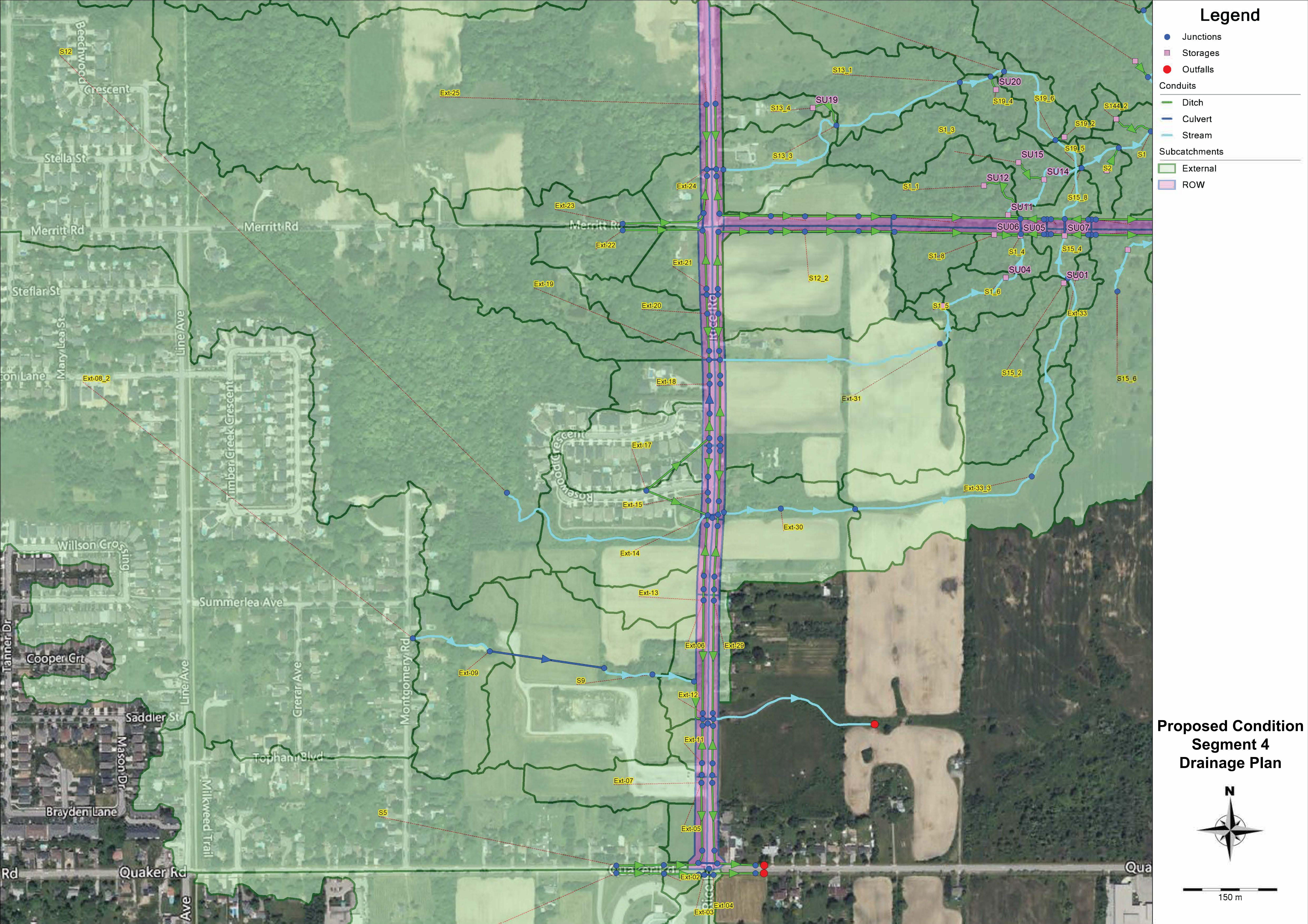
DATE: 5 June 2023

Appendix E

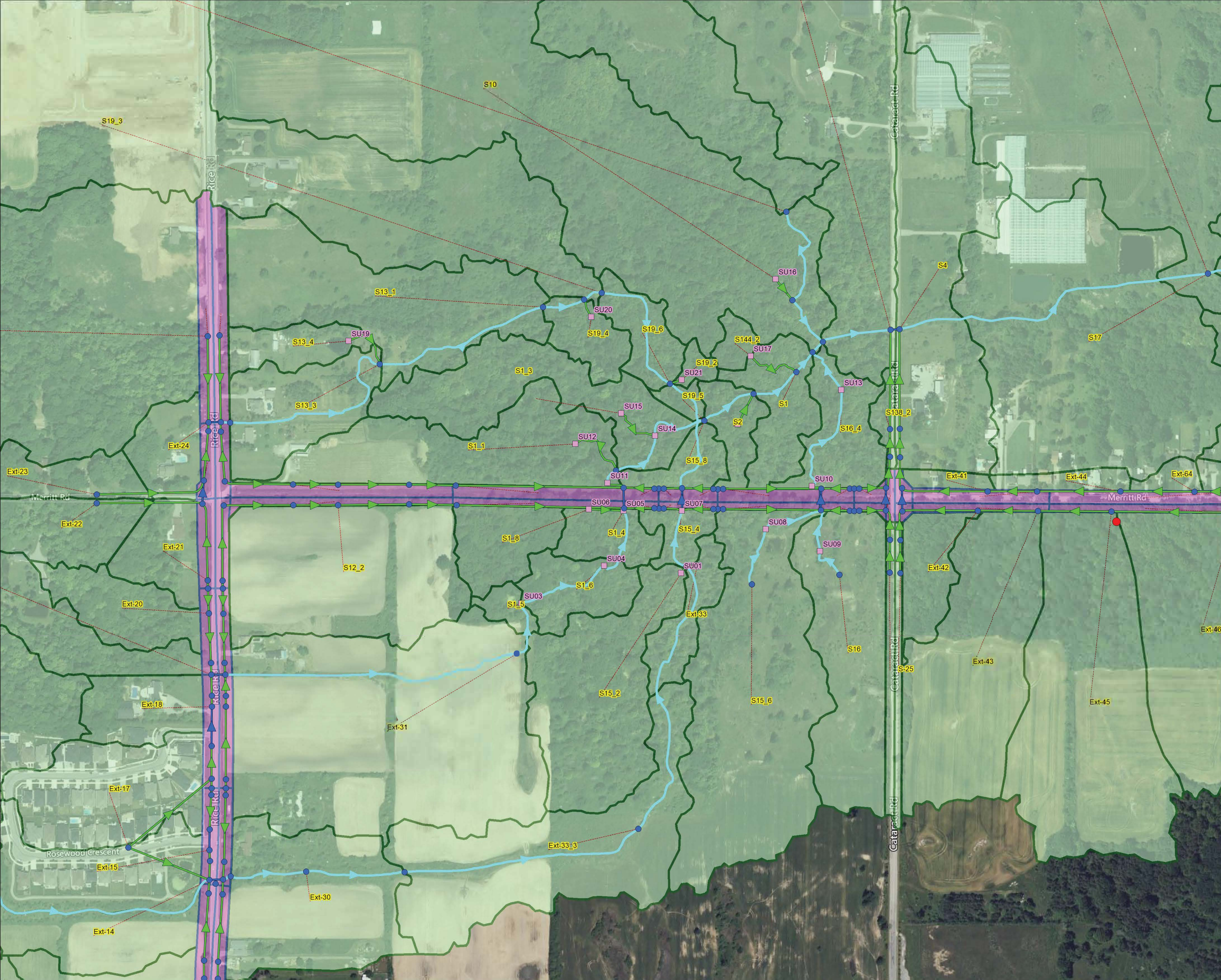
Proposed Conditions Subcatchment Drainage Plans



Proposed Condition Overall Drainage Plan



Proposed Condition
Segment 4
Drainage Plan



Legend

- Junctions
- Storages
- Outfalls

Conduits

- Ditch
- Culvert
- Stream

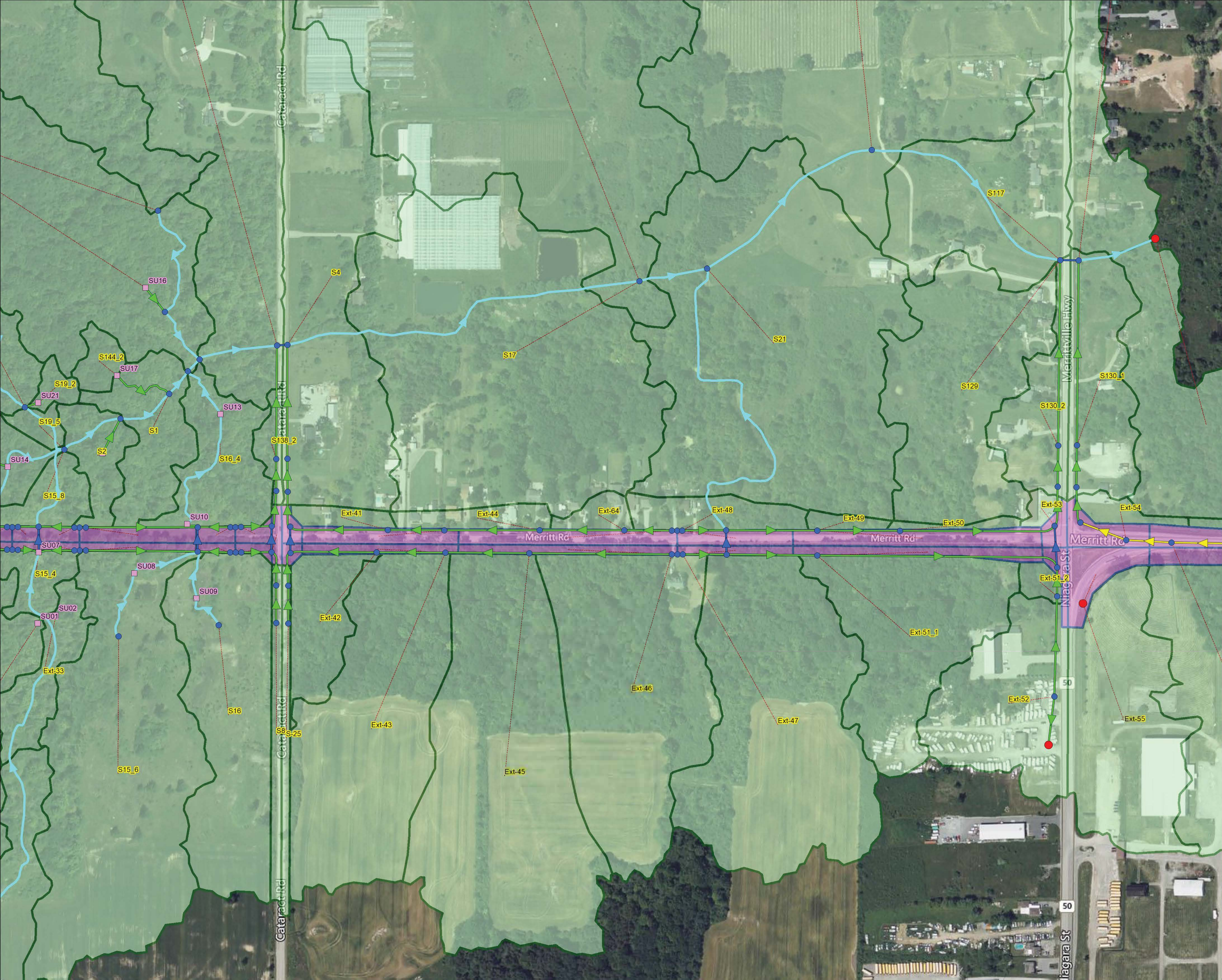
Subcatchments

- External
- ROW

Proposed Condition Segment 1 Drainage Plan

N

150 m



Legend

- Junctions
- Storages
- Outfalls

Conduits

- Ditch
- Culvert
- Stream
- Conceptual Storm Sewer Alignment

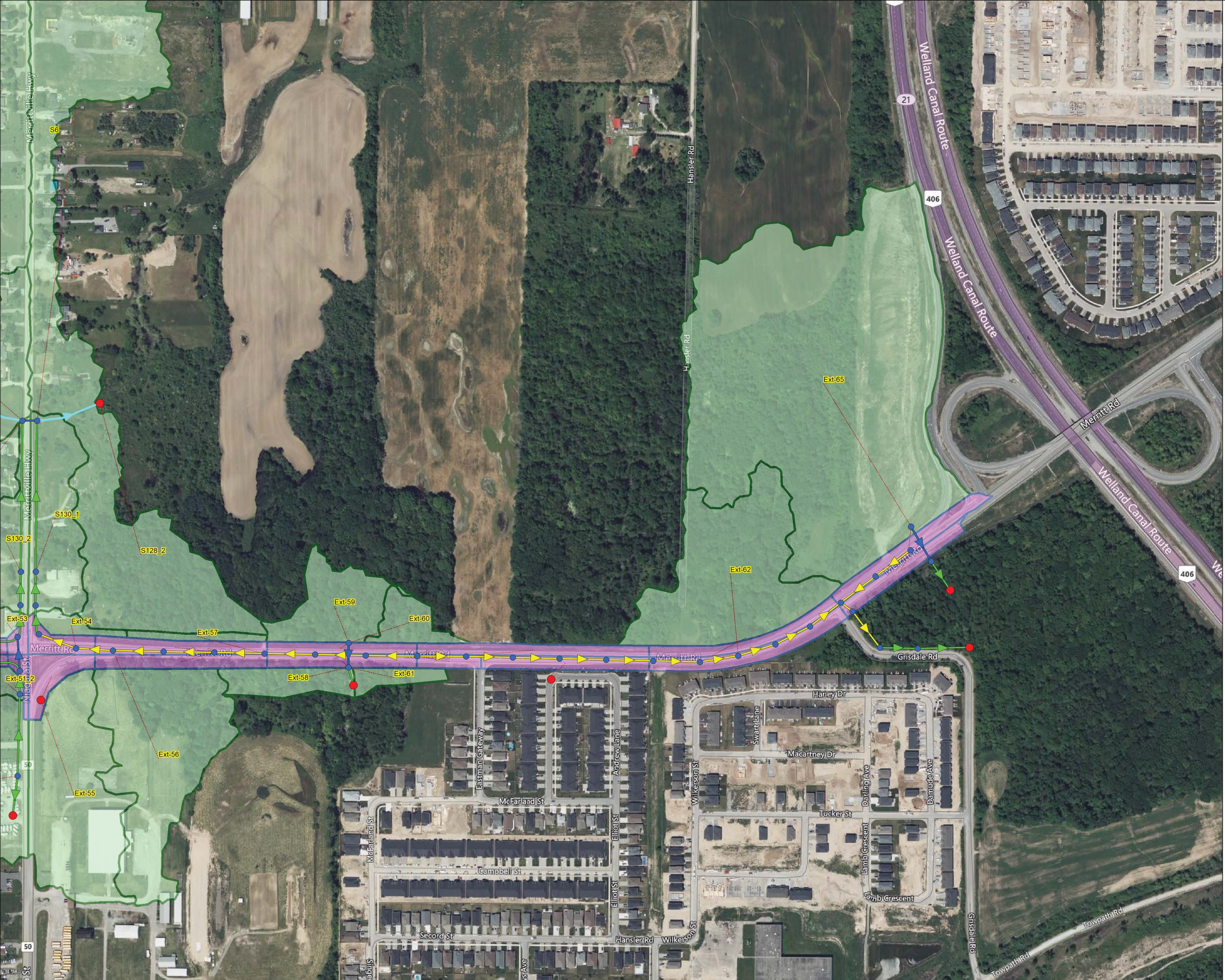
Subcatchments

- External
- ROW

Proposed Condition Segment 2 Drainage Plan

N

100 m



Legend

- Junctions
- Storages
- Outfalls

Conduits

- Ditch
- Culvert
- Stream
- Conceptual Storm Sewer Alignment

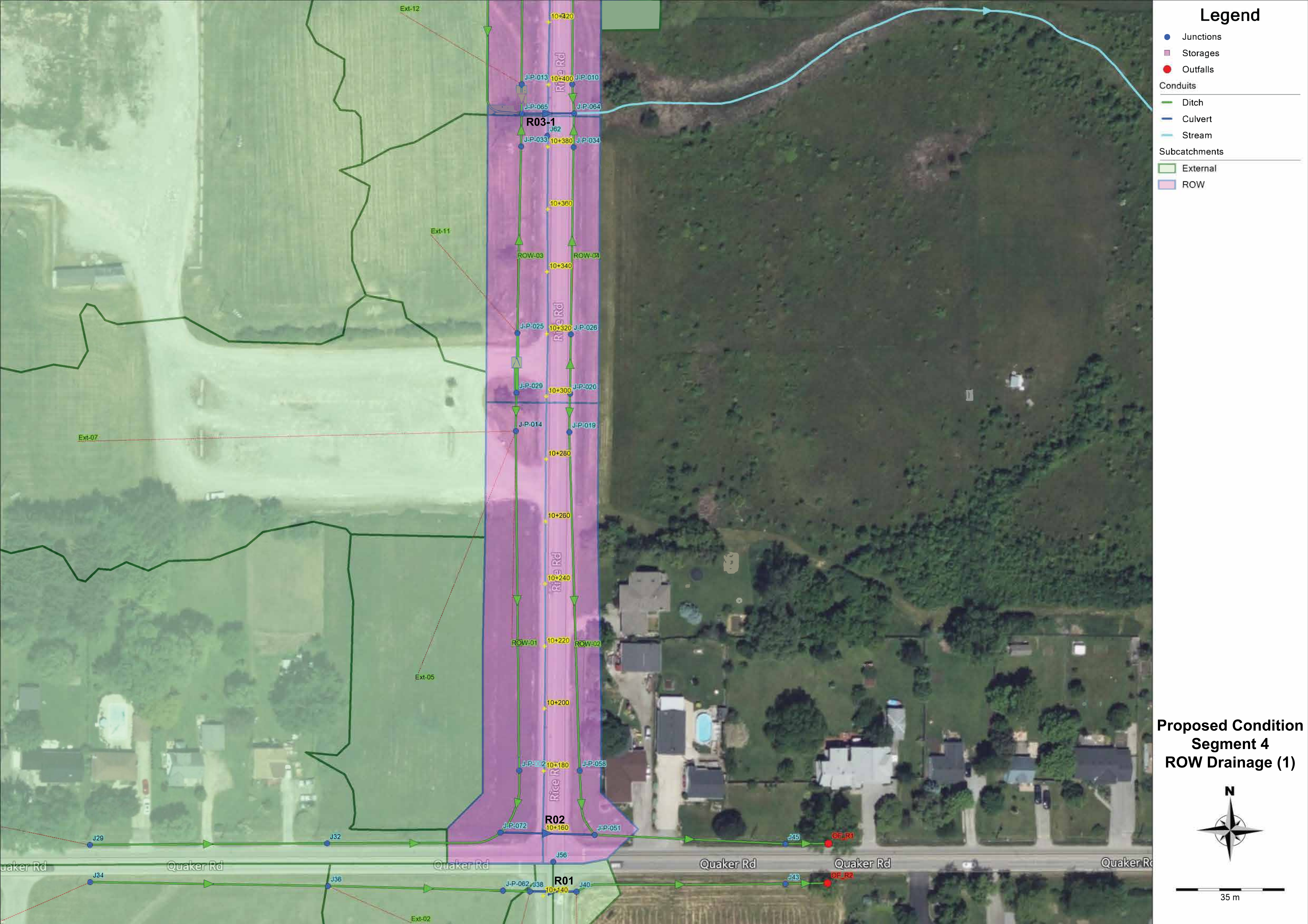
Subcatchments

- External
- ROW

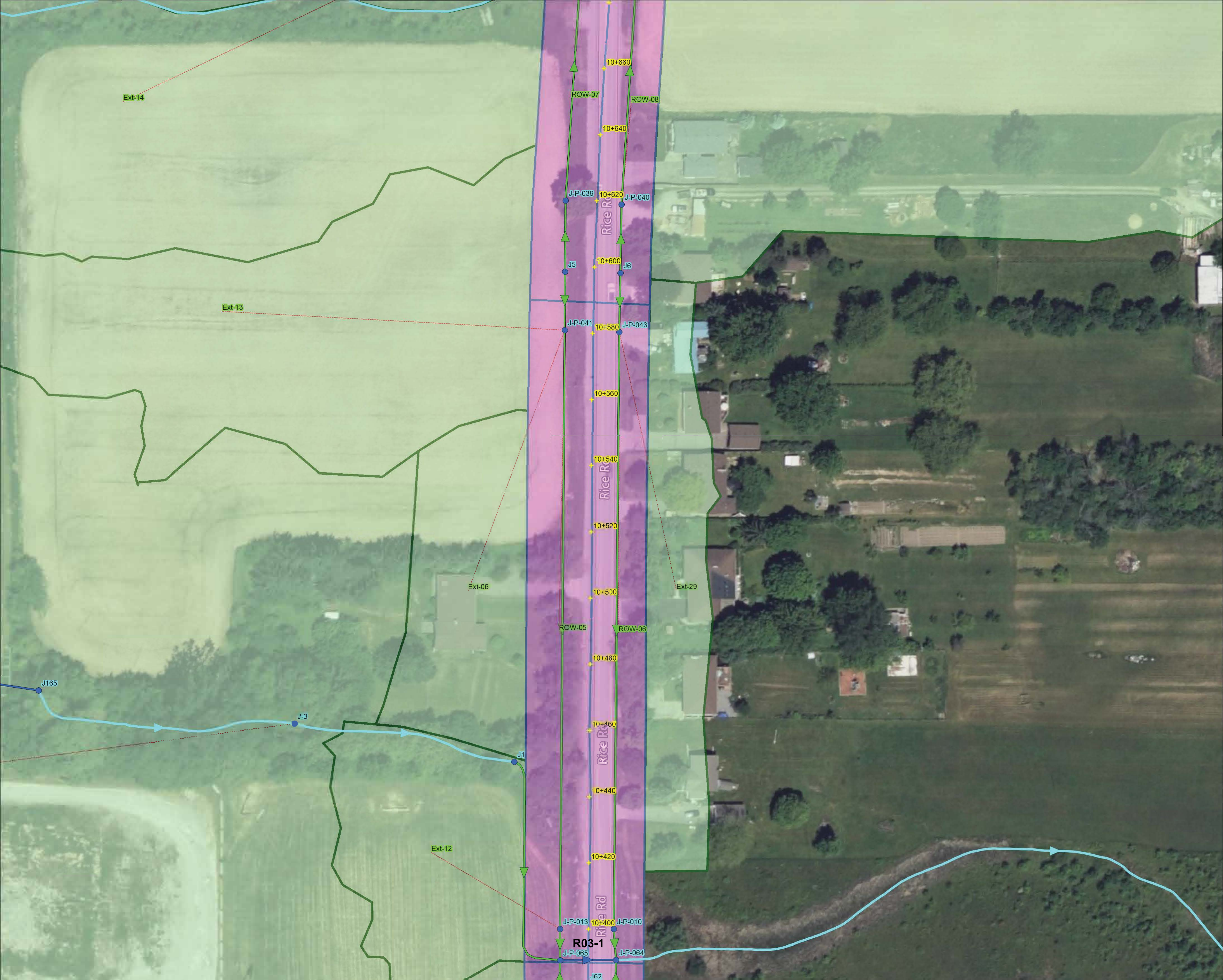
Proposed Condition Segment 3 Drainage Plan

N

150 m



Legend
Junctions
Storages
Outfalls
Conduits
Ditch
Culvert
Stream
Subcatchments
External
ROW
Proposed Condition
Segment 4
ROW Drainage (1)
N
35 m
Rice Rd
Quaker Rd
R03-1
R02
R01
Ext-12
Ext-11
Ext-07
Ext-05
Ext-02
ROW-01
ROW-02
ROW-03
ROW-04
OF_R1
OF_R2
10+420
10+400
10+380
10+360
10+340
10+320
10+300
10+280
10+260
10+240
10+220
10+200
10+180
10+160
10+140



Legend

- Junctions
- Storages
- Outfalls

Conduits

- Ditch
- Culvert
- Stream

Subcatchments

- External
- ROW

Proposed Condition
Segment 4
ROW Drainage (2)

N

35 m

Legend

- Junctions
- Storages
- Outfalls

Conduits

- Ditch
- Culvert
- Stream

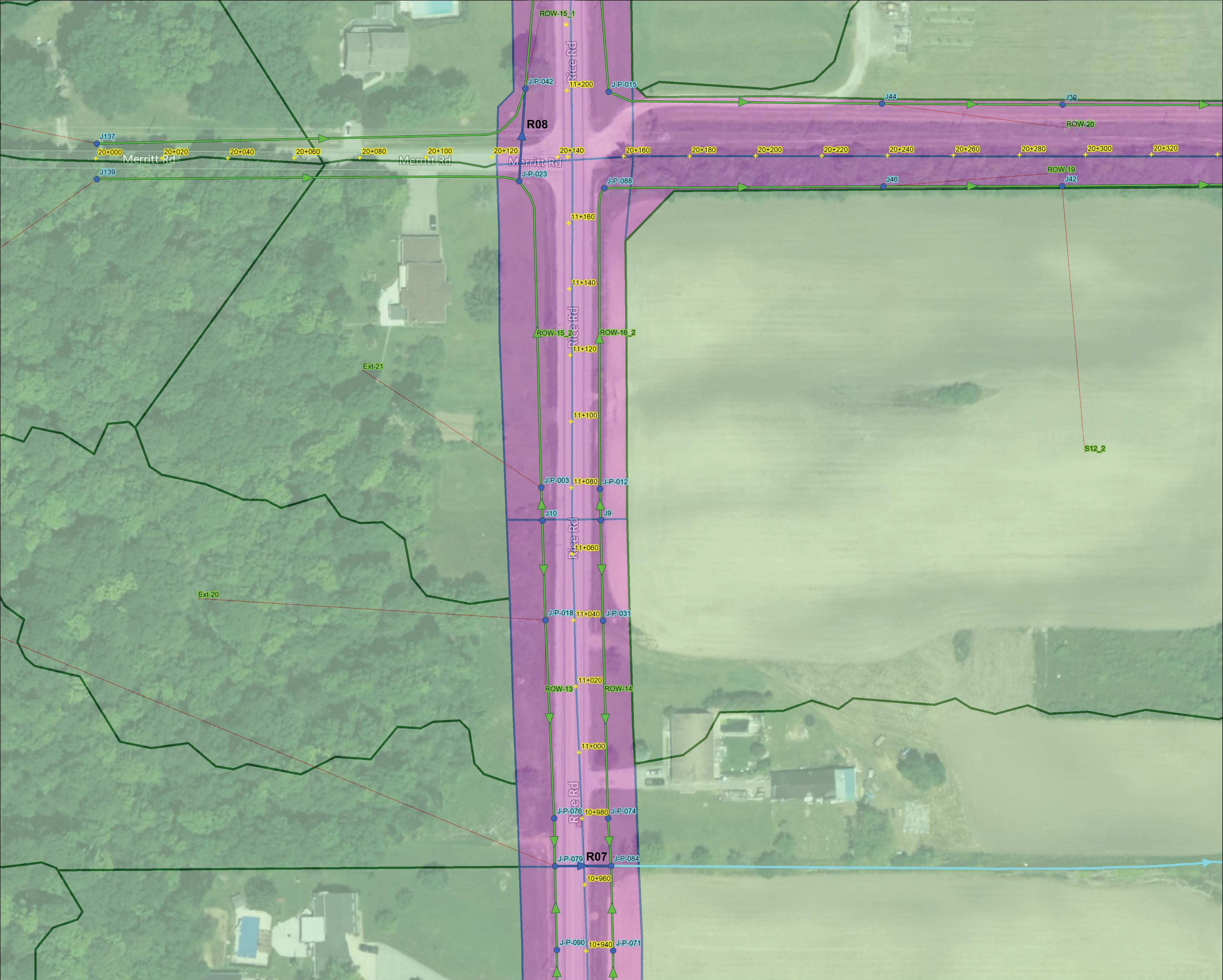
Subcatchments

- External
- ROW

Proposed Condition
Segment 4
ROW Drainage (3)

N

35 m



Legend

- Junctions
- Storages
- Outfalls

Conduits

- Ditch
- Culvert
- Stream

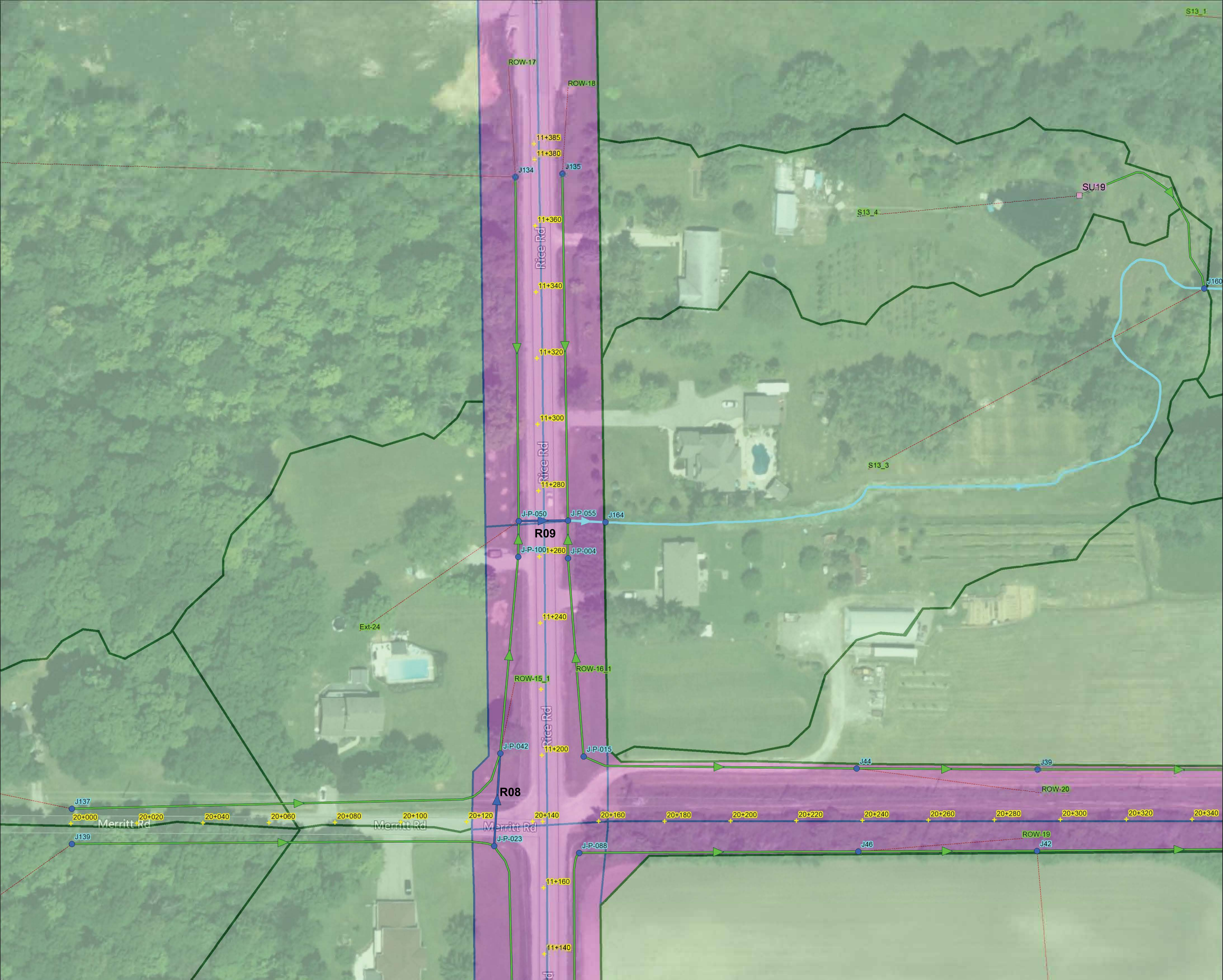
Subcatchments

- External
- ROW

Proposed Condition
Segment 4
ROW Drainage (4)

N

35 m



Legend

- Junctions
- Storages
- Outfalls

Conduits

- Ditch
- Culvert
- Stream

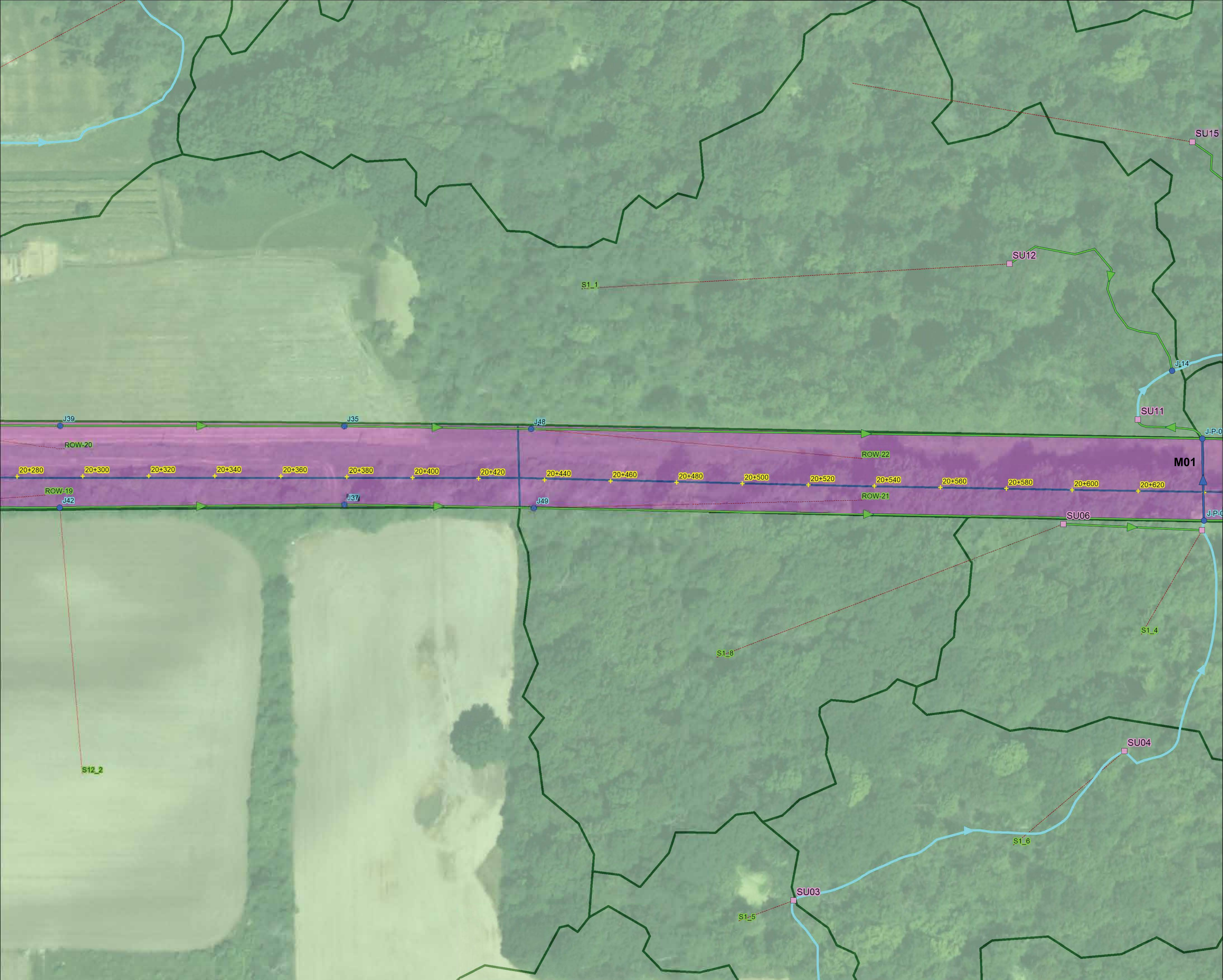
Subcatchments

- External
- ROW

Proposed Condition
Segment 4
ROW Drainage (5)

N

35 m



Legend

- Junctions
- Storages
- Outfalls

Conduits

- Ditch
- Culvert
- Stream

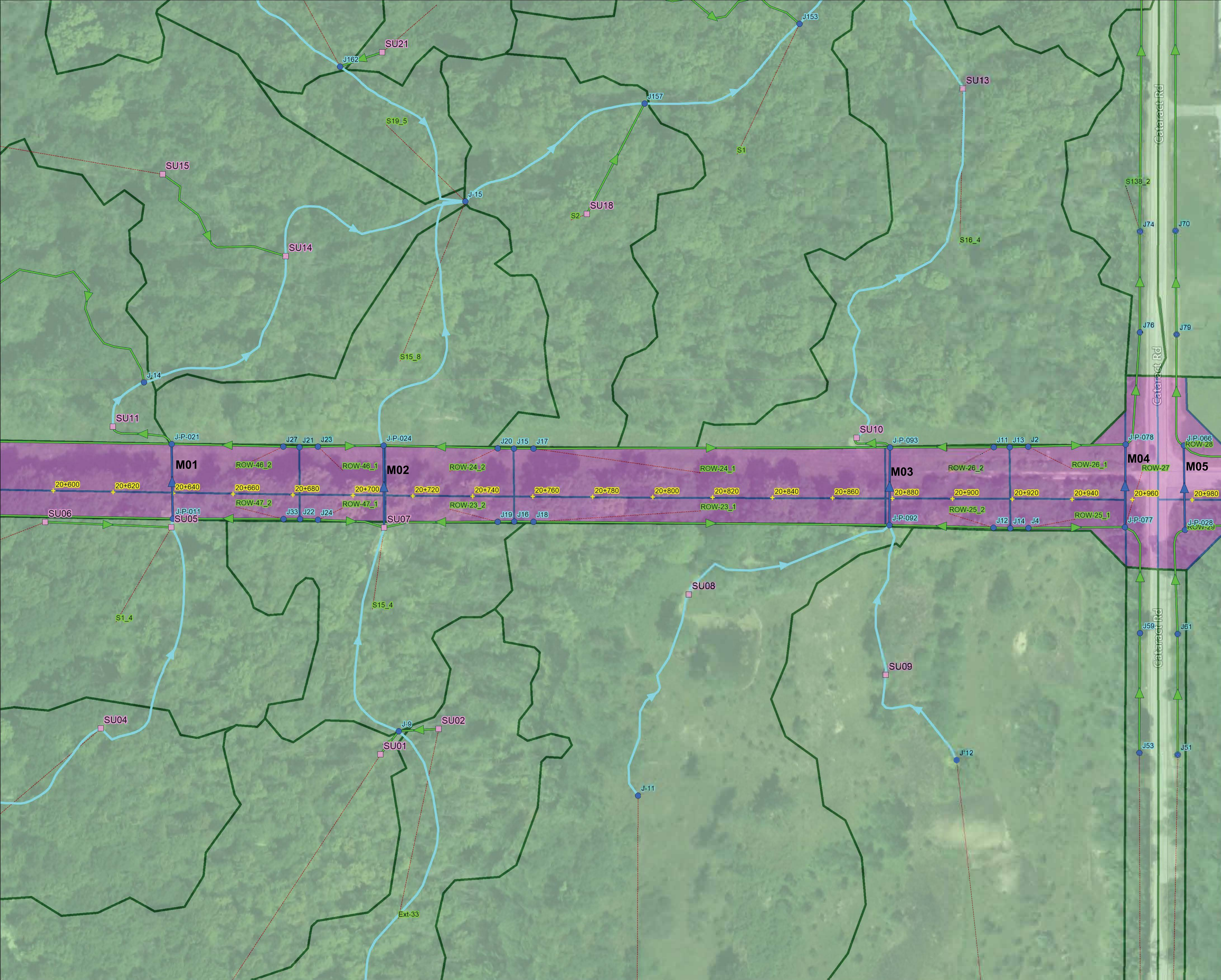
Subcatchments

- External
- ROW

Proposed Condition
Segment 1
ROW Drainage (1)

N

35 m



Legend

- Junctions
- Storages
- Outfalls

Conduits

- Ditch
- Culvert
- Stream

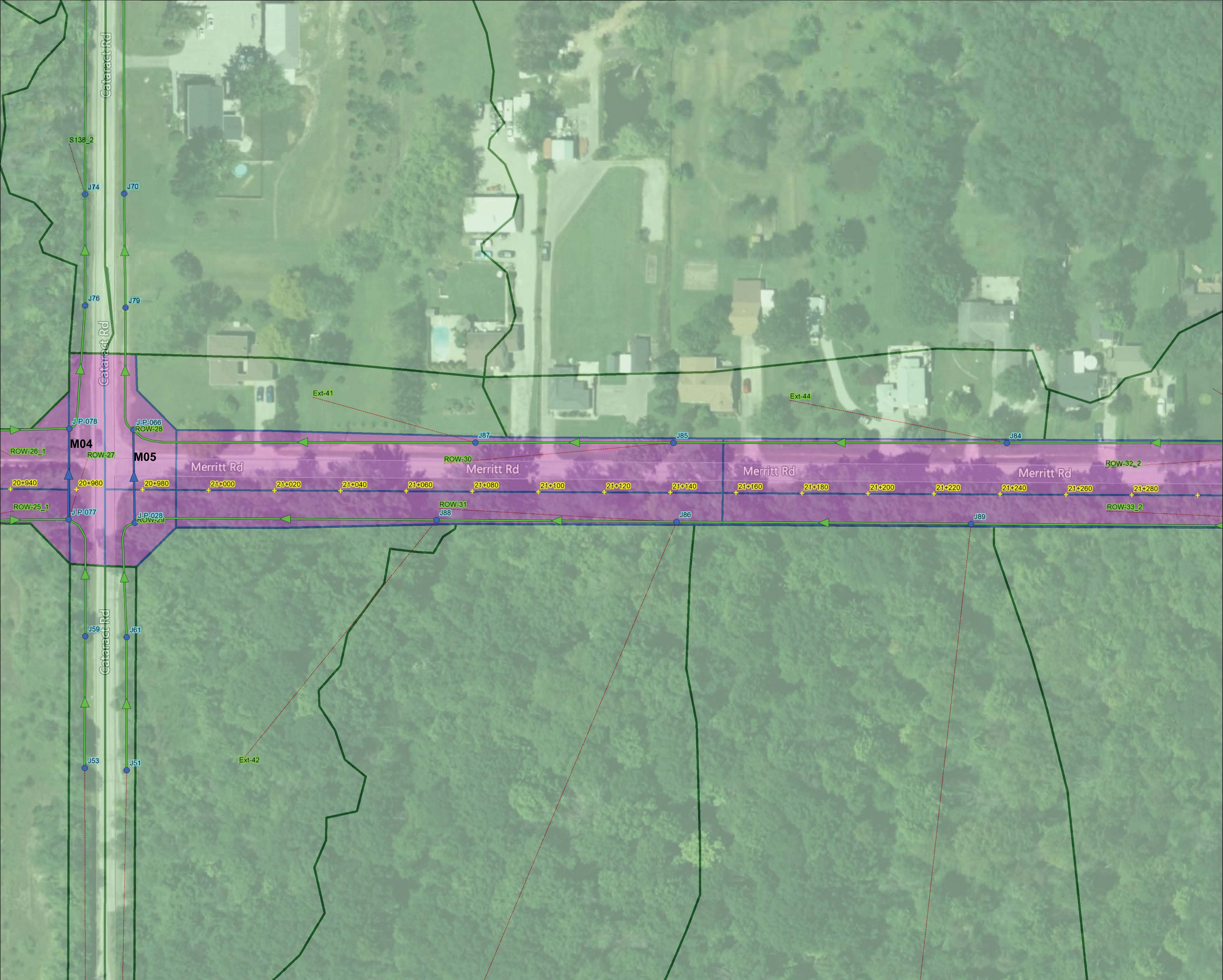
Subcatchments

- External
- ROW

Proposed Condition
Segment 1
ROW Drainage (2)

N

40 m



Legend

- Junctions
- Storages
- Outfalls

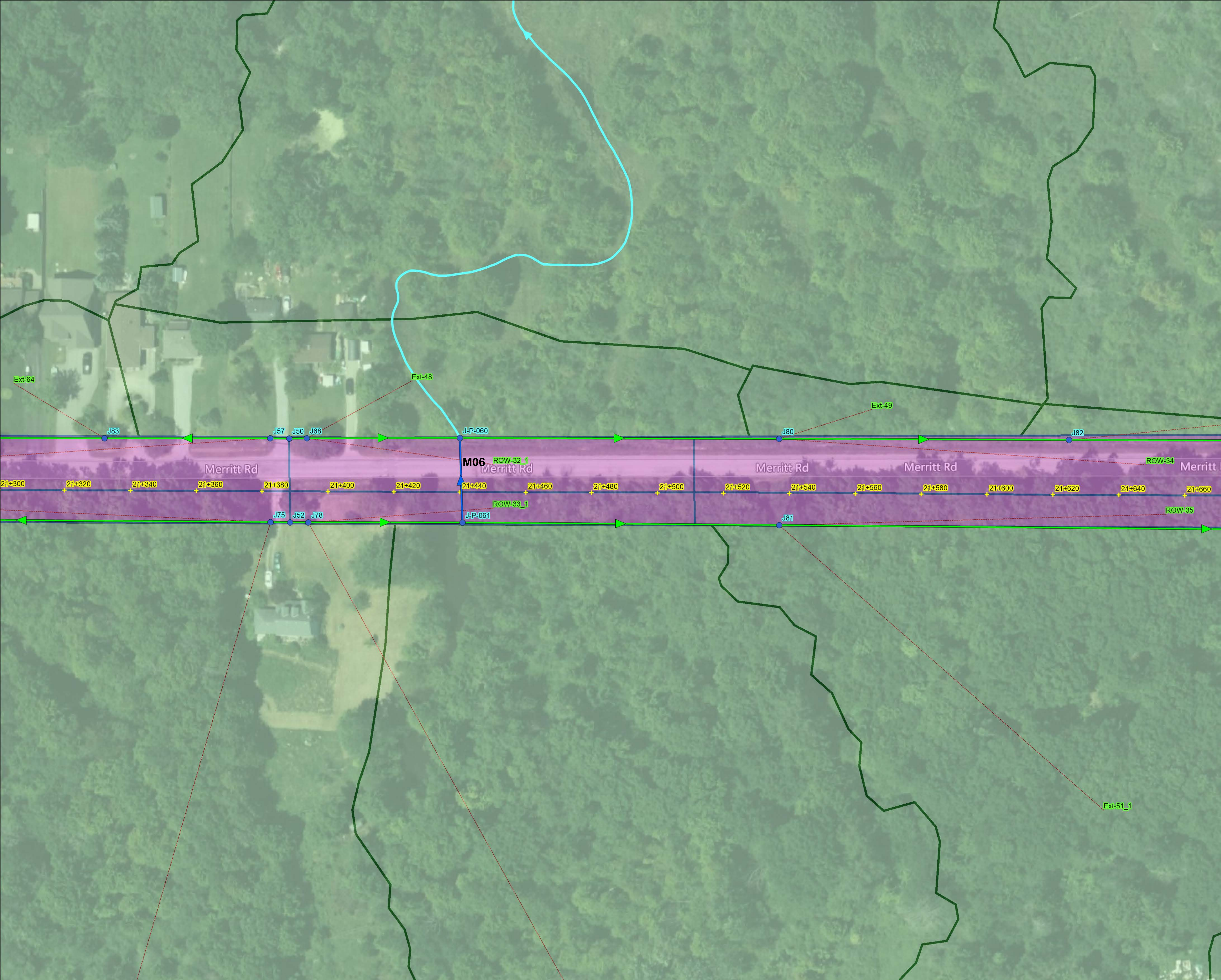
Conduits
- Ditch
- Culvert
- Stream

Subcatchments
- External
- ROW

Proposed Condition
Segment 2
ROW Drainage (1)

N

35 m



Legend

- Junctions
- Storages
- Outfalls

Conduits

- Ditch
- Culvert
- Stream

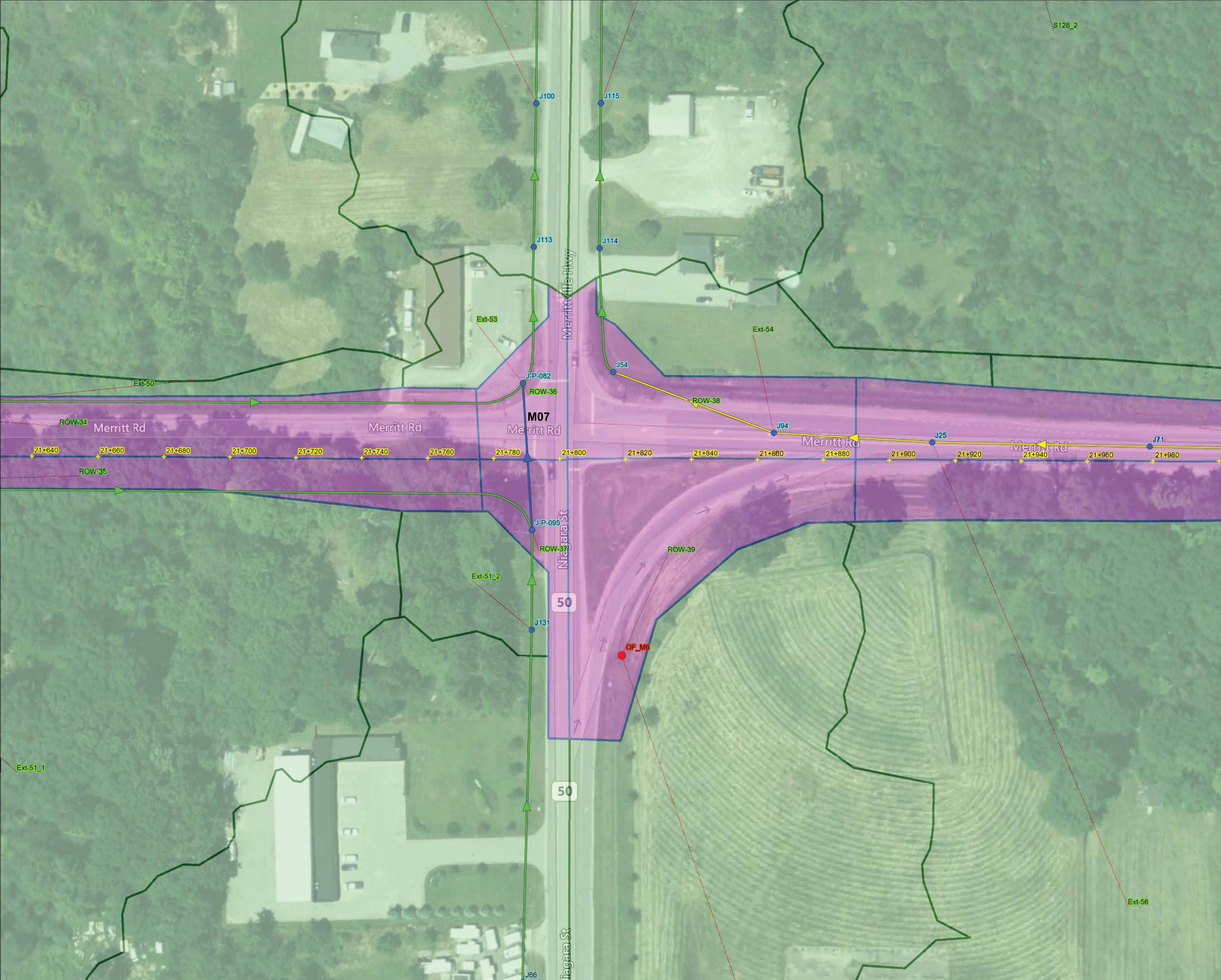
Subcatchments

- External
- ROW

Proposed Condition
Segment 2
ROW Drainage (2)

N

35 m



Legend

- Junctions
- Storages
- Outfalls

Conduits

- Ditch
- Culvert
- Stream
- Conceptual Storm Sewer Alignment

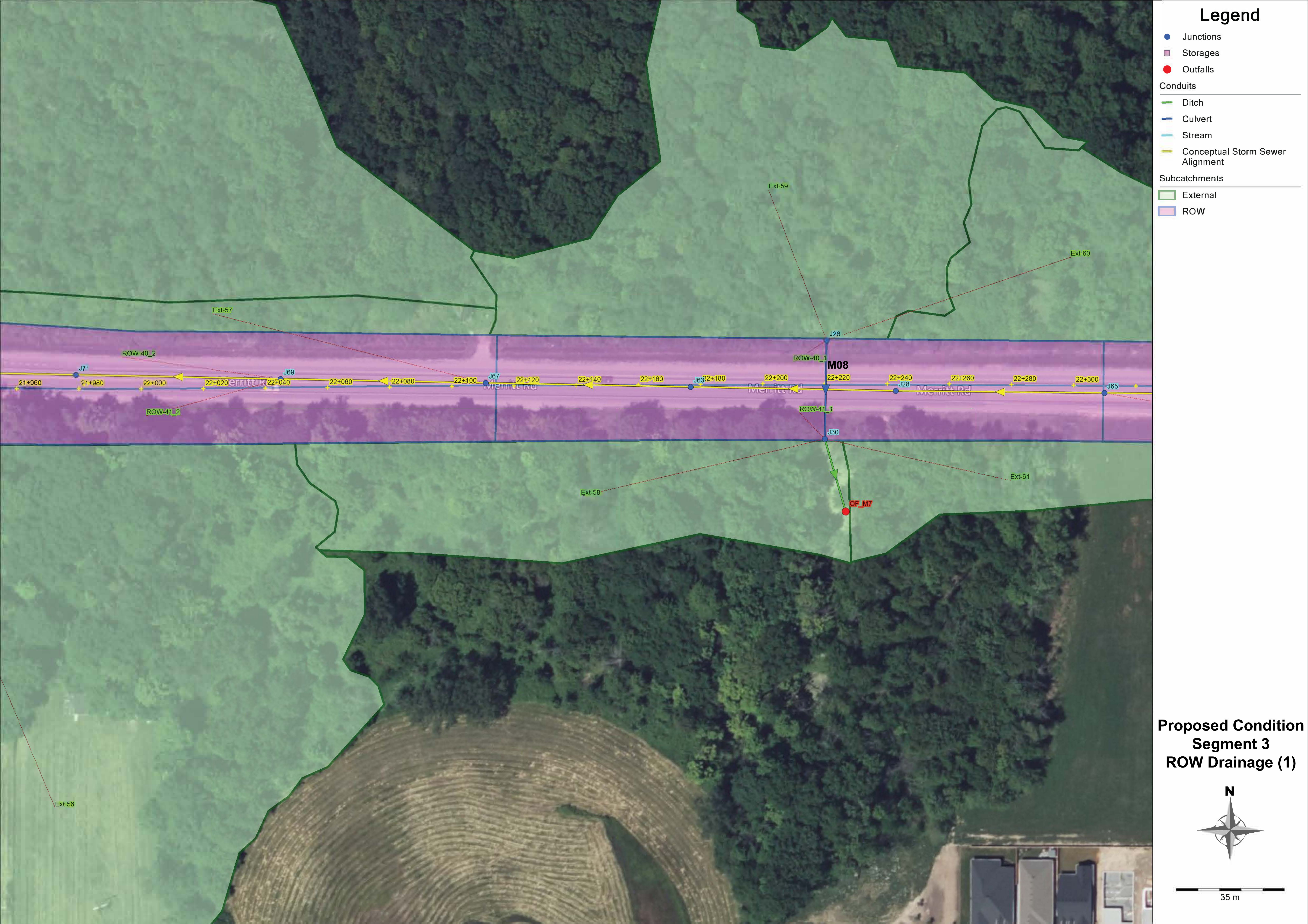
Subcatchments

- External
- ROW

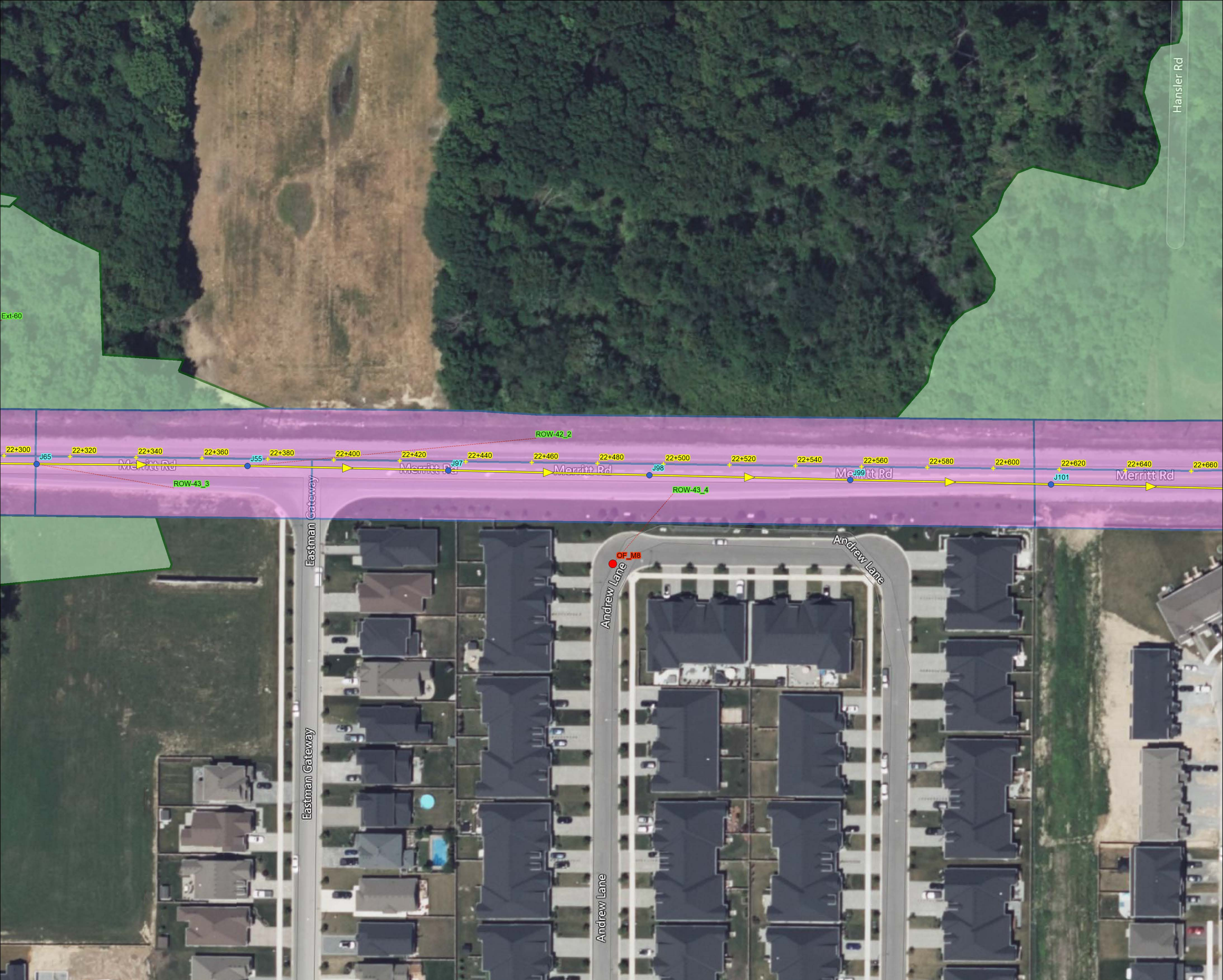
Proposed Condition
Segment 2
ROW Drainage (3)

N

35 m



Proposed Condition
Segment 3
ROW Drainage (1)



Legend

- Junctions
- Storages
- Outfalls

Conduits

- Ditch
- Culvert
- Stream
- Conceptual Storm Sewer Alignment

Subcatchments

- External
- ROW

Proposed Condition Segment 3 ROW Drainage (2)

N

35 m

Legend

- Junctions
- Storages
- Outfalls

Conduits

- Ditch
- Culvert
- Stream
- Conceptual Storm Sewer Alignment

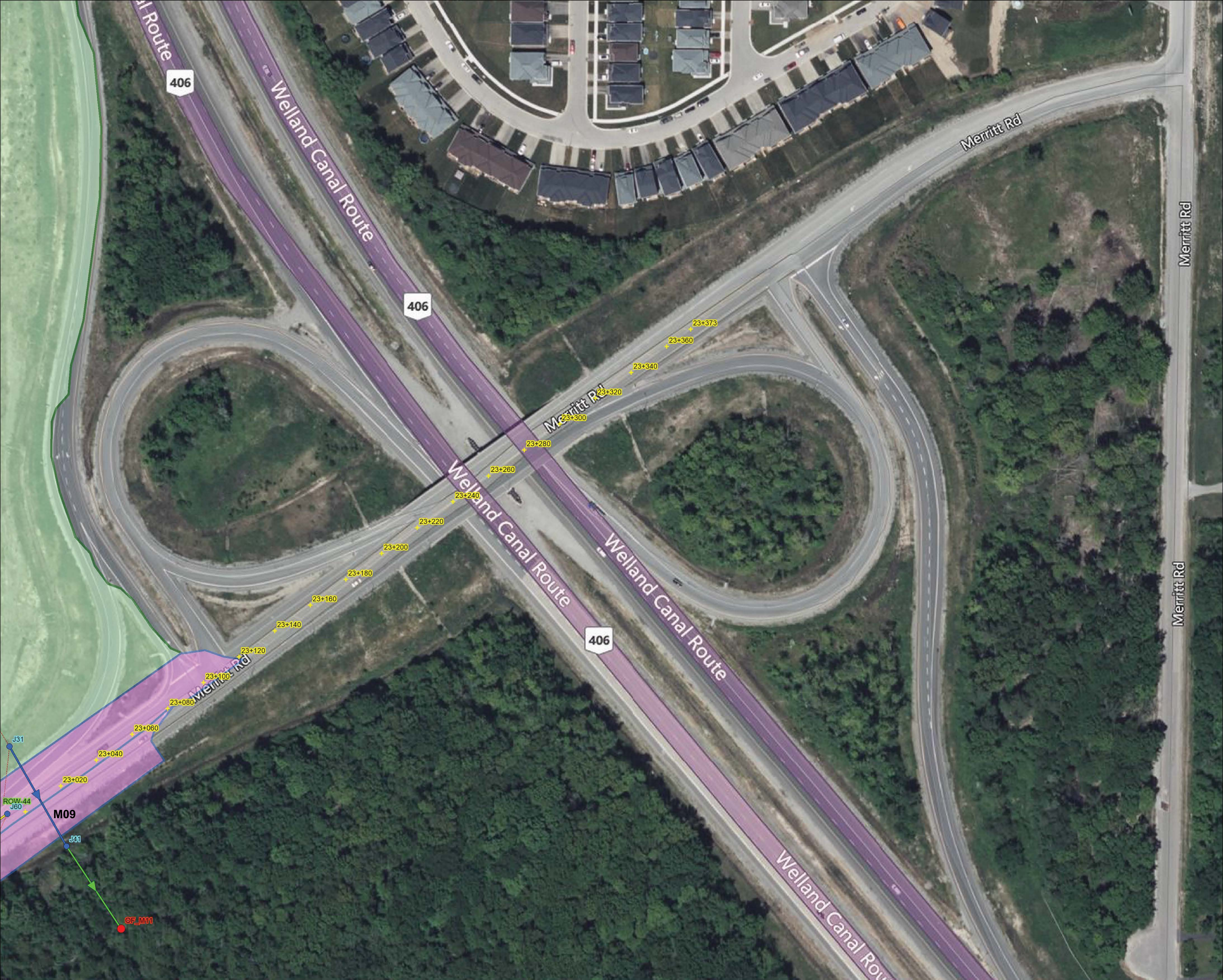
Subcatchments

- External
- ROW

Proposed Condition
Segment 3
ROW Drainage (3)

N

40 m



Legend

- Junctions
- Storages
- Outfalls

Conduits

- Ditch
- Culvert
- Stream
- Conceptual Storm Sewer Alignment

Subcatchments

- External
- ROW

Proposed Condition
Segment 3
ROW Drainage (4)

N

50 m

Appendix F

Characterization Data & PCSWMM Subcatchment Parameters

Existing Subcatchments Parameters

Name	Tag	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Imperv. (%)
Ext-01	Ext	10.76	160.5	670.0	0.9	24.6
Ext-02	Ext	0.23	39.7	57.0	0.9	65.3
Ext-03	Ext	0.51	41.2	125.0	1.2	66.8
Ext-04	Ext	0.17	15.3	110.0	0.5	55.5
Ext-05	Ext	0.40	89.4	44.7	0.6	5.0
Ext-06	Ext	0.35	48.9	72.0	0.8	10.3
Ext-07	Ext	1.71	59.3	288.0	0.8	30.7
Ext-08_2	Ext	58.10	304.2	1910.0	1.3	55.0
Ext-09	Ext	3.70	231.5	160.0	0.7	41.8
Ext-11	Ext	0.26	34.3	76.0	0.9	30.0
Ext-12	Ext	0.40	51.5	77.0	0.8	29.4
Ext-13	Ext	1.26	49.9	252.0	0.8	14.3
Ext-14	Ext	1.61	218.2	74.0	0.9	13.0
Ext-15	Ext	2.26	327.0	69.0	0.5	35.0
Ext-17	Ext	2.61	217.4	120.0	0.5	53.9
Ext-18	Ext	1.14	72.3	157.0	0.9	28.4
Ext-19	Ext	3.96	74.9	529.0	0.9	19.0
Ext-20	Ext	1.25	56.5	222.0	1.0	25.0
Ext-21	Ext	0.98	90.3	109.0	1.5	26.3
Ext-22	Ext	1.35	175.6	77.0	0.9	27.0
Ext-23	Ext	1.66	326.1	51.0	1.3	19.0
Ext-24	Ext	0.89	158.4	56.0	2.0	26.7
Ext-25	Ext	24.24	1524.7	159.0	1.2	10.2
Ext-29	Ext	0.32	125.4	25.4	0.5	43.6
Ext-30	Ext	3.44	220.8	156.0	0.5	17.5
Ext-31	Ext	8.72	220.8	395.0	1.1	11.4
Ext-33	Ext	0.79	47.1	168.0	0.5	5.0
Ext-33_3	Ext	4.75	154.3	308.0	0.5	7.5
Ext-41	Ext	0.22	22.4	98.0	0.5	48.3
Ext-42	Ext	0.94	43.6	216.0	0.6	21.4
Ext-43	Ext	4.38	108.9	402.0	0.6	10.1
Ext-44	Ext	0.38	24.7	154.0	0.5	45.0
Ext-45	Ext	6.25	136.1	459.0	0.6	5.1
Ext-46	Ext	4.57	130.0	352.0	0.6	8.8
Ext-47	Ext	5.39	153.9	350.0	0.6	10.4
Ext-48	Ext	0.62	38.5	161.0	0.5	21.6
Ext-49	Ext	0.14	17.2	79.0	0.5	5.0
Ext-50	Ext	0.11	15.4	73.0	0.5	10.9
Ext-51_1	Ext	2.92	119.6	244.0	0.6	45.3
Ext-51_2	Ext	0.16	31.1	51.0	0.6	10.6
Ext-52	Ext	2.30	157.7	146.0	0.6	74.3
Ext-53	Ext	0.11	33.8	33.0	0.5	91.3
Ext-54	Ext	0.22	34.8	64.0	0.5	18.7
Ext-55	Ext	2.97	100.7	295.0	0.5	32.0
Ext-56	Ext	3.42	108.5	315.0	0.5	30.0
Ext-57	Ext	0.19	10.9	174.0	0.5	7.2
Ext-58	Ext	0.60	35.7	169.0	0.5	27.3
Ext-59	Ext	1.19	88.8	134.0	0.5	10.0
Ext-60	Ext	0.48	50.2	95.0	0.5	10.0
Ext-61	Ext	0.28	38.3	74.0	0.5	5.0
Ext-62	Ext	3.47	145.7	238.0	0.5	9.5
Ext-64	Ext	0.24	29.2	81.0	0.5	45.0
Ext-65	Ext	12.91	292.7	441.0	0.5	12.8
S1	Ext	4.02	95.1	422.0	3.2	10.6
S1_1	Ext	1.35	73.1	185.0	4.6	9.4
S1_3	Ext	2.71	84.5	320.0	4.6	5.7
S1_4	Ext	0.67	63.9	105.0	4.6	5.0
S1_5	Ext	0.28	45.2	61.0	4.6	10.0
S1_6	Ext	1.01	91.0	111.0	4.6	6.6
S10	Ext	19.65	227.4	864.0	0.9	14.8
S11	Ext	18.82	206.4	912.0	0.9	15.0

Name	Tag	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Imperv. (%)
S-01	ROW	0.26	195.6	13.3	2.0	28.7
S-02	ROW	0.10	103.0	9.8	2.0	48.3
S-03	ROW	0.13	170.2	7.4	2.0	38.9
S-04	ROW	0.12	95.5	12.1	2.0	39.0
S-05	ROW	0.19	157.8	12.2	2.0	39.7
S-06	ROW	0.15	172.3	8.5	2.0	37.9
S-07	ROW	0.38	313.4	12.2	2.0	34.2
S-08	ROW	0.15	196.2	7.8	2.0	47.1
S-09	ROW	0.10	126.1	7.9	2.0	48.4
S-10	ROW	0.17	142.2	11.9	2.0	30.9
S-11	ROW	0.20	207.9	9.7	2.0	36.5
S-12	ROW	0.16	159.7	10.0	2.0	38.5
S-13	ROW	0.09	108.3	8.1	2.0	46.8
S-14	ROW	0.14	111.1	12.3	2.0	27.3
S-15	ROW	0.18	231.4	7.6	2.0	50.0
S-16	ROW	0.39	310.0	12.5	2.0	27.2
S-17	ROW	0.11	133.0	8.0	2.0	44.3
S-18	ROW	0.04	46.7	8.7	2.0	41.4
S-19	ROW	0.06	51.7	11.4	2.0	35.8
S2	ROW	0.14	113.4	12.3	2.0	32.9
S-20	ROW	0.10	99.2	9.7	2.0	39.3
S-21	ROW	0.23	240.8	9.7	2.0	39.8
S-22	ROW	0.28	241.1	11.7	2.0	38.1
S-23	ROW	0.08	89.6	9.2	2.0	40.9
S-27	ROW	0.17	162.2	10.6	2.0	40.6
S-28	ROW	0.48	476.2	10.0	2.0	39.2
S-29	ROW	0.17	167.6	10.0	2.0	39.8
S3	ROW	0.31	261.2	12.0	2.0	35.7
S-30	ROW	0.50	495.1	10.0	2.0	33.8
S-34	ROW	0.16	156.3	10.5	2.0	51.9
S-35	ROW	0.21	145.3	14.4	2.0	39.6
S-36	ROW	0.07	90.8	7.8	2.0	50.0
S-37	ROW	0.11	90.7	12.3	2.0	32.9
S-38	ROW	0.19	239.6	7.9	2.0	50.0
S-41	ROW	0.17	222.3	7.8	2.0	49.8
S-42	ROW	0.14	113.1	12.3	2.0	36.4
S-43	ROW	0.22	172.8	12.7	2.0	33.2
S-44	ROW	0.10	125.8	7.7	2.0	49.8
S-45	ROW	0.11	141.1	7.9	2.0	49.4
S-46_1	ROW	0.24	163.4	14.7	2.0	29.0
S-46_2	ROW	0.18	66.0	26.8	2.0	41.1
S-47	ROW	0.11	70.2	15.6	2.0	52.2
S-48	ROW	0.41	132.1	31.0	2.0	50.0
S-49	ROW	0.58	534.3	10.9	2.0	49.6
S-50	ROW	0.36	297.9	12.2	2.0	44.9
S-51	ROW	0.30	301.7	10.0	2.0	46.6
S-52	ROW	0.21	240.0	8.8	2.0	49.6
S-53	ROW	0.16	186.9	8.8	2.0	49.7
S-54	ROW	0.26	274.5	9.4	2.0	49.6
S-55	ROW	0.20	214.6	9.1	2.0	48.1
S-56	ROW	0.34	338.2	10.0	2.0	50.0
S-57	ROW	0.45	516.1	8.7	2.0	49.8
S-58	ROW	0.45	454.7	10.0	2.0	50.0
S-59	ROW	0.35	349.6	10.0	2.0	45.1
S-60	ROW	0.41	401.5	10.3	2.0	50.0
S-63	ROW	0.28	329.6	8.5	2.0	49.2
S7	ROW	0.07	51.2	13.5	2.0	49.3

Existing Subcatchments Parameters

Name	Tag	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Imperv. (%)
S117	Ext	2.96	650.5	45.5	1.5	22.9
S12	Ext	69.12	2126.8	325.0	2.7	40.6
S12_2	Ext	4.59	145.2	316.0	1.1	20.5
S128_2	Ext	3.35	82.3	407.0	1.5	41.2
S129	Ext	3.62	113.8	318.0	1.5	12.0
S13_1	Ext	4.35	109.0	399.0	0.6	15.7
S13_3	Ext	1.90	84.3	226.0	0.6	25.0
S13_4	Ext	0.77	52.9	146.0	0.6	25.0
S130_1	Ext	1.67	80.6	207.0	0.8	42.6
S130_2	Ext	1.09	56.4	194.0	1.5	29.7
S138_2	Ext	0.23	30.6	76.0	2.0	30.6
S144_2	Ext	0.26	43.2	61.0	0.8	5.0
S144_3	Ext	1.22	84.2	145.0	0.8	5.0
S144_4	Ext	0.59	84.0	70.0	0.8	5.0
S15	Ext	6.33	168.8	375.0	0.6	5.0
S15_2	Ext	3.49	105.6	330.0	1.2	5.7
S15_3	Ext	0.81	58.9	137.6	1.2	5.0
S15_4	Ext	0.45	58.1	77.0	1.2	5.0
S16	Ext	3.20	108.7	294.0	0.9	5.2
S16_2	Ext	1.63	98.1	166.0	0.6	5.2
S17	Ext	8.59	278.9	308.0	1.3	30.9
S18	Ext	78.73	308.6	2551.0	0.8	22.0
S19_2	Ext	0.17	32.9	52.0	1.5	5.0
S19_3	Ext	20.83	175.7	1186.0	1.5	25.5
S19_4	Ext	0.70	86.9	81.0	1.5	5.0
S19_5	Ext	0.19	24.2	77.0	1.5	5.0
S19_6	Ext	0.79	49.9	158.0	1.5	5.0
S21	Ext	8.64	268.3	322.0	0.5	10.5
S22	Ext	25.39	287.5	883.0	1.1	16.1
S-25	Ext	0.33	69.1	47.7	0.8	50.0
S4	Ext	5.10	131.5	388.0	0.5	34.2
S5	Ext	13.28	174.7	760.0	0.9	50.8
S6	Ext	5.65	82.6	684.0	1.5	18.8
S6_4	Ext	34.48	399.6	863.0	1.3	21.8
S8	Ext	0.40	83.1	47.9	0.8	50.0
S9	Ext	7.35	326.6	225.0	0.7	27.1

Name	Tag	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Imperv. (%)

Proposed Subcatchments Parameters

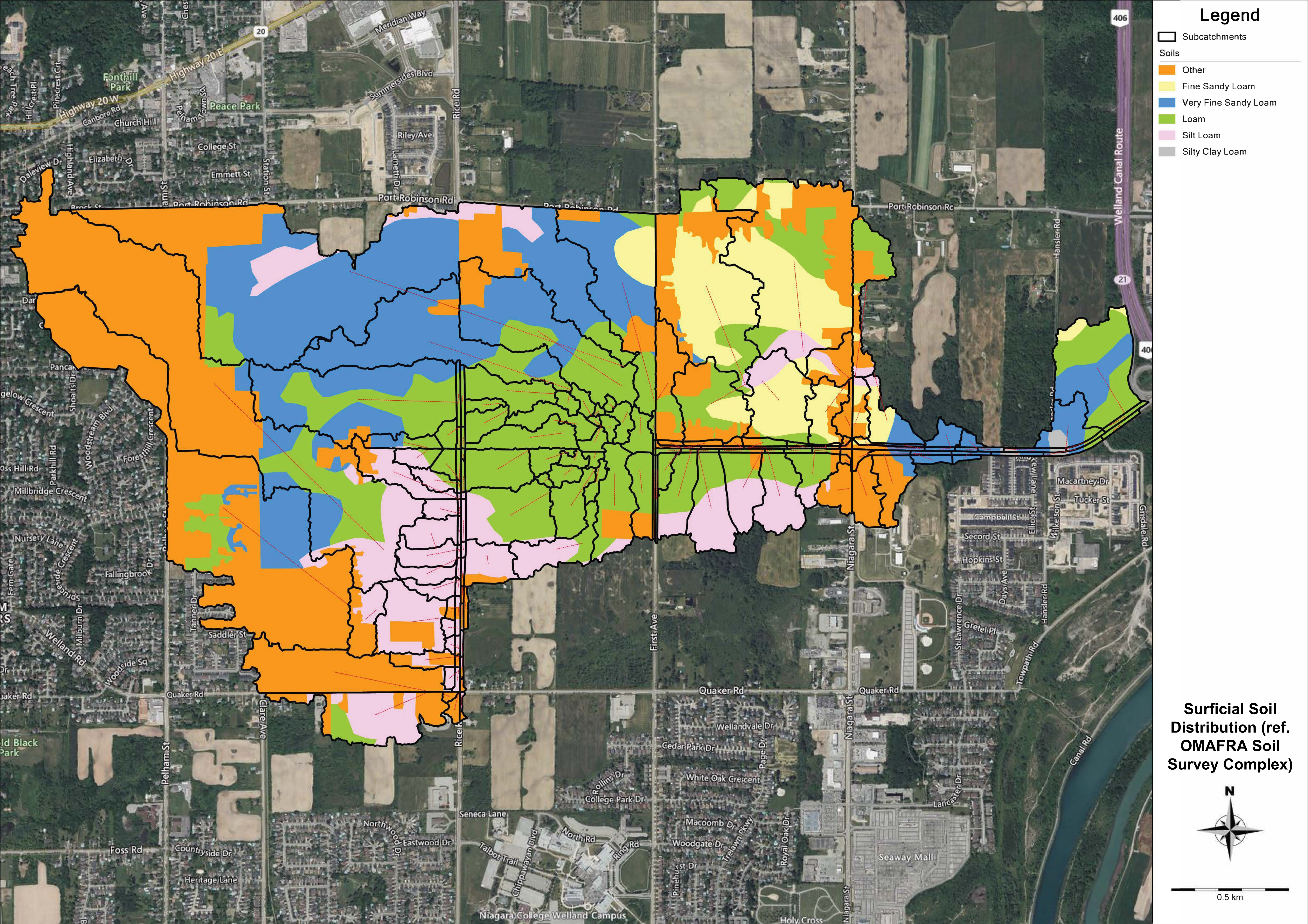
Name	Tag	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Imperv. (%)
Ext-01	Ext	10.76	160.5	670.0	0.9	24.6
Ext-02	Ext	0.23	39.7	57.0	0.9	65.3
Ext-03	Ext	0.51	41.2	125.0	1.2	66.8
Ext-04	Ext	0.17	15.3	110.0	0.5	55.5
Ext-05	Ext	0.40	89.4	44.7	0.6	5.0
Ext-06	Ext	0.35	48.9	72.0	0.8	10.3
Ext-07	Ext	1.71	59.3	288.0	0.8	30.7
Ext-08_2	Ext	58.10	304.2	1910.0	1.3	55.0
Ext-09	Ext	3.70	231.5	160.0	0.7	41.8
Ext-11	Ext	0.26	34.3	76.0	0.9	30.0
Ext-12	Ext	0.40	51.5	77.0	0.8	29.4
Ext-13	Ext	1.26	49.9	252.0	0.8	14.3
Ext-14	Ext	1.61	218.2	74.0	0.9	13.0
Ext-15	Ext	2.26	327.0	69.0	0.5	35.0
Ext-17	Ext	2.61	217.4	120.0	0.5	53.9
Ext-18	Ext	1.14	72.3	157.0	0.9	28.4
Ext-19	Ext	3.96	74.9	529.0	0.9	19.0
Ext-20	Ext	1.25	56.5	222.0	1.0	25.0
Ext-21	Ext	0.98	90.3	109.0	1.5	26.3
Ext-22	Ext	1.35	175.6	77.0	0.9	27.0
Ext-23	Ext	1.66	326.1	51.0	1.3	19.0
Ext-24	Ext	0.89	158.4	56.0	2.0	26.7
Ext-25	Ext	24.24	1524.7	159.0	1.2	10.2
Ext-29	Ext	0.32	125.4	25.4	0.5	43.6
Ext-30	Ext	3.44	220.8	156.0	0.5	17.5
Ext-31	Ext	8.72	220.8	395.0	1.1	11.4
Ext-33	Ext	0.79	47.1	168.0	0.5	5.0
Ext-33_3	Ext	4.75	154.3	308.0	0.5	7.5
Ext-41	Ext	0.22	22.4	98.0	0.5	48.3
Ext-42	Ext	0.94	43.6	216.0	0.6	21.4
Ext-43	Ext	4.38	108.9	402.0	0.6	10.1
Ext-44	Ext	0.38	24.7	154.0	0.5	45.0
Ext-45	Ext	6.25	136.1	459.0	0.6	5.1
Ext-46	Ext	4.57	130.0	352.0	0.6	8.8
Ext-47	Ext	5.39	153.9	350.0	0.6	10.4
Ext-48	Ext	0.62	38.5	161.0	0.5	21.6
Ext-49	Ext	0.14	17.2	79.0	0.5	5.0
Ext-50	Ext	0.11	15.4	73.0	0.5	10.9
Ext-51_1	Ext	2.92	119.6	244.0	0.6	45.3
Ext-51_2	Ext	0.16	31.1	51.0	0.6	10.6
Ext-52	Ext	2.30	157.7	146.0	0.6	74.3
Ext-53	Ext	0.11	33.8	33.0	0.5	91.3
Ext-54	Ext	0.22	34.8	64.0	0.5	18.7
Ext-55	Ext	2.97	100.7	295.0	0.5	32.0
Ext-56	Ext	3.42	108.5	315.0	0.5	30.0
Ext-57	Ext	0.19	10.9	174.0	0.5	7.2
Ext-58	Ext	0.60	35.7	169.0	0.5	27.3
Ext-59	Ext	1.19	88.8	134.0	0.5	10.0
Ext-60	Ext	0.48	50.2	95.0	0.5	10.0
Ext-61	Ext	0.28	38.3	74.0	0.5	5.0
Ext-62	Ext	3.47	145.7	238.0	0.5	9.5
Ext-64	Ext	0.24	29.2	81.0	0.5	45.0
Ext-65	Ext	12.91	292.7	441.0	0.5	12.8
S1	Ext	1.24	82.7	150.4	0.7	5.0
S1_1	Ext	3.17	75.0	422.0	3.2	10.6
S1_3	Ext	2.71	84.5	320.0	4.6	5.7
S1_4	Ext	0.72	68.4	105.0	4.6	5.0
S1_5	Ext	0.28	45.2	61.0	4.6	10.0
S1_6	Ext	1.01	91.0	111.0	4.6	6.6
S1_8	Ext	1.08	58.2	185.0	4.6	9.4
S10	Ext	19.65	227.4	864.0	0.9	14.8
S11	Ext	18.82	206.4	912.0	0.9	15.0

Name	Tag	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Imperv. (%)
ROW-01	ROW	0.31	144.7	21.4	2.0	64.4
ROW-02	ROW	0.27	161.1	17.0	2.0	51.4
ROW-03	ROW	0.18	207.3	8.6	2.0	65.3
ROW-04	ROW	0.15	206.2	7.5	2.0	44.2
ROW-05	ROW	0.39	209.3	18.7	2.0	65.4
ROW-06	ROW	0.33	204.5	16.2	2.0	43.8
ROW-07	ROW	0.24	138.4	17.2	2.0	65.6
ROW-08	ROW	0.21	165.3	12.4	2.0	43.7
ROW-09	ROW	0.23	194.4	11.6	2.0	71.3
ROW-10	ROW	0.20	215.8	9.1	2.0	44.2
ROW-11	ROW	0.27	239.9	11.2	2.0	70.5
ROW-12	ROW	0.23	272.1	8.4	2.0	43.9
ROW-13	ROW	0.20	142.9	14.3	2.0	61.2
ROW-14	ROW	0.18	164.9	10.6	2.0	43.6
ROW-15_1	ROW	0.17	87.8	19.5	2.0	62.0
ROW-15_2	ROW	0.23	119.7	19.5	2.0	62.0
ROW-16_1	ROW	0.17	81.4	20.6	2.0	43.9
ROW-16_2	ROW	0.18	88.9	20.6	2.0	43.9
ROW-17	ROW	0.50	495.1	10.0	2.0	33.8
ROW-18	ROW	0.48	476.2	10.0	2.0	39.2
ROW-19	ROW	0.27	298.3	9.0	2.0	23.8
ROW-20	ROW	0.46	287.7	16.0	2.0	57.0
ROW-21	ROW	0.18	202.3	9.0	2.0	22.4
ROW-22	ROW	0.34	211.3	16.0	2.0	54.3
ROW-23_1	ROW	0.11	118.3	9.0	2.0	20.8
ROW-23_2	ROW	0.04	41.2	9.0	2.0	20.8
ROW-24_1	ROW	0.21	128.1	16.0	2.0	55.1
ROW-24_2	ROW	0.07	44.0	16.0	2.0	55.1
ROW-25_1	ROW	0.05	52.4	9.0	2.0	31.7
ROW-25_2	ROW	0.04	46.0	9.0	2.0	31.7
ROW-26_1	ROW	0.08	47.5	16.0	2.0	57.0
ROW-26_2	ROW	0.07	45.6	16.0	2.0	57.0
ROW-27	ROW	0.07	51.2	13.5	1.1	82.2
ROW-28	ROW	0.07	181.8	3.8	2.0	51.1
ROW-29	ROW	0.04	181.7	2.4	2.0	40.9
ROW-30	ROW	0.28	176.3	16.0	2.0	56.3
ROW-31	ROW	0.17	188.9	9.0	2.0	23.2
ROW-32_1	ROW	0.20	127.6	16.0	2.0	54.4
ROW-32_2	ROW	0.38	238.0	16.0	2.0	54.4
ROW-33_1	ROW	0.12	132.9	9.0	2.0	19.0
ROW-33_2	ROW	0.22	249.2	9.0	2.0	19.0
ROW-34	ROW	0.49	303.6	16.0	2.0	54.1
ROW-35	ROW	0.29	322.1	9.0	2.0	30.9
ROW-36	ROW	0.10	126.6	7.8	2.0	63.7
ROW-37	ROW	0.10	126.6	7.9	2.0	76.0
ROW-38	ROW	0.26	163.9	16.0	2.0	53.2
ROW-39	ROW	0.38	235.6	16.0	2.0	52.3
ROW-40_1	ROW	0.29	182.6	16.0	2.0	49.3
ROW-40_2	ROW	0.43	271.8	16.0	2.0	49.3
ROW-41_1	ROW	0.35	217.8	16.0	2.0	76.0
ROW-41_2	ROW	0.41	253.1	16.0	2.0	76.0
ROW-42_1	ROW	0.37	229.9	16.0	2.0	59.2
ROW-42_2	ROW	0.45	279.8	16.0	2.0	59.2
ROW-43_1	ROW	0.50	314.8	16.0	2.0	79.2
ROW-43_3	ROW	0.15	93.8	16.0	2.0	79.2
ROW-43_4	ROW	0.39	244.1	16.0	2.0	79.2
ROW-44	ROW	0.45	282.0	16.0	2.0	59.9
ROW-45	ROW	0.34	214.2	16.0	2.0	91.8
ROW-46_1	ROW	0.05	29.4	16.0	2.0	54.2
ROW-46_2	ROW	0.07	43.3	16.0	2.0	54.2
ROW-47_1	ROW	0.03	27.8	9.0	2.0	22.0
ROW-47_2	ROW	0.04	41.7	9.0	2.0	22.0

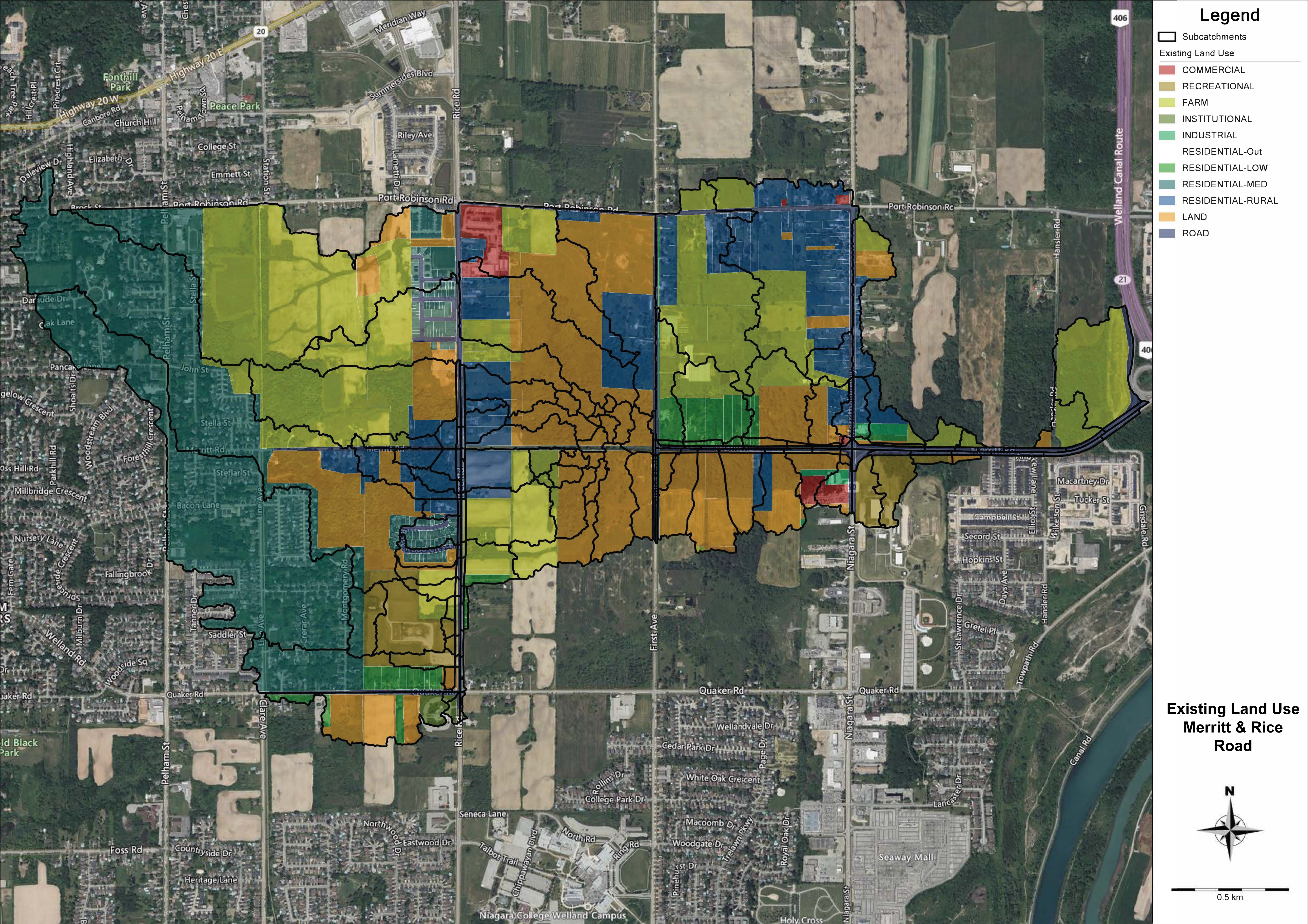
Proposed Subcatchments Parameters

Name	Tag	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Imperv. (%)
S117	Ext	2.96	650.5	45.5	1.5	22.9
S12	Ext	69.12	2126.8	325.0	2.7	40.6
S12_2	Ext	4.40	139.3	316.0	1.1	20.5
S128_2	Ext	3.35	82.3	407.0	1.5	41.2
S129	Ext	3.62	113.8	318.0	1.5	12.0
S13_1	Ext	4.35	109.0	399.0	0.6	15.7
S13_3	Ext	1.90	84.3	226.0	0.6	25.0
S13_4	Ext	0.77	52.9	146.0	0.6	25.0
S130_1	Ext	1.67	80.6	207.0	0.8	42.6
S130_2	Ext	1.09	56.4	194.0	1.5	29.7
S138_2	Ext	0.23	30.6	76.0	2.0	30.6
S144_2	Ext	0.26	43.2	61.0	0.8	5.0
S15_2	Ext	3.49	105.6	330.0	1.2	5.7
S15_4	Ext	0.45	58.1	77.0	1.2	5.0
S15_6	Ext	6.05	161.4	375.0	0.6	5.0
S15_8	Ext	0.55	39.8	137.6	1.2	5.0
S16	Ext	3.20	108.7	294.0	0.9	5.2
S16_4	Ext	1.28	77.3	166.0	0.6	5.2
S17	Ext	8.59	278.9	308.0	1.3	30.9
S18	Ext	78.73	308.6	2551.0	0.8	22.0
S19_2	Ext	0.17	32.9	52.0	1.5	5.0
S19_3	Ext	20.83	175.7	1186.0	1.5	25.5
S19_4	Ext	0.70	86.9	81.0	1.5	5.0
S19_5	Ext	0.19	24.2	77.0	1.5	5.0
S19_6	Ext	0.79	49.9	158.0	1.5	5.0
S2	Ext	0.63	78.8	79.7	0.7	5.0
S21	Ext	8.64	268.3	322.0	0.5	10.5
S22	Ext	25.39	287.5	883.0	1.1	16.1
S-25	Ext	0.33	69.1	47.7	0.8	50.0
S4	Ext	5.10	131.5	388.0	0.5	34.2
S5	Ext	13.28	174.7	760.0	0.9	50.8
S6	Ext	5.65	82.6	684.0	1.5	18.8
S6_4	Ext	34.48	399.6	863.0	1.3	21.8
S8	Ext	0.40	83.1	47.9	0.8	50.0
S9	Ext	7.35	326.6	225.0	0.7	27.1

Name	Tag	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Imperv. (%)



Surficial Soil Distribution (ref. OMAFRA Soil Survey Complex)


Legend
Subcatchments
Existing Land Use
COMMERCIAL
RECREATIONAL
FARM
INSTITUTIONAL
INDUSTRIAL
RESIDENTIAL-Out
RESIDENTIAL-LOW
RESIDENTIAL-MED
RESIDENTIAL-RURAL
LAND
ROAD
Existing Land Use
Merritt & Rice
Road
N
0.5 km
Port Robinson Rd
Merritt Rd
Quaker Rd
Rice Rd
First Ave
Niagara St
Pelham St
Welland Canal Route
Highway 20 E
Highway 20 W
Fonthill Park
Peace Park
Summersides Blvd
Meridian Way
Riley Ave
College St
Emmett St
Station St
Stella St
John St
Bacon Lane
Clare Ave
Crerar Ave
Montgomery Rd
Saddler St
Welland Rd
Woodside Sq
Seneca Lane
Northwood Dr
Eastwood Dr
Talbot Trail
Chippawa Blvd
North Rd
Ring Rd
College Park Dr
Rollins Dr
Cedar Park Dr
White Oak Crescent
Wellandvale Dr
Macoomb Dr
Woodgate Dr
Trelawn Pkwy
Royal Oak Dr
Page Dr
Seaway Mall
Lancaster Dr
Niagara College Welland Campus
Holy Cross
Foss Rd
Countryside Dr
Heritage Lane
Old Black Park
Hopkins St
Second St
Campbell St
Tucker St
Macartney Dr
Hansler Rd
Towpath Rd
Canal Rd
Gretel Pl
St Lawrence Dr
Days Ave
Ellott St
Wilkerson St
Grisdale Rd
Fallingbrook Dr
Nursery Lane
Millbridge Crescent
Parkhill Rd
Woodstream Blvd
Foresthill Crescent
Shoalts Dr
Pancake Lane
Oak Lane
Daleview Dr
Highland Ave
Elizabeth Dr
Church Hill
Canboro Rd
Brock St
Tanner Dr
Milburn Dr
Fern Gate
Springside Crescent
406
20
21

Summary Table of Existing & Preliminary Proposed Roadway Culverts (PCSWMM Check)

Road Segment	Culvert ID	Existing Conditions - PCSWMM Culverts						Preliminary Upgrade Required?	Preliminary Proposed Conditions - PCSWMM Culverts					
		Existing Name	LENGTH (m)	SHAPE	SIZE 1 (m)	SIZE 2 (m)	SLOPE (m/m)		Proposed Name	LENGTH (m)	SHAPE	SIZE 1 (m)	SIZE 2 (m)	SLOPE (m/m)
4	R01	C42	15	ARCH	0.3	0	0.015	No	-	-	-	-	-	-
	R02	CC_R1	20	CIRCULAR	0.4	0	0.001	Yes	C46	30	CIRCULAR	0.9	0	0.001
	R03-1	CC_R2-1	14	CIRCULAR	0.6	0	0.021	Yes	C167	17	CIRCULAR	0.9	0	0.001
	R03-2	CC_R2-2	18	CIRCULAR	0.6	0	0.004	Removed	-	-	-	-	-	-
	R05	CC_R4	24	CIRCULAR	0.45	0	0.008	Yes	C11	25	CIRCULAR	0.6	0	0.015
	R06	CC_R5	19	CIRCULAR	0.45	0	0.000	Yes	C13	48	CIRCULAR	0.6	0	0.005
	R07	CC_R6	12	CIRCULAR	0.5	0	0.002	Yes	C173	17	CIRCULAR	0.75	0	0.001
	R08	CC_R7	13	CIRCULAR	0.6	0	0.005	Yes	C20	28	CIRCULAR	0.75	0	0.005
	R09	CC_R8	15	CIRCULAR	0.6	0	0.016	No	-	-	-	-	-	-
1	M03	-	-	-	-	-	-	NEW	C181	26	CIRCULAR	0.5	0	0.000
	M04	CC_M1	6	CIRCULAR	0.3	0	0.000	Yes	C205	27	CIRCULAR	0.5	0	0.000
2	M05	CC_M2	17	CIRCULAR	0.4	0	0.003	Yes	C206	28	CIRCULAR	0.75	0	0.001
	M10	CC_M3	11	CIRCULAR	0.35	0	0.002	Removed	-	-	-	-	-	-
	M06	-	-	-	-	-	-	NEW	C76	26	CIRCULAR	0.3	0	0.000
	M11	CC_M4	11	CIRCULAR	0.4	0	0.018	Removed	-	-	-	-	-	-
	M12	CC_M5	13	CIRCULAR	0.6	0	0.016	Removed	-	-	-	-	-	-
	M07	CC_M6	14	CIRCULAR	0.5	0	0.001	Yes	C83	44	CIRCULAR	0.9	0	0.014
3	M13	CC_M7	25	CIRCULAR	0.75	0	0.000	No	-	-	-	-	-	-
	M08	CC_M8	25	CIRCULAR	0.9	0	0.005	No	-	-	-	-	-	-
	M09	CC_M9	52	CIRCULAR	1.05	0	0.001	No	-	-	-	-	-	-

Note: Does not include the watercourse crossings - see Section 4 of the report for HEC-RAS assessment.

Appendix G

Comments and Correspondences

Responses to Niagara Peninsula Conservation Authority (NPCA) Comments
Merritt Road/Rice Road Municipal Class Environmental Assessment

#	Section	NPCA Comments (January 17, 2024)	WSP Response (February 13, 2024)
Environmental Study Report, Draft, dated September 29, 2023			
1	3.2.6 NPCA Policy Document	This section refers to NPCA's Policy Document from September 2018, which was superseded in November 2022. As this EA started before the 2022 policies were in effect, referencing our previous policies is fine. However, please include a note that NPCA updated its policies in November 2022.	A note has been added to the ESR.
Appendix E, Environmental Impact Study, dated June 16, 2023			
2	8.2.6 Wetland Form and Function	NPCA is supportive of enhancement opportunities to increase ecological resilience and function of natural heritage features. However, NPCA does not consider enhancement as a substitute for wetland re-creation when considering compensation for the impacts of this degree of wetland removal. Please clarify how the proposed compensation clearly demonstrates conformance with NPCA's Policy, specifically 2.5.2 k. Please note that NPCA may consider areas under agricultural production AND areas that do not contain a permanent form of development as possible areas for wetland compensation.	As noted in comment 1, the NPCA allows a policy document from 2018 to be used in this EA. Comment 2 references a policy document from 2022. However, as NPCA is a public commenting body for EAs and has a Protocol for Planning Services with the Region dated January 2018, their input to the project is valued and considered. Policy 2.5.2 k) recommends that the decision to pursue compensation be subject to: i. all efforts to protect the feature being exhausted first; ii. the feature is not protected by any other applicable federal, provincial or municipal requirement(s); and iii. it taking place in consultation with the municipality or the proponent. In response: i), the Region led EA considered the options of the road alignment in this location. A background transportation master plan was completed (by others) and is the factor in selecting this location. ii) Provincial and municipal requirements protect the feature iii) The project is led by the Region, and their staff from various departments (including environmental planning) was engaged. The Region will consult with the NPCA during detailed design phase to confirm wetland compensation requirements and location. The Region will also discuss with MNRF as the wetland is a PSW.
3	8.2.6 Wetland Form and Function	Please provide the total area of wetland proposed for removal due to the proposed undertaking and the total area of wetland proposed for compensation. NPCA staff acknowledge that this area will be refined as detailed design progresses. a. As previously commented, compensation of swamps is not typically allowed by NPCA due to the lag effect between feature removal and feature recreation and the inherent challenges associated with effectively recreating swamp communities. As such NPCA recommends a compensation ratio of not less than 2:1 to be achieved to compensate for the loss of swamps within the study area and 1:1 for marsh habitats removed from the study area.	The scope of this study was limited to an EA. The detailed design will be completed under a subsequent separate phase. The EA presented a preliminary option for road design. The roadway design may be subject to further refinement during detailed design, along with the delineation of the grading limits, which may impact the area of wetland removal. As such, it was WSP's opinion that, to avoid confusion or misrepresentation, no estimates of impact area were provided. In our experience, providing numbers preemptively makes updates difficult. Therefore, WSP felt it was preemptive to provide areas of loss. The Region will undertake consultation with the NPCA during detailed design to confirm wetland compensation requirements and location. A detailed compensation plan is recommended based on the detailed design (NPCA also notes this in comment #4).
4	8.2.6 Wetland Form and Function	NPCA staff request that a Wetland Compensation Monitoring Plan be developed to demonstrate that wetland compensation has been achieved. a. This Plan must be implemented for the re-configured/re-created wetland feature(s), to accurately monitor any changes in the wetland community over time and to measure the success of the re-configuration/restoration and management actions. b. Monitoring must be conducted annually at a similar time of year (i.e., late July). c. All plants identified as part of the Wetland Compensation Monitoring Program must be categorized by the wetness index based on the Floristic Quality Assessment System for Southern Ontario. d. The results of the Wetland Compensation Monitoring Program must be submitted to NPCA annually prior to December 31, until planting of the wetland compensation area is complete. It is recommended that a monitoring plan be implemented for a minimum of 5-years upon completion of the wetland compensation plantings. e. Details regarding this Plan can be submitted at the detailed design stage for review and comment.	WSP agrees that a detailed Wetland Compensation Plan must be developed. As noted in Comment response #3, the compensation plan should be conducted after EA completion and during detailed design. NPCA seems to agree with this timeline based on comment #4e. NPCA will need to provide necessary input for the plan. It is also recommended that compensation requirements be tailored to the compensation location.
Appendix F, Stormwater Management and Hydraulic Assessment Report (Draft), dated August 2023			
5	2.2.1 Singers Drain	Singers Drain is erroneously classed as a municipal drain, please revise.	Text has been updated.

Responses to Niagara Peninsula Conservation Authority (NPCA) Comments
Merritt Road/Rice Road Municipal Class Environmental Assessment

#	Section	NPCA Comments (January 17, 2024)	WSP Response (February 13, 2024)
6	2.2.2 Towpath Drain	Towpath Drain is erroneously classed as a municipal drain, please revise.	Text has been updated.
7	6.2 Recommendations & Requirements for Future Study; HEC-RAS Model	As noted within Key Comment #3, the area of segment 1 (wetlands south of the unopened road allowance) does not have clear channels and required the use of levees, and staff note that cross sections 313 and 284 could benefit from levees on the right-hand side of the cross sections. NPCA is in support of the assessment that further 2D modeling would be beneficial.	The HEC-RAS model has been updated to incorporate levees along the right-hand side of cross sections 313 and 284. The hydraulics modelling results have remained the same.
8	HEC-RAS	Model The utilized terrain file appears to use a 2m grid, please provide clarification regarding why this was selected.	Two sets of LiDAR data have been received/sourced and reviewed accordingly. These include the 2 m resolution SWOOP DEM, which was based upon Orthophotography collected by MNRF in 2015 (ref. Land Information Ontario, 2015), and a 5 m resolution DEM provided by the NPCA in 2022. In comparing the two data sets, it was found that the SWOOP DEM had a better resolution (2 m) and had the potential to provide further detail in the areas of focus. Accordingly, SWOOP DEM was used for model development. Nonetheless, the NPCA DEM was also used to compare the findings from the SWOOP DEM and confirm the understanding of the features of interest.
9	HEC-RAS	Several cross sections have an artificially deepened channel, please clarify if surveying was completed to establish creek bed depths.	Channel elevations were determined at locations where survey data was available in proximity to cross-road culverts.
10	HEC-RAS	Cross section 1171 LOB length and cross section 65 ROB length were unexpectedly long, please provide clarification.	The cross-section 65 could not be found in the model. The HEC-Ras model has been updated accordingly. The modelling results were not impacted by the change in the model.

January 17, 2024

Via Email Only

Mir Ahsan Talpur, M.Env.Sc., EP
Senior Environmental Planner
WSP E&I Canada Limited
3450 Harvester Road, Suite 100
Burlington, Ontario L7N 3W5

NPCA File: PLEA202100316

To Mir Talpur,

Re: Niagara Peninsula Conservation Authority (NPCA) Comments
Merritt Road/Rice Road Municipal Class Environmental Assessment
Regional Municipality of Niagara
Environmental Study Report

Proposal

NPCA received and reviewed the above noted Environmental Study Report (ESR) and Appendices regarding Niagara Region's Schedule C Municipal Class Environmental Assessment for Merritt Road and Rice Road, dated September 29, 2023, prepared by WSP E&I. Staff offer the following **Key Comments** below, and **Detailed Comments** within **Appendix A** to be addressed within the next submission.

Key Comments

1. NPCA Planning Ecology staff have reviewed the *Environmental Impact Study for the Schedule C Municipal Class Environmental Assessment for Merritt Road and Rice Road*, dated June 16, 2023. At this time, NPCA requires additional information on wetland compensation to ensure that there will be no net loss to the form and function of the wetlands.

   Detailed Comments related to wetland compensation have been provided within **Appendix A**.

2. NPCA Engineering staff have reviewed the *Stormwater Management and Hydraulic Assessment Report (Draft) Merritt Road & Rice Road Schedule 'C' Municipal Class Environmental Assessment,* dated August 2023, and the accompanying HEC-RAS model files, and have no objection to:

- The revised 100-year floodplain under existing conditions;
- The utilization of the study's calibrated peak flows;
- The conclusion that the proposed road and associated culvert crossings have no negative impact on the floodplain;
- The concluded 100-year floodplain under proposed conditions; and
- The assessment that area of segment 1 (wetlands south of the unopened road allowance) would benefit from 2D modeling. The area does not have clear channels and required the use of levees, NPCA notes cross sections 313 and 284 could benefit from levees on the right-hand side of the cross sections.

3. NPCA Engineering staff require a few revisions and details to be clarified, which are specified within **Appendix A**.

Conclusion

NPCA staff hopes this information is helpful and looks forward to reviewing the next submission. We request that the next submission include a comment response matrix including the **Detailed Comments** within **Appendix A**. If you have any questions or would like to discuss further, please contact the undersigned.

Sincerely,

Colleen Bain, MES Planning
Senior Watershed Planner,
Environmental Planning and Policy, NPCA
cbain@npca.ca

cc: Leilani Lee-Yates, NPCA (email only)
David Deluce, NPCA (email only)
Amy Parks, NPCA (email only)
Theresa Bukovics, NPCA (email only)
Carly Mason, NPCA (email only)
Maged Elmadhoon, Niagara Region (email only)

Appendix A: Detailed Comments

Appendix A: Detailed Comments

NPCA staff have reviewed the Environmental Study Report (ESR) and Appendices prepared by WSP E&I regarding Niagara Region's Schedule C Municipal Class Environmental Assessment for Merritt Road and Rice Road, dated September 29, 2023, and offer the following comments to be addressed in the next submission. Please include a comment matrix using the format below.

#	Section	NPCA Comments, January 2024
***Environmental Study Report, Draft,* dated September 29, 2023**		
1.	3.2.6 NPCA Policy Document	This section refers to NPCA's Policy Document from September 2018, which was superseded in November 2022. As this EA started before the 2022 policies were in effect, referencing our previous policies is fine. However, please include a note that NPCA updated its policies in November 2022.
Appendix E, *Environmental Impact Study*, dated June 16, 2023		
2.	8.2.6 Wetland Form and Function	NPCA is supportive of enhancement opportunities to increase ecological resilience and function of natural heritage features. However, NPCA does not consider enhancement as a substitute for wetland re-creation when considering compensation for the impacts of this degree of wetland removal. Please clarify how the proposed compensation clearly demonstrates conformance with NPCA's Policy, specifically 2.5.2 k. Please note that NPCA may consider areas under agricultural production AND areas that do not contain a permanent form of development as possible areas for wetland compensation.

3.	8.2.6 Wetland Form and Function	Please provide the total area of wetland proposed for removal due to the proposed undertaking and the total area of wetland proposed for compensation. NPCA staff acknowledge that this area will be refined as detailed design progresses. a. As previously commented, compensation of swamps is not typically allowed by NPCA due to the lag effect between feature removal and feature recreation and the inherent challenges associated with effectively recreating swamp communities. As such NPCA recommends a compensation ratio of not less than 2:1 to be achieved to compensate for the loss of swamps within the study area and 1:1 for marsh habitats removed from the study area.
4.	8.2.6 Wetland Form and Function	NPCA staff request that a Wetland Compensation Monitoring Plan be developed to demonstrate that wetland compensation has been achieved. a. This Plan must be implemented for the re-configured/re-created wetland feature(s), to accurately monitor any changes in the wetland community over time and to measure the success of the re-configuration/restoration and management actions. b. Monitoring must be conducted annually at a similar time of year (i.e., late July). c. All plants identified as part of the Wetland Compensation Monitoring Program must be categorized by the wetness index based on the Floristic Quality Assessment System for Southern Ontario. d. The results of the Wetland Compensation Monitoring Program must be submitted to NPCA annually prior to December 31, until planting of the wetland compensation area is complete. It is recommended that a

		monitoring plan be implemented for a minimum of 5-years upon completion of the wetland compensation plantings. e. Details regarding this Plan can be submitted at the detailed design stage for review and comment.
Appendix F, *Stormwater Management and Hydraulic Assessment Report (Draft),* dated August 2023		
5.	2.2.1 Singers Drain	Singers Drain is erroneously classed as a municipal drain, please revise.
6.	2.2.2 Towpath Drain	Towpath Drain is erroneously classed as a municipal drain, please revise.
7.	6.2 Recommendations & Requirements for Future Study; HEC-RAS Model	As noted within **Key Comment** #3, the area of segment 1 (wetlands south of the unopened road allowance) does not have clear channels and required the use of levees, and staff note that cross sections 313 and 284 could benefit from levees on the right-hand side of the cross sections. NPCA is in support of the assessment that further 2D modeling would be beneficial.
8.	HEC-RAS Model	The utilized terrain file appears to use a 2m grid, please provide clarification regarding why this was selected.
9.	HEC-RAS Model	Several cross sections have an artificially deepened channel, please clarify if surveying was completed to establish creek bed depths.
10.	HEC-RAS Model	Cross section 1171 LOB length and cross section 65 ROB length were unexpectedly long, please provide clarification.

RE: Merritt Rd-Rice Rd EA - SWM & Hydraulic Assessment Report (DRAFT)

Talpur, Mir <mir.talpur@wsp.com>

Fri 2023-08-04 11:18 AM

To:Hussain, Kashif (MTO) <kashif.hussain@ontario.ca>

Cc:Weng, Xin (MTO) <Xin.Weng@ontario.ca>;MacKinnon, John (MTO) <John.MacKinnon@ontario.ca>;Elmadhoon, Maged <Maged.Elmadhoon@niagararegion.ca>;Chipps, Steve <steve.chipps@wsp.com>;HaugKindellan, Emma <emma.haugkindellan@wsp.com>;Azarkhish, Amin <amin.azarkhish@wsp.com>;Asif, Shahbaz (MTO) <Shahbaz.Asif@ontario.ca>

Hi Kashif,

Thank you for the prompt response on this. We will send you the updated final report in the next few days.

Sincerely,

Mir Ahsan Talpur, M.Env.Sc., EP
Senior Environmental Planner
Environmental Impact Assessment - Energy & Resources
He/Him
M+ 1 647-545-8974

WSP E&I Canada Limited

Please be aware that, effective September 21st, 2022, Wood Environment & Infrastructure Solutions Canada Limited was acquired by WSP.

From: Hussain, Kashif (MTO) <Kashif.Hussain@ontario.ca>
Sent: Friday, August 4, 2023 9:09 AM
To: Talpur, Mir <mir.talpur@wsp.com>
Cc: Weng, Xin (MTO) <Xin.Weng@ontario.ca>; MacKinnon, John (MTO) <John.MacKinnon@ontario.ca>; Elmadhoon, Maged <Maged.Elmadhoon@niagararegion.ca>; Chipps, Steve <steve.chipps@wsp.com>; HaugKindellan, Emma <emma.haugkindellan@wsp.com>; Azarkhish, Amin <amin.azarkhish@wsp.com>; Asif, Shahbaz (MTO) <Shahbaz.Asif@ontario.ca>
Subject: RE: Merritt Rd-Rice Rd EA - SWM & Hydraulic Assessment Report (DRAFT)

Hi Mir,

The MTO Drainage office has reviewed your responses and is fine with them. Please update the Drainage Report and add recommendations for drainage studies to be completed during the detailed design stage as noted in responses to MTO's comments. Please also forward us the final Drainage Report.

Thanks
Kashif

From: Hussain, Kashif (MTO)
Sent: August 3, 2023 9:30 AM
To: Talpur, Mir <mir.talpur@wsp.com>
Cc: Weng, Xin (MTO) <Xin.Weng@ontario.ca>; MacKinnon, John (MTO) <John.MacKinnon@ontario.ca>;

Elmadhoon, Maged <Maged.Elmadhoon@niagararegion.ca>; Chipps, Steve <steve.chipps@wsp.com>; HaugKindellan, Emma <emma.haugkindellan@wsp.com>; Azarkhish, Amin <amin.azarkhish@wsp.com>; Asif, Shahbaz (MTO) <Shahbaz.Asif@ontario.ca>
Subject: RE: Merritt Rd-Rice Rd EA - SWM & Hydraulic Assessment Report (DRAFT)

Hi Mir,

I will discuss it with our Drainage office and let you know our response.

Thanks
Kashif

From: Talpur, Mir <mir.talpur@wsp.com>
Sent: August 3, 2023 8:40 AM
To: Hussain, Kashif (MTO) <Kashif.Hussain@ontario.ca>
Cc: Weng, Xin (MTO) <Xin.Weng@ontario.ca>; MacKinnon, John (MTO) <John.MacKinnon@ontario.ca>; Elmadhoon, Maged <Maged.Elmadhoon@niagararegion.ca>; Chipps, Steve <steve.chipps@wsp.com>; HaugKindellan, Emma <emma.haugkindellan@wsp.com>; Azarkhish, Amin <amin.azarkhish@wsp.com>; Asif, Shahbaz (MTO) <Shahbaz.Asif@ontario.ca>
Subject: RE: Merritt Rd-Rice Rd EA - SWM & Hydraulic Assessment Report (DRAFT)

Good Morning Kashif,

We have discussed MTO's comments on the draft SWM & Hydraulic Assessment Report with Niagara Region staff. We were advised that some of the comments and additional analysis are only feasible as part of Phase 5 of the EA (Detailed Design Phase), which will be undertaken by the Region when the ESR is complete. Please see responses in red below to MTO's comments on the draft SWM & Hydraulic Assessment Report.

We would appreciate MTO staff's review of these responses and advise if these responses are satisfactory. We can then update and send you the final report.

Sincerely,

Mir Ahsan Talpur, M.Env.Sc., EP
Senior Environmental Planner
Environmental Impact Assessment - Energy & Resources
He/Him
M+ 1 647-545-8974

WSP E&I Canada Limited

From: Talpur, Mir
Sent: Friday, July 21, 2023 10:54 AM
To: Hussain, Kashif (MTO) <Kashif.Hussain@ontario.ca>
Cc: Weng, Xin (MTO) <Xin.Weng@ontario.ca>; MacKinnon, John (MTO) <John.MacKinnon@ontario.ca>; Elmadhoon, Maged <Maged.Elmadhoon@niagararegion.ca>; Chipps, Steve <steve.chipps@wsp.com>; HaugKindellan, Emma <emma.haugkindellan@wsp.com>; Azarkhish, Amin <amin.azarkhish@wsp.com>; Asif, Shahbaz (MTO) <Shahbaz.Asif@ontario.ca>
Subject: RE: Merritt Rd-Rice Rd EA - SWM & Hydraulic Assessment Report (DRAFT)

Hi Kashif,

Thank you for sharing MTO staff's comments on the SWM & Hydraulic Assessment Report. We will review these comments and will let you know if there are any questions.

Sincerely,

Mir Ahsan Talpur, M.Env.Sc., EP
Senior Environmental Planner
Environmental Impact Assessment - Energy & Resources
He/Him
M+ 1 647-545-8974

WSP E&I Canada Limited

From: Hussain, Kashif (MTO) <Kashif.Hussain@ontario.ca>
Sent: Friday, July 21, 2023 10:35 AM
To: Talpur, Mir <mir.talpur@wsp.com>
Cc: Weng, Xin (MTO) <Xin.Weng@ontario.ca>; MacKinnon, John (MTO) <John.MacKinnon@ontario.ca>; Elmadhoon, Maged <Maged.Elmadhoon@niagararegion.ca>; Chipps, Steve <steve.chipps@wsp.com>; HaugKindellan, Emma <emma.haugkindellan@wsp.com>; Azarkhish, Amin <amin.azarkhish@wsp.com>; Asif, Shahbaz (MTO) <Shahbaz.Asif@ontario.ca>
Subject: RE: Merritt Rd-Rice Rd EA - SWM & Hydraulic Assessment Report (DRAFT)

Hi Mir,

The MTO Drainage office has reviewed the draft stormwater management report and has the following comments;

1. Reference to "Roadway crossings shall be designed in accordance with the MTO Design Flood Criteria Directive B-100" is given in Stormwater Management (SWM) report whereas this document is superseded by MTO's Highway Drainage Standards (2008). They are available at the following location and should be reviewed for design criteria.
   https://www.library.mto.gov.on.ca/SydneyPLUS/TechPubs/Portal/tp/tdViews.aspx

   The report will be updated to reference MTO's Highway Drainage Standards (2008).

2. Proposed cross section of Segment 3 is Urban. provide calculations for external drainage (Minor and Major flow) from MTO's RoW and proposed changes to confirm that there is no impact on conveyance when catch basins and storm sewer system is installed.
   This is considered beyond the scope of the current assessment and would be better suited to be evaluated as part of the detailed design phase of the project. The recommendation for future study as part of the detailed design will be amended in the report to include the requirement for major / minor flow assessment for MTO's RoW within the study area.

3. Provide Spread Analysis for Segment 3 and confirm if it meets Highway Drainage Standards (2008).
   This is considered beyond the scope of the current assessment and would be better suited to be evaluated as part of the detailed design phase of the project. The recommendation for future study as part of the detailed design will be amended in the

report to include the requirement for roadway spread assessment for MTO's RoW within the study area.

4. MTO shall review stormwater management and drainage at detail design stage to confirm that proposed road improvements do not impact MTO's drainage system.
   Comment noted. MTO's review at the future detailed design stage will be acknowledged within the final report.

5. Please note that unconventional underground storage such as chambers and infiltration systems are not permitted by MTO. Underground storages provided in manholes, stormsewer, super pipe or storage tank are permitted as such storages are accessible through a manhole and can be easily inspected for their continued functionality. If unconventional storages are provided then calculations and comparison of post- to pre-development flows without underground storages and ponding limit for 100-year storm event should be provided to confirm that the proposed development will not impact the MTO's drainage system under such condition.
   Comment noted. These considerations will be added into the discussion of potential SWM practices located within MTO's RoW.

6. Please provide summary table to confirm that culverts within MTO's RoW meet standards as per Highway Drainage Standards (2008).
   This is considered beyond the scope of the current assessment and would be better suited to be evaluated as part of the detailed design phase of the project. The recommendation for future study as part of the detailed design will be amended in the report to include the requirement for culvert capacity analysis for MTO's RoW within the study area.

Please update the report accordingly and submit the revised report and the required information for our review. If the above responses are satisfactory to MTO staff, we will update the report accordingly, and share the updated final report with MTO staff.

Please let us know if you have any questions.

Thanks
Kashif

From: Talpur, Mir Ahsan Ali <mir.talpur@wsp.com>
Sent: July 10, 2023 2:49 PM
To: Hussain, Kashif (MTO) <Kashif.Hussain@ontario.ca>
Cc: Weng, Xin (MTO) <Xin.Weng@ontario.ca>; MacKinnon, John (MTO) <John.MacKinnon@ontario.ca>; Elmadhoon, Maged <Maged.Elmadhoon@niagararegion.ca>; Chipps, Steve <steve.chipps@wsp.com>; HaugKindellan, Emma <emma.haugkindellan@wsp.com>; Azarkhish, Amin <amin.azarkhish@wsp.com>
Subject: Merritt Rd-Rice Rd EA - SWM & Hydraulic Assessment Report (DRAFT)

Hi Kashif,

I hope you are doing well. We have now completed the draft Stormwater Management and Hydraulic Assessment Report for Merritt Rd-Rice Rd Class EA. We would like to share this report with you for MTO staff's review. Please use this OneDrive link to download the report: 2023-07-10 Merritt Rd-Rice Rd - SWM & Hydraulic Assessment Report

The information related to proposed works at Highway 406 interchange can be found in Section 3.2.1 (page 26), Section 3.2.5 (page 45) and Section 6.2 (page 86) of the report.

RE: NPCA Comments 2 - Merritt Rd-Rice Rd EA - SWM & Hydraulic Assessment Report (DRAFT)

Talpur, Mir <mir.talpur@wsp.com>
Fri 2023-08-04 11:16 AM
To:David Deluce <ddeluce@npca.ca>
Cc:Leilani Lee-Yates <Llee-yates@npca.ca>;Elmadhoon, Maged <Maged.Elmadhoon@niagararegion.ca>;Chipps, Steve <steve.chipps@wsp.com>;HaugKindellan, Emma <emma.haugkindellan@wsp.com>;Azarkhish, Amin <amin.azarkhish@wsp.com>;Colleen Bain <CBain@npca.ca>;Theresa Bukovics <tbukovics@npca.ca>

Hi David,

Thank you very much. We really appreciate NPCA staff's input and advice on this project. We will document these comments in the SWM Report.

The Region staff and MTO staff had minor comments on the report. We will incorporate those comments into the report and will provide you the final report in the next few days.

Sincerely,

Mir Ahsan Talpur, M.Env.Sc., EP
Senior Environmental Planner
Environmental Impact Assessment - Energy & Resources
He/Him
M+ 1 647-545-8974

WSP E&I Canada Limited

Please be aware that, effective September 21st, 2022, Wood Environment & Infrastructure Solutions Canada Limited was acquired by WSP.

From: David Deluce <ddeluce@npca.ca>
Sent: Thursday, August 3, 2023 4:09 PM
To: Talpur, Mir <mir.talpur@wsp.com>
Cc: Leilani Lee-Yates <Llee-yates@npca.ca>; Elmadhoon, Maged <Maged.Elmadhoon@niagararegion.ca>; Chipps, Steve <steve.chipps@wsp.com>; HaugKindellan, Emma <emma.haugkindellan@wsp.com>; Azarkhish, Amin <amin.azarkhish@wsp.com>; Colleen Bain <CBain@npca.ca>; Theresa Bukovics <tbukovics@npca.ca>
Subject: RE: NPCA Comments 2 - Merritt Rd-Rice Rd EA - SWM & Hydraulic Assessment Report (DRAFT)

Hi Mir,

Further to my comments of August 1, we've completed our review of the wetland assessment component of the report. NPCA staff support the recommended mitigation measures and requirements presented in the report such as but not limited to:

a. Section 5.1 recommends that a bathymetric survey and more detailed topographic survey be undertaken for Segment 1 to support the hydraulic analysis and future design. The NPCA is supportive of this.

b. Five wetland groups SU06, SU10, SU11, SU12 and SU13 have been assessed as High Risk. These wetland groups are all located within or directly adjacent to the ROW. It is noted in the SWM and Hydraulic Assessment report that on average across the total PSW system, the magnitude of hydrological change is considered Low Risk (associated with the proposed roadway works) but given that the localized sections of the PSW system would experience greater levels of risk based upon local changes, the report recommends carrying forward the TRCA wetland impact assessment recommendations. The NPCA is supportive of this.

c. NPCA staff recognize that the continuous simulation modelling is currently high-level/conceptual and does not account for any impacts to the systems beyond the road ROW as details related to grading, staging, etc. as these are not known at this time. The NPCA staff recognize that further details are to be provided at detailed design. The NPCA is supportive of this.

d. Results from the continuous simulation indicate that the wetlands which do not receive direct runoff from the proposed ROW can still be impacted through backwater conditions and the interconnectedness of the wetland pockets. The report recommends further review of this as part of future detailed design to better understand the connections and functional relationships of the wetland units. The NPCA is supportive of this.

e. In addition to including a restoration and compensation plan to offset the negative impacts of habitat loss, the report recommends the restoration and compensation plan to include hydrology / hydraulics. This is to ensure that the storage available within this PSW is maintained to ensure no impacts further downstream, as the PSW provides storage / attenuation prior to discharging at Cataract Road. NPCA is supportive of future efforts at detail design to ensure that the functionality of the wetland is maintained both upstream and downstream of the proposed roadway, and that the key hydrologic connections are maintained through bridges (spanning the watercourses) and culverts.

f. Section 5.3.3 recommends additional long-term monitoring within the study area to include additional surface water monitoring gauges both upstream and downstream as well as within the PSW system. The NPCA recognize that detailed understanding of surface hydrology is imperative to ensure post development flows match pre-development conditions. This is especially important given the relatively flat topography within this region and the PSW located within Segment 1 is primarily a surface water fed system. The additional surface water monitoring is recommended to follow completion of the Class EA Study / during the detailed design phase and be confirmed with NPCA. NPCA is supportive of this recommendation and look forward to further review.

In closing, the NPCA is supportive of the recommendations, mitigation measures and requirements discussed in the report and look forward to reviewing further information at the detailed design stage. Please let me know if you have any questions.

Best Regards,

David Deluce, MCIP, RPP
Senior Manager, Environmental Planning & Policy

Niagara Peninsula Conservation Authority (NPCA)
250 Thorold Road West, 3rd Floor | Welland, ON L3C 3W2

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From: David Deluce
Sent: Tuesday, August 1, 2023 4:40 PM
To: Talpur, Mir <mir.talpur@wsp.com>
Cc: Leilani Lee-Yates <llee-yates@npca.ca>; Elmadhoon, Maged <Maged.Elmadhoon@niagararegion.ca>; Chipps, Steve <steve.chipps@wsp.com>; HaugKindellan, Emma <emma.haugkindellan@wsp.com>; Azarkhish, Amin <amin.azarkhish@wsp.com>; Colleen Bain <CBain@npca.ca>; Theresa Bukovics <tbukovics@npca.ca>
Subject: NPCA Comments 1 - Merritt Rd-Rice Rd EA - SWM & Hydraulic Assessment Report (DRAFT)

Hi Mir,

NPCA has reviewed 'Stormwater Management and Hydraulic Assessment Report (Draft) Merritt Road & Rice Road Schedule 'C' Municipal Class Environmental Assessment' dated July 2023 by WSP. We are still finalizing our review of the wetland assessment component of the report and anticipate those comments by Thursday but offer the following comments on the other components of the report:

1. The NPCA has no objection to the revised 100-year floodplain under existing conditions.

2. The NPCA has no objection to the utilization of the study's calibrated peak flows.

3. The NPCA has no objection to the conclusion that the proposed road and associated culvert crossings have no negative impact on the floodplain.

4. The NPCA has no objection to the concluded 100-year floodplain under proposed conditions.

5. The NPCA supports the recommendations & requirements for future study and we look forward to reviewing this information as the project moves towards detailed design.

Please let me know if you have any questions.

Best Regards,

David Deluce, MCIP, RPP
Senior Manager, Environmental Planning & Policy

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RE: Merritt Rd-Rice Rd EA - SWM & Hydraulic Assessment Report (DRAFT)

Elmadhoon, Maged <Maged.Elmadhoon@niagararegion.ca>

Thu 2023-08-03 8:32 AM

To:Talpur, Mir <mir.talpur@wsp.com>

Cc:Chipps, Steve <steve.chipps@wsp.com>;HaugKindellan, Emma <emma.haugkindellan@wsp.com>;Azarkhish, Amin <amin.azarkhish@wsp.com>

Thanks Mir

Maged Elmadhoon, M.Eng., P.Eng. (he/him)
Manager, Transportation Planning
Transportation Services Division
Public Works, Niagara Region
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Maged.Elmadhoon@niagararegion.ca
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Niagara Region

From: Talpur, Mir <mir.talpur@wsp.com>
Sent: Thursday, August 3, 2023 8:31 AM
To: Elmadhoon, Maged <Maged.Elmadhoon@niagararegion.ca>
Cc: Chipps, Steve <steve.chipps@wsp.com>; HaugKindellan, Emma <emma.haugkindellan@wsp.com>; Azarkhish, Amin <amin.azarkhish@wsp.com>
Subject: RE: Merritt Rd-Rice Rd EA - SWM & Hydraulic Assessment Report (DRAFT)

Thanks, Maged. I will incorporate this edit and any other edits from the SWM Report into the ESR.

Sincerely,

wsp

Mir Ahsan Talpur, M.Env.Sc., EP
Senior Environmental Planner
Environmental Impact Assessment - Energy & Resources
He/Him
M+ 1 647-545-8974

WSP E&I Canada Limited

Please be aware that, effective September 21st, 2022, Wood Environment & Infrastructure Solutions Canada Limited was acquired by WSP.

From: Elmadhoon, Maged <Maged.Elmadhoon@niagararegion.ca>
Sent: Thursday, August 3, 2023 8:01 AM

To: Talpur, Mir <mir.talpur@wsp.com>
Cc: Chipps, Steve <steve.chipps@wsp.com>; HaugKindellan, Emma <emma.haugkindellan@wsp.com>; Azarkhish, Amin <amin.azarkhish@wsp.com>
Subject: RE: Merritt Rd-Rice Rd EA - SWM & Hydraulic Assessment Report (DRAFT)

Good morning Mir,

Thanks for the response. Please ensure this edit is updated in both the ESR and appendices.

Regards
Maged

Maged Elmadhoon, M.Eng., P.Eng. (he/him)
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From: Talpur, Mir <mir.talpur@wsp.com>
Sent: Wednesday, August 2, 2023 8:14 PM
To: Elmadhoon, Maged <Maged.Elmadhoon@niagararegion.ca>
Cc: Chipps, Steve <steve.chipps@wsp.com>; HaugKindellan, Emma <emma.haugkindellan@wsp.com>; Azarkhish, Amin <amin.azarkhish@wsp.com>
Subject: RE: Merritt Rd-Rice Rd EA - SWM & Hydraulic Assessment Report (DRAFT)

Hi Maged,

I have received the following from our team in response to Maggie's comment:

The recommendation text will be refined to acknowledge potential options / flexibility in strategy where certain physical / site constraints may exist, which are to be verified as part of the detailed design stage.

Sincerely,

Mir Ahsan Talpur, M.Env.Sc., EP
Senior Environmental Planner
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WSP E&I Canada Limited

Please be aware that, effective September 21st, 2022, Wood Environment & Infrastructure Solutions Canada Limited was acquired by WSP.

From: Elmadhoon, Maged <Maged.Elmadhoon@niagararegion.ca>
Sent: Monday, July 24, 2023 12:10 PM
To: Talpur, Mir <mir.talpur@wsp.com>
Cc: Chipps, Steve <steve.chipps@wsp.com>; HaugKindellan, Emma <emma.haugkindellan@wsp.com>; Azarkhish, Amin <amin.azarkhish@wsp.com>
Subject: RE: Merritt Rd-Rice Rd EA - SWM & Hydraulic Assessment Report (DRAFT)

Hi Mir,

I received the below request from Maggie:

"*I have minor comments to offer. Would the flexibility of 'Erosion Control' be included in the below (refer to the Report Section 6.2 'Recommendations & Requirements for Future Study')? Retention of 28-29mm runoff volume could be difficult to achieve if soil/groundwater/land constraints exist*".

— Erosion control is to be provided through the application of LID BMPs designed to retain the Runoff Volume Control Target as identified through the MECP's Draft LID Guidance (i.e., 28-29 mm) for the increased impervious area within each roadway Segment. The LID BMPs may include infiltration trenches beneath the roadside ditches (hybrid segments), or Silva Cells / Bioretention features within the urban segment.

Please advise.

Thanks

Maged Elmadhoon, M.Eng., P.Eng. (he/him)
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From: Talpur, Mir <mir.talpur@wsp.com>
Sent: Monday, July 24, 2023 9:02 AM
To: D Deluce <ddeluce@npca.ca>
Cc: Llee Yates <Llee-yates@npca.ca>; Elmadhoon, Maged <Maged.Elmadhoon@niagararegion.ca>; Chipps, Steve <steve.chipps@wsp.com>; HaugKindellan, Emma <emma.haugkindellan@wsp.com>; Azarkhish, Amin <amin.azarkhish@wsp.com>
Subject: RE: Merritt Rd-Rice Rd EA - SWM & Hydraulic Assessment Report (DRAFT)

CAUTION EXTERNAL EMAIL: This email originated from outside of the Niagara Region email system. Use caution when clicking links or opening attachments unless you recognize the sender and know the content is safe.

Good Morning David,

This is a gentle reminder regarding our request of NPCA's review of the draft Stormwater Management and Hydraulic Assessment Report for Merritt Rd-Rice Rd Class EA. We would appreciate any questions or comments by July 31, 2023.

Sincerely,

Mir Ahsan Talpur, M.Env.Sc., EP
Senior Environmental Planner
Environmental Impact Assessment - Energy & Resources
He/Him
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WSP E&I Canada Limited

Please be aware that, effective September 21st, 2022, Wood Environment & Infrastructure Solutions Canada Limited was acquired by WSP.

From: Talpur, Mir Ahsan Ali
Sent: Monday, July 10, 2023 2:49 PM
To: ddeluce@npca.ca
Cc: Leilani Lee-Yates <Llee-yates@npca.ca>; Elmadhoon, Maged <Maged.Elmadhoon@niagararegion.ca>; Chipps, Steve <steve.chipps@wsp.com>; HaugKindellan, Emma <emma.haugkindellan@wsp.com>; Azarkhish, Amin <amin.azarkhish@wsp.com>
Subject: Merritt Rd-Rice Rd EA - SWM & Hydraulic Assessment Report (DRAFT)

Hi David,

We have now completed the draft Stormwater Management and Hydraulic Assessment Report for Merritt Rd-Rice Rd Class EA. We would like to share this report with you for NPCA staff's review. Please use this OneDrive link to download the report: 2023-07-10 Merritt Rd-Rice Rd - SWM & Hydraulic Assessment Report

We would appreciate any questions or comments by July 31, 2023.

Sincerely,

Mir Ahsan Talpur, M.Env.Sc., EP
Senior Environmental Planner
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Please be aware that, effective September 21st, 2022, Wood Environment & Infrastructure Solutions Canada Limited was acquired by WSP.

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Appendix H

Limitations

Limitations

1. The work performed in the preparation of this report and the conclusions presented are subject to the following:
    a. The Standard Terms and Conditions which form a part of our Professional Services Contract;
    b. The Scope of Services;
    c. Time and Budgetary limitations as described in our Contract; and
    d. The Limitations stated herein.
2. No other warranties or representations, either expressed or implied, are made as to the professional services provided under the terms of our Contract, or the conclusions presented.
3. The conclusions presented in this report were based, in part, on visual observations of the Site and attendant structures. Our conclusions cannot and are not extended to include those portions of the Site or structures, which are not reasonably available, in WSP's opinion, for direct observation.
4. The environmental conditions at the Site were assessed, within the limitations set out above, having due regard for applicable environmental regulations as of the date of the inspection. A review of compliance by past owners or occupants of the Site with any applicable local, provincial or federal bylaws, orders-in-council, legislative enactments and regulations was not performed.
5. The Site history research included obtaining information from third parties and employees or agents of the owner. No attempt has been made to verify the accuracy of any information provided, unless specifically noted in our report.
6. Where testing was performed, it was carried out in accordance with the terms of our contract providing for testing. Other substances, or different quantities of substances testing for, may be present on-site and may be revealed by different or other testing not provided for in our contract.
7. Because of the limitations referred to above, different environmental conditions from those stated in our report may exist. Should such different conditions be encountered, WSP must be notified in order that it may determine if modifications to the conclusions in the report are necessary.
8. The utilization of WSP's services during the implementation of any remedial measures will allow WSP to observe compliance with the conclusions and recommendations contained in the report. WSP's involvement will also allow for changes to be made as necessary to suit field conditions as they are encountered.
9. This report is for the sole use of the party to whom it is addressed unless expressly stated otherwise in the report or contract. Any use which any third party makes of the report, in whole or the part, or any reliance thereon or decisions made based on any information or conclusions in the report is the sole responsibility of such third party. WSP accepts no responsibility whatsoever for damages or loss of any nature or kind suffered by any such third party as a result of actions taken or not taken or decisions made in reliance on the report or anything set out therein.
10. This report is not to be given over to any third party for any purpose whatsoever without the written permission of WSP.
11. Provided that the report is still reliable, and less than 12 months old, WSP will issue a third-party reliance letter to parties that the client identifies in writing, upon payment of the then current fee for such letters. All third parties relying on WSP's report, by such reliance agree to be bound by our proposal and WSP's standard reliance letter. WSP's standard reliance letter indicates that in no event shall WSP be liable for

any damages, howsoever arising, relating to third-party reliance on WSP's report. No reliance by any party is permitted without such agreement.