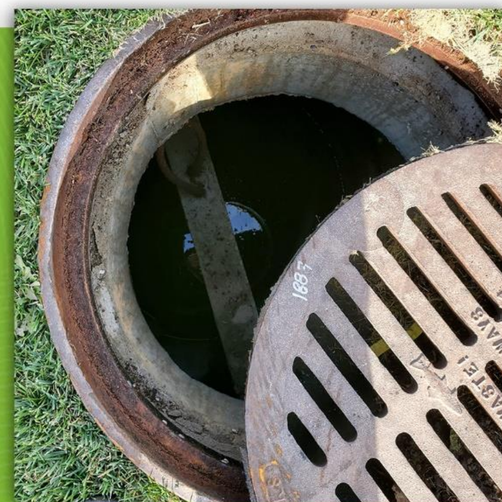
MULTI-JURISDICTIONAL STORMWATER MASTER PLAN



Prepared for:

City of Mt. Pleasant

F&V Project No. 841610

FLEIS&VANDENBRINK

DESIGN. BUILD. OPERATE.

July 2021

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1.0 INTRODUCTION

In late 2019, the City of Mt. Pleasant ('City') retained Fleis & VandenBrink (F&V) to develop a Multi-Jurisdictional Storm Water Master Plan (SWMP) for the greater Mt. Pleasant area. For the purposes of developing this SWMP, the greater Mt. Pleasant area ('planning area') was defined to generally be bounded by: River Road to the north, Deerfield Road to the south, Lincoln Road to the west, and US-127 to the east. The planning area is highlighted in Figure 1.

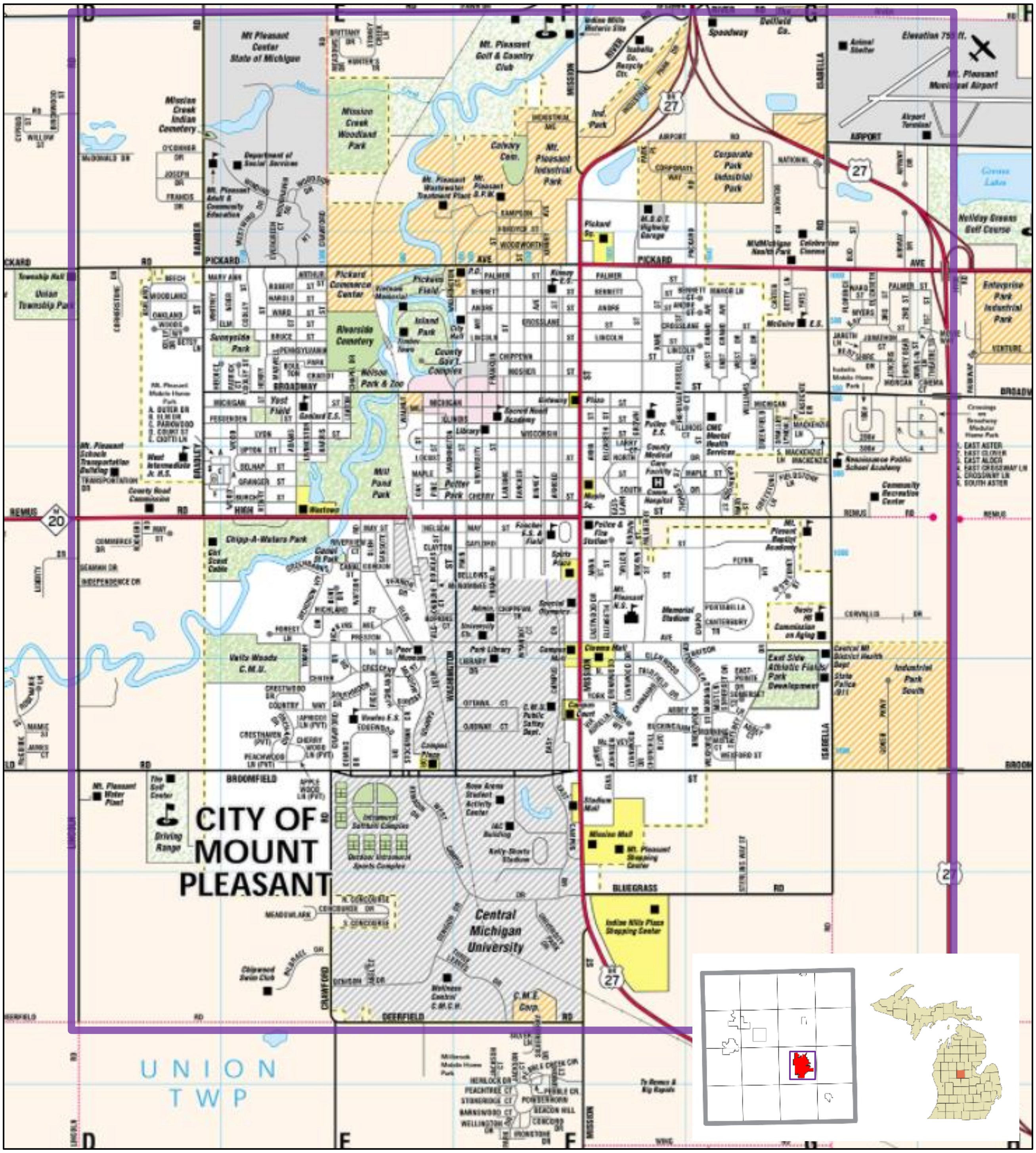

Figure 1. Greater Mt. Pleasant, Michigan Area with General Planning Area Overlay.

The stakeholder agencies and organizations identified as having storm water assets and/or drainage within the planning area include:

- the City of Mt. Pleasant[1];
    - Central Michigan University (nested within the boundaries of the City)
- Union Charter Township[2] ('Township');
- Isabella County (represented by two agencies):
    - Road Commission (ICRC)
    - Drain Commissioner (ICDC)
- The Michigan Department of Transportation (MDOT)[3]; and,
- The Saginaw Chippewa Indian Tribe (SCIT)[4].

This plan was produced with the City of Mt. Pleasant as the lead agency for project management and funding. The development of this plan was also funded in part through a grant from the Saginaw Chippewa Indian Tribe. The ICDC also contributed funding to support the evaluation of county drain information.

1.1 Master Plan Goals and Objectives

The goal of developing this SWMP is to define **a unified, collaborative approach to storm water management issues for the Mt. Pleasant, Michigan area**; the need for which was envisioned following the severe flooding in the area that was experienced in June 2017 (in addition to other historic flooding events). To achieve the goal of the SWMP, the two main objectives to be achieved by this SWMP and its subsequent implementation are to:

1) identify shortcomings of the current storm water management systems; and
2) cooperatively address the identified shortcomings that cross jurisdictional boundaries.

In other words, this SWMP ultimately defines an approach that achieves a desired level of service in the most cost-effective way through the proper operation, maintenance, and replacement/rehabilitation of assets to provide reliable storm water collection and the discharge of flows while minimizing the impact of regional and localized flooding to the developed and natural environment to the maximum extent feasible.

In furtherance of these objectives, the SWMP has five essential elements to be considered with respect to the planning area, including:

1) identification of watershed areas and overlaid jurisdictional considerations;
2) analysis of the storm water runoff generation and transport capacities of the various drainage systems;
3) identification of storm water conveyance limitations with a prioritization towards those where flooding has been previously documented;
4) identification of immediate actions to be taken based on structural and functional infrastructure conditions; and
5) recommendations and proposed schedule for system improvements, changes, and controls.

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[1] The City regulates storm water management from land within its jurisdiction. It also owns most of the storm water infrastructure withi8n its jurisdiction except for those serving or associated with: non-City-owned parcels, rights-of-way through the City maintained by the ICRC (roads) or MDOT (roads and railroads), or county drains (managed by the ICDC). The City is also owner of the Mt. Pleasant Municipal Airport (located within the Township).

[2] The Township regulates storm water management from land within its jurisdiction. The only storm water assets owned by the Township are those serving Township-owned land and facilities such as the wastewater treatment plant, parks, etc.

[3] MDOT regulates storm water management on its rights-of-way (ROWs) throughout the planning area, including roads and railroads. Certain regulations may also be enforced on adjacent non-MDOT-owned lands that drain to MDOT rights-of-way or the storm water assets that serve these ROWs/. MDOT is the only entity in the planning area that is subject to a National Pollutant Discharge Elimination System (NPDES) permit and the implementation of a 'comprehensive storm water management program'. This program is detailed in MDOT's Storm Water Management Plan.

[4] The Isabella Reservation was established by treaty with the United States in 1855 and a 2010 decision by the U.S. District Court for the Eastern District of Michigan (*Saginaw Chippewa Indian Tribe of Michigan and United States v. Granholm, et al.*) re-affirmed the boundaries of the reservation such that all lands north of High Street / Remus Road in the planning area are part of the reservation. The regulation of the majority of this land falls to the State and its municipal agencies though various intergovernmental memoranda of agreement while the tribe has primary jurisdiction over lands held in trust by the U.S. government (where ownership is limited to tribal members). Some land in the planning area is owned by the SCIT or tribal members on a fee simple basis (where no ownership restrictions exist) and may be subject to storm water regulations above and beyond those imposed by the State or its municipalities.

Addressing these five essential elements involved accomplishing six major tasks:

1) Developing a storm water system asset inventory (i.e. asset database with locations and characteristics with pipe / conveyance network routing details);
2) Incorporating data on the structural conditions of these assets (and estimating conditions for other assets based on other available information) and identifying critical assets
3) Evaluating the functional conditions of these assets (i.e. developing and utilizing a hydraulic model), with major sub-tasks including:
    a. Identifying model inputs and boundary conditions (e.g. rainfall events of interest and associated river flooding levels);
    b. Defining storm water runoff catchments and characteristics (e.g. areas flowing to specific pipes and the characteristics of these areas – acreage, soils, imperviousness, slopes); and
    c. Estimating impacts of distributed-but-not-universal conditions (e.g. private storm water controls, sump pump connections, and tile pipe infiltration)
    d. Consideration of current conditions and estimated future development patterns
4) Assembling a straightforward, scheduled storm water capital improvements plan (CIP) to address structural and functional issues identified with storm water assets with specific, tailored CIPs available to each jurisdiction
5) Packaging the data utilized to develop, and generated by, the inventory, assessment, and evaluation of the storm water drainage network into:
    a. a comprehensive spatial database (i.e. geodatabase);
    b. a hydraulic model developed in Autodesk's® Sanitary & Storm Analysis (SSA) program; and
    c. an organized repository of digital plans and products utilized throughout the project
6) Synthesizing the inputs and outputs of the other major tasks into a comprehensive SWMP which summarizes the efforts and provides additional information and context for utilizing and understanding the various technical products developed through the entire project.

Working with staff from the various stakeholder agencies, F&V took the lead in synthesizing existing asset and condition information, identification of additional assets, condition assessment estimation for non-inspected assets, hydraulic modeling, and capital improvement planning for the storm water system.

1.2 Master Plan Scope Limitations

The master plan does not involve modeling the Chippewa River and its various road crossings and other hydraulic elements in the planning area. The crossings are identified in the database but are not assessed for capacity, structural conditions, or considered in plans for future work. Flooding along the Chippewa River corridor (e.g. in the various FEMA floodplain designations) is primarily a function of the river hydraulics, including capacities of road-crossing bridges and other infrastructure (all relative to the volume and rate of precipitation runoff within the entire watershed). Mitigating flooding directly caused by the Chippewa River is beyond the scope of this plan. However, the FEMA-determined flood elevations for various design storms are utilized as the boundary conditions (i.e. outfall water surface elevations) that may impact the discharge capacity for outfalls and potential flooding in upstream areas.

A significant number of private assets have been added to the geodatabase to assist in establishing flow boundaries for the model. In general, the private assets are located but have no additional information associated (e.g. condition) with them. Private ponds were identified from plans and from aerial imagery and are identified in a distinct geodatabase layer. This information was generated to provide additional information to be considered in modeling area runoff characteristics.

Driveway culverts are generally located but are associated with very little asset information and are generally not modeled except where the associated ditch or channel is modeled.

Generally, 12-inch and larger storm water pipes are included in the model (except for catch basin leads, building roof drain sewers, sump pump leads, and other minor pipes) although some smaller pipes are included, and some larger pipes are excluded based on engineering judgement. Main pipes that were not modeled are still included in the asset condition assessment.

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2.0 Watersheds and Jurisdictional Areas

The United States Geological Survey (USGS) has a standardized naming system for watersheds throughout the United States and uses a Hydrologic Unit Code (HUC) system for precise naming. The planning area is in the Great Lakes Region (HUC: 04), Southwestern Lake Huron Sub-Region (HUC: 0408), Saginaw River Accounting Unit (HUC: 040802), and Pine River Cataloging Unit – used interchangeably with the term 'watershed' (HUC: 04080202). There are two sub-watersheds that cover the planning area: the Chippewa River Downstream (HUC: 0408020205), downstream of its confluence with the North Branch of the Chippewa River, and the Chippewa River Upstream (HUC: 040802020207), upstream of this area. Within these two sub-watersheds, there are four drainage basins. In order of planning area coverage, these are:

- The Mission Creek-Chippewa River drainage basin (HUC12: 040802020501);
- The Onion Creek drainage basin (HUC 12: 040802020504);
- The Dice Drain – Chippewa River drainage basin (HUC12: 040802020508); and
- The Johnson Creek – Chippewa River drainage basin (HUC12: 040802020207).

These boundaries are modified from the USGS original areas and are drawn with consideration of the actual drainage infrastructure and local, recent, high resolution local digital elevation data. See Figure 2. For a large-format map with basin boundaries see Exhibit 1 in Appendix J.

2.1 Major Drainage Basins

The major drainage basins covering the planning area and the sub-basins comprising them are discussed below. The receiving water body is noted, as well its jurisdictional status. Some sub-basins shown in Figure 2 lack details such as exclave/enclave areas due to the scale of the figure.

County-owned facility assets (e.g. courthouse) are considered 'private' for the purposes of this plans (since they fall into the jurisdiction of where the facility is located rather than as part of the ICDC or ICRC infrastructure). Township assets (e.g. WWTP) are treated the same way.

The various jurisdictional outfalls within a given sub-basin are identified in the asset database.

Red highlights in the tables in the following text denote areas that are not modeled and where major assets are included in the geodatabase but are not assessed or explicitly part of the master plan process. Green highlights indicate sub-basins with significant interconnections that require consideration if modifications are planned in the future. Highlighting of just the interconnection text indicates this is between drainage basins.

Those sub-basins shown in Figure 2 are indicated with . The symbols and are also used to indicate how the area is displayed in the main figure.

Where sub-basins discharge outside of the planning area, these areas are shown with gray text. The portions of the hydrologic sub-basins within the planning area are shown indented with *italic text* and are treated as planning area sub-basins for the purposes of this plan.

2.1.1 Mission Creek – Chippewa River Drainage Basin

This drainage basin is situated along the Chippewa River upstream, downstream, and as it passes through the planning area. The area along the river that drains directly to it or through private assets only is not modeled (although some of the private drainage area may be processed for runoff and some assets in the hydraulic model, the assets are not included in the planning process). Most of this area is floodplain, undeveloped, and/or private development. The modeling of the Chippewa River is part of the FEMA floodplain mapping process. The locations of known obstructions along the river are included in the geodatabase.

The Mission Creek Sub-Basin, which was recently studied for the ICDC, is treated in much that same manner as the Chippewa River direct drainage area. The West Downtown Development Authority (WDDA) Drain Sub-Basin, the Dumas Drain Sub-Basin, and the South Lincoln Sub-Basin are excluded from the larger planning efforts due to the small drainage areas within the planning area but the assets within the planning area portions of these sub-basins are included in the geodatabase.

Table 1 presents the sub-basins of the Mission Creek – Chippewa River Drainage Basin in the planning area.

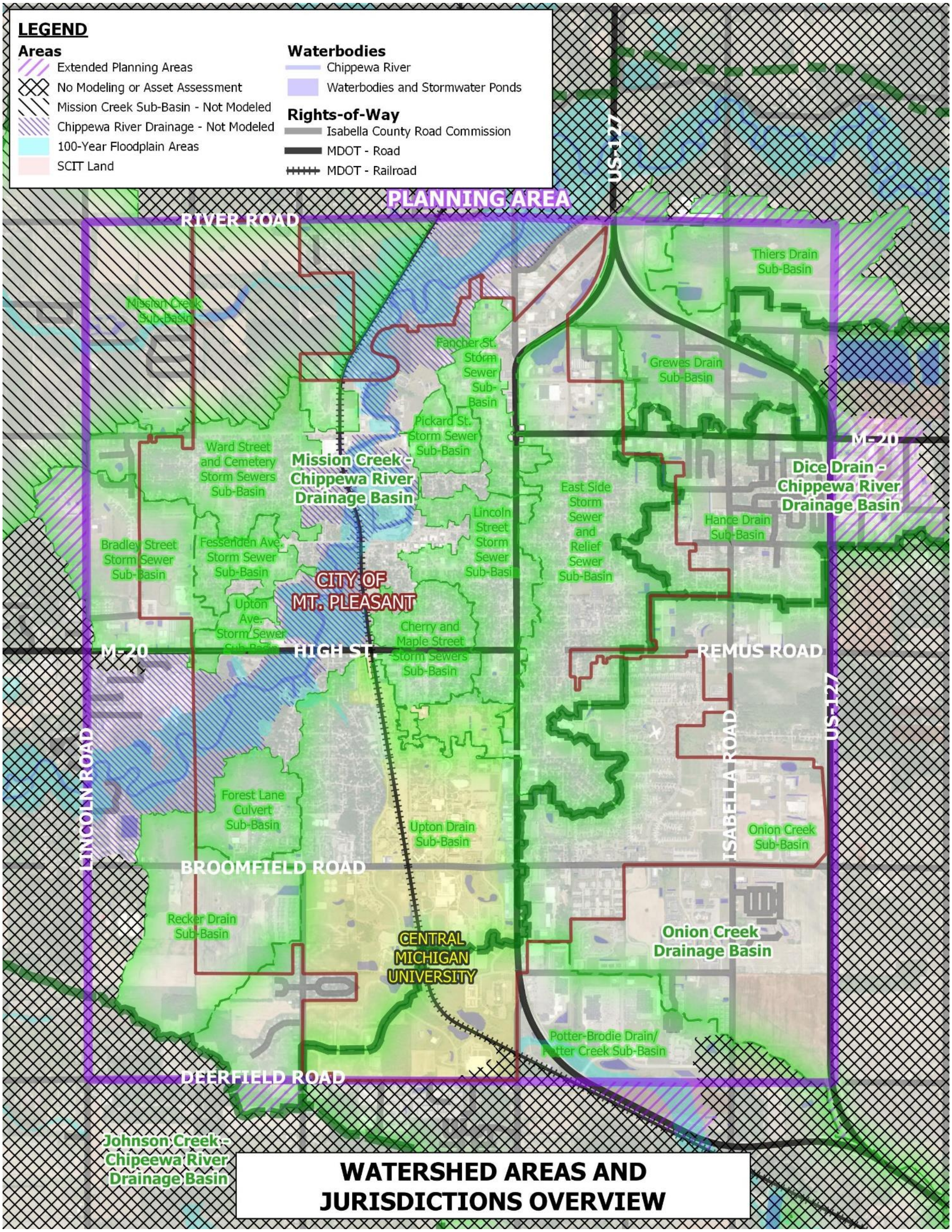

Figure 2. Planning Area Drainage Areas and Storm Water Jurisdictions.

Table 1. Sub-Basins within the Mission Creek – Chippewa River Drainage Basin.

Sub-Basin	Serves ^	Area (acres)	Outfall(s)	Agency	Discharges To	Comments *WoS denotes 'waters of the State'*
Mission Creek	City SCIT Twp. ICDC ICRC MDOT		120-inch by 84-inch culvert	MDOT	Chippewa River	WoS channel from outfall to Bamber Road; ICDC county drain upstream of Bamber Road
Upton Drain	City CMU Twp. ICDC ICRC MDOT		144-inch by 96-inch culvert	ICDC	Upton Creek (short channel to Chippewa River)	Cole Drain and Log Cabin Drain districts in this sub-basin 1 upstream interconnection point with the Potter Creek SB in the Onion Creek Drainage Basin
Forest Lane Culvert	City		18-inch 30-inch culvert	City	Forest Lane Creek (WoS)	Outfall to channel Culvert to Chippewa River area
Recker Drain	City IC Twp. IC		42-inch 12-inch	ICDC	Recker Creek	WoS channel portion from outfall to Chippewa River
Upton Creek Lowlands	City		12-inch 12-inch	City	Upton Creek Lowlands Br.	Outfall to Upton Creek LB (WoS) Outfall to Upton Creek LB (WoS)
Canal Area	City		15-inch 15-inch 10-inch	City	Chippewa River	Greenbanks Drive Storm Sewer Canal Street Riverview Court
M-20 / High Street River Crossing Area	City CMU MDOT		12-inch 12-inch 12-inch 12-inch 18-inch 18-inch via PS	MDOT	Chippewa River	West of bridge East of bridge Watson Road East of Watson Road West of Pump Station Pump Station Outfall
Cherry Street Storm Sewer	City CMU MDOT		36-inch	City	Chippewa River	3 interconnection points with Maple Street SSSB
Maple Street Storm Sewer	City MDOT		36-inch	City	Chippewa River	3 interconnection points with Cherry Street SSSB 1 interconnection point with Mill Street SSSB
Mill Street Storm Sewer	City MDOT		24-inch	City	Chippewa River	1 interconnection point with Maples Street SSSB
Broadway St. East Storm Sewer	City		30-inch	City	Chippewa River	
Island Park Area	City		18-inch 10-inch 10-inch 8-inch 10-inch 8-inch 8-inch 8-inch 8-inch 8-inch 12-inch 12-inch 12-inch 12-inch	City	Chippewa River	City Hall SW Island Park SE Island Park WSW Island Park ESE Island Park WNW Island Park ENE Island Park NW Island Park NE Island Park North Island Park West Pickens Field East Pickens Field West Pickard @ Pickens Field East Pickard @ Pickens Field
Washington St. Storm Sewer	City		30-inch	City	Chippewa River	
Lincoln Street Storm Sewer	City CMU MDOT		60-inch	City		1 interconnection point with Andre Avenue SSSB 2 interconnection points with Fancher Street SSSB 1 possible interconnection point with East Side SS&RSSB **
Andre Street Storm Sewer	City		24-inch	City	Chippewa River	1 minor interconnection point with Lincoln Street SSSB 1 interconnection point with Fancher Street SSSB
Fancher Street Storm Sewer	City		54-inch	City	Chippewa River	2 interconnection points with Pickard Street SSSB 1 interconnection point with Andre Avenue SSSB
Pickard Street Storm Sewer	City		36-inch	City	Chippewa River	1 interconnection points with Fancher Street SSSB
WWTP Storm Sewer	City		27-inch	City	Chippewa River	

Table 1. Sub-Basins within the Mission Creek – Chippewa River Drainage Basin. (continued)

Sub-Basin	Serves ^	Area (acres)	Outfall(s)	Agency	Discharges To	Comments *WoS denotes 'waters of the State'*
River Road Storm Sewer and Culvert	City Twp. ICRC MDOT		24-inch 24-inch culvert	ICRC	Chippewa River US-127 Ditch	Ditch to Chippewa River
East Side Storm Sewer & Relief Sewer	City CMU Twp. ICRC MDOT		48-inch	City	Chippewa River	2 interconnection points with the Onion Creek SB (in the Onion Creek Drainage Basin) 1 interconnection point with the Upton Drain SB 1 minor interconnection point with the Maple Street SSSB 1 possible interconnection point with Lincoln Street SSSB **
Grewes Drain and River Road East Storm Sewer	City* Twp. ICDC ICRC MDOT		Open Channel 24-inch	State of Mich. ICRC	Chippewa River River Road Channel (to Chippewa River)	Primary drainage for US-127 north of Pickard; passes through private and ICRC culverts A short channel parallel to the Grewes Drain north of River Road
Thiers Drain	City (Airport) Twp. ICDC ICRC		15-inch culvert	ICDC	Thiers Creek	Non-ICDC channel portion to Chippewa River
Mission Road Storm Sewer	City Twp. ICRC MDOT		30-inch	ICRC	Chippewa River	Old MDOT assets / ROW now maintained by ICRC
Pickard St. – RR Storm Sewer	City		12-inch	City	Chippewa River	
Ward Avenue Storm Sewer	City Twp. ICRC		42-inch	City	Chippewa River	3 interconnection points with the Cemetery SSSB 1 interconnection point with the Mission Creek SB
Cemetery Storm Sewer	City		36-inch	City	Chippewa River	3 interconnection points with the Ward Avenue SSSB 2 interconnection point with the Fessenden Avenue SSSB
Fessenden Ave. Storm Sewer	City		36-inch	City	Chippewa River	2 interconnection point with the Fessenden Avenue SSSB 1 interconnection point with the Broadway St. West SSSB
Broadway St. West Storm Sewer	City		18-inch	City	Chippewa River	1 interconnection point with the Fessenden Ave. SSSB
Upton Avenue Storm Sewer	City MDOT		42-inch	City	Chippewa River	
Bradley Street Storm Sewer	City Twp. ICDC ICRC MDOT		48-inch	City	Chippewa River	Discharges to adjacent low-lying area that overflows to River via 18-inch sewer and/or spillway ICDC Beltnick Drain served within this Sub-Basin
Adams Street Storm Sewer	City MDOT		42-inch	City	Chippewa River	
Western River Isolated Outfalls	City		8-inch 12-inch 15-inch 24-inch	City	Chippewa River	Cemetery Site Storm Sewer Broadway Street CBs West Michigan Storm Sewer Lyons Street Storm Sewer
Chipp-A-Waters Park Area	City MDOT		12-inch 24-inch	City	Chippewa River	CAW Park Storm Sewer CAW North Side Ditch
Dumas Drain	Twp. ICDC ICRC		8-inch (outside of planning area)	ICDC	Chippewa River	Serves portion of Lincoln Road drainage south of Broomfield Rd
Lincoln Rd. S. Storm Sewer	Twp. ICRC		<unknown>	ICRC	Chippewa River	
WDDA Drain	Twp. ICDC ICRC MDOT		60-inch	ICDC	Chippewa River	Primary service outside of planning area but does serve an area SE of High St. / Lincoln Rd.

^ - for the Township this applies only to land served; for others it implies land and assets unless indicated with a * to denote land only
** - the inter-basin connection at Mission Road and Gaylord Street is assumed to NOT be active for modeling purposes and the pipe is shown as abandoned in the geodatabase

2.1.2 Onion Creek Drainage Basin

This drainage basin comprises the southeast portion of the planning area and consists of two large sub-basins that route flow to the south and east of the City where the where the Onion Creek eventually discharges to the Salt Creek (east of Dickinson Road) that eventually discharges to the Chippewa River east of 11 Mile Road. Table 2 presents the sub-basins of the Onion Creek Drainage Basin in the planning area. Note that the US-127 median drainage that flows to the east is not included in the planning area sub-basins.

Table 2. Sub-Basins within the Onion Creek Drainage Basin.

Sub-Basin	Serves	Area (acres)	Outfall(s)	Agency	Discharges To	Comments *WoS denotes 'waters of the State'*
Onion Creek			Open Channel (outside of planning area)	State of Mich.	Salt Creek (open channel)	Salt Creek flows east into the Chippewa River east of 11 Mile Road The ICDC portion of the Onion Creek ends north of Remus Road east of Genuine Road
Onion Creek Headwaters Area	City Twp. ICDC ICRC SCIT		2 96-inch by 96-inch culverts	ICDC	Onion Creek (open channel)	Planning area outfall – located in-line of Onion Creek Drain within sub-basin @ US-127 northbound lanes The Armstrong Drain and the nested Mead Drain districts are within this area 2 interconnection points with the East Side S&SRS SB (in the Mission Creek – Chippewa River Drainage Basin)
Southeast SCIT Parcel	Twp. SCIT Twp. MDOT		15-inch culvert	MDOT	US-127 east side ditch	Planning area outfall US-127 east side ditch flows north to Onion Creek
Neff Extension Drain:			Open Channel (outside of planning area)	ICDC	Onion Creek (ICDC portion)	Outfall for the entire Neff Extension Drain district is to the Onion Creek east of Leaton Rd.
Neff Extension Drain Head-waters Area	City* ICRC Twp. ICDC		30-inch	ICDC	Neff Extension Drain	Planning area outfall – located in-line of Neff Extension Drain as it passes under the US-127 northbound lanes
Potter Creek			Open Channel (outside of planning area)	State of Mich.	Onion Creek (open channel)	Discharge into Onion Creek just west of Dickinson Road
Potter-Brodie Drain						The Potter-Brodie Drain ends at Broomfield Road on the east side of Loomis Road where it becomes Potter Creek
Potter-Brodie Drain Head-waters Areas	City CMU Twp. ICDC ICRC SCIT		36-inch	ICDC		Planning area outfall – located in-line of Potter-Brodie Drain passing under railroad west of Isabella Road Potter-Brodie Branch No. 3 Drain is within this area 1 upstream interconnection point with the Upton Drain Sub-Basin in the Mission Creek – Chippewa River Drainage Basin
Potter Brodie Branch No. 2 Drain	City* CMU* Twp. ICDC ICRC MDOT		Open Channel (outside of planning area)	ICDC	Potter Brodie Drain	Serves portion of planning area between Deerfield Road and the railroad east of Three Leaves Drive
Fox of the Union	Twp. ICDC ICRC SCIT		15-inch (outside of planning area)	ICDC	Potter-Brodie Drain	
Isabella Road So. Storm Sewer			30-inch (outside of planning area)	ICRC	Potter-Brodie Drain	

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2.1.3 Dice Drain – Chippewa River Drainage Basin

This drainage basin is situated largely along the Chippewa River downstream (east) of the planning area. The western most portion of the drainage basin is the Hance Drain Sub-Basin that extends into the planning area. Info about the overall Sub-Basin and the two locations chosen as to be the boundary of the planning / assessment area for this project are presented in the Table 3.

Table 3. Sub-Basins within the Dice Drain – Chippewa River Drainage Basin.

Sub-Basin	Serves ^	Area (acres)	Outfall(s)	Agency	Discharges To	Comments *WoS denotes 'waters of the State'*
Hance Drain			Open Channel (outside of planning area)	ICDC	Chippewa River	Sub-basin discharge point downstream of planning area (east of Leaton Road along Airport Road extended)
Hance Drain Headwaters Area	City SCIT Twp. ICDC ICRC		96-inch	ICDC	Hance Drain (open channel)	Planning area outfall – located in-line of Hance Drain within sub-basin, northwest of Pickard and Summerton Roads
Quarterline Drain Head-waters Area	City (Airport) Twp. ICDC ICRC MDOT SCIT		24-inch culvert	ICDC	Quarterline Drain (open channel)	Planning area outfall – located in-line of Quarterline Drain along Airport Road within sub-basin, just west of western edge of Grewes Lake

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2.1.4 Johnson Creek – Chippewa River Drainage Basin

The southwest portion of the planning area is in the Johnson Creek Sub-Basin (not labeled on Figure 2) part of the larger Johnson Creek – Chippewa River Drainage Basin. Runoff in this area is routed to Johnson Creek via Deerfield Road and Lincoln Road ditches, the Pope Drain, and the Doris Drain. Most assets in this area are located approximately but this area is excluded from modeling and planning efforts due to its insignificant exposure in the planning area. See Table 4 for more details.

Table 4. Sub-Basins within the Johnson Creek – Chippewa River Drainage Basin.

Sub-Basin	Serves ^	Area (acres)	Outfall(s)	Agency	Discharges To	Comments *WoS denotes 'waters of the State'*
Johnson Creek (county drain)	Twp. ICDC ICRC		Open Channel (*outside of planning area*)	ICDC	Johnson Creek	WoS channel portion to Chippewa River (at Bluegrass Road culvert

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2.2 JURISDICTIONS AND STANDARDS

As described in Section 1.0, there are seven major entities (non-private) that either own storm water infrastructure and/or regulate its discharge within the planning area:

- The City of Mt. Pleasant[5]
- Central Michigan University (located wholly within the City)[6]
- The Charter Township of Union[7]
- The Isabella County Road Commission[8]
- The Isabella County Drain Commissioner[9]
- The Michigan Department of Transportation
- The Saginaw Chippewa Indian Tribe[10]

Additionally, the State of Michigan directly and the United States of America have an interest in 'waters of the State' and 'waters of the U.S.'[11]. The Michigan Department of Great Lakes and Environment (EGLE) has jurisdiction over issues related to 100-year floodplains, inland lakes and streams, and wetlands. EGLE, empowered under the Clean Water Act by the U.S. Environmental Protection Agency (EPA), also has storm water permitting authority. Currently, MDOT is the only agency within the planning area that is subject to these storm water permit requirements (under the National Pollutant Discharge Elimination System – NPDES) and it maintains a permit that covers its facilities on a statewide basis. MDOT meets its permit requirements through the implementation of storm water management plan[12].

The City[13], Township[14], and ICDC[15] have collaboratively developed a codified set of storm water management standards for new developments and re-development. The purpose of these standards is to:

- Reduce artificially induced flood damage;
- Minimize increased storm water runoff rates and volumes from identified new land development;
- Minimize the deterioration of existing watercourses, culverts and bridges, and other structures;
- Encourage water recharge into the ground where geologically favorable conditions exist;
- Reduce non-point source pollution;
- Maintain the integrity of stream channels for their biological functions, as well as for drainage and other purposes;
- Minimize the impact of development upon stream bank and streambed stability;
- Reduce erosion from development or construction projects;
- Preserve and protect water supply facilities and water resources by means of controlling increased flood discharges, stream erosion, and runoff pollution;
- Reduce storm water runoff rates and volumes, soil erosion, and non-point source pollution, wherever practicable, from lands that were developed without storm water management controls meeting the purposes and standards; and
- Reduce the adverse impact of changing land use on water bodies and, to that end, this text establishes minimum standards to protect water bodies from degradation resulting from changing land use where there are insufficient storm water management controls.

[5] Mt. Pleasant is a 'home rule' city in Michigan that is responsible for providing services and has associated fund-raising powers (and is excluded from governance by its overlay township).

[6] Central Michigan University is a public institution chartered in the State of Michigan. As a state-chartered institution, CMU is exempt from certain regulations at the local and county level.

[7] As a 'charter township' in Michigan, Union Township has similar responsibilities and powers to a home rule city.

[8] The ICRC is the agency responsible for the county road system and utilizes federal, state, and local dollars (in the form of general revenue, millages, and/or special assessments) to maintain and improve this system.

[9] The ICDC is the agency in Isabella County vested with the power of maintaining county-wide drainage systems under the aegis of Michigan's 'drain code'. Costs associated with county drains may legally be apportioned to: 1) county property owners outside of chartered municipalities; 2) the county and other municipalities directly; 3) the county road commission; and 4) MDOT via special administrative rules. Among a number of classes, the drain code exempts federal- and state-owned lands and municipal lands used for public purposes (these classes exempt CMU) from existing drain maintenance assessments (although the State of Michigan may elect to pay an assessment for a newly established drain, if petitioned).

[10] The Saginaw Chippewa Indian Tribe is a federally recognized band in treaty with the U.S government with the power of self-governance and the right to regulate property within their jurisdiction (among other fundamental rights).

[11] Among numerous agencies with environmental regulatory authority, the U.S. Army Corps of Engineers maintains permitting programs for activities that impact inland lakes, streams, and wetlands that may be required for some storm water-related actions or programs.

[12] https://www.michigan.gov/mdot/0,4616,7-151-9621_11041_91575_91582-114322--,00.html

[13] https://codelibrary.amlegal.com/codes/mtpleasant/latest/mtpleasant_mi_code/0-0-0-7763

[14] https://library.municode.com/mi/union_charter_township%2C_(isabella_co.)/codes/compilation-general_ordinances?nodeId=PT90_90.000STMAORORNO1992-9ADNO111992

[15] https://www.isabellacounty.org/wp-content/uploads/2018/12/StormWaterManagementRules.pdf

General flow and storage requirements for storm drainage systems include:

- The peak runoff rate during a 25-year storm event from a developed or redeveloped site shall not exceed the allowable discharge rate (Q_a). This rate is determined using the design impervious factor (IF). The impervious factor of demolished sites is assumed undeveloped. Either detention storage with a regulated discharge must be provided or all impervious surfaces must be removed from the site.
- The drainage area used for computation will be the total area of land on the subject property that flows to the site outlet. Extraneous flows from off-site upland areas shall be permitted to bypass or pass through the storm water management system on the subject property. Bypass or pass-through devices must be sized with sufficient capacity to receive the flow generated by a ten-year storm from upland areas.
- The allowable discharge is a maximum of 0.15 cfs per acre.
- Proposed storm drainage detention facilities shall be designed to have capacity to detain, at minimum, the 25-year recurrence interval design storm runoff volume that exceeds the allowable discharge from the site.
- Proposed storm sewer shall be designed to have capacity to pass the ten-year design storm runoff rate (Q_d).

The Township is currently using an older set of standards that generally agree with the City / ICDC standards but uses different language (in contrast to the language in the City / ICDC standards that indicate they were developed together) and is more restrictive in the allowed per-acre runoff rates.

Each of these agencies maintain a distinct permitting process that relies on the standards currently enforced.

The ICRC has a permitting process that applies to landowners discharging storm water into, or crossing (e.g. installing a driveway and culvert) ICRC drainage conveyances along all county rights-of-way (i.e. roads and other purposes).

MDOT has a permitting process that applies to landowners discharging storm water into MDOT drainage conveyances along all MDOT ROWs. MDOT has a consolidated drainage manual that sets unified storm water design standards for its facilities[16].

The Isabella County Department of Community Development is the enforcement agent for the County in matters related to Soil Erosion and Sediment Control (SESC).

Central Michigan University follows internal storm water design standards that comply with the City requirements (with more stringent or site-specific requirements applied based on real-world drainage conditions and flooding issues).

The Saginaw Chippewa Indian Tribe is currently in the process of designating water quality standards (WQS) for waters within its jurisdiction. Currently, waters under SCIT jurisdiction are subject to federal regulations and more stringent State of Michigan standards are applied on a voluntary basis on a case-by-case basis. SCIT generally applies storm water management standards based on those of the co-located State of Michigan municipality for a given location (e.g. SCIT lands overlaying Union Township area apply Union Township storm water standards).

[16] https://www.michigan.gov/mdot/0,4616,7-151-9621_11041_91575_91583-93193--,00.html

3.0 Storm Water System Asset Inventory

The following is a summary of the collection system assets for the planning area.

This asset inventory is generally limited to the publicly owned storm water pipe network and corresponding structures. The storm water collection system assets include, but are not limited to: open channels, sewers, pumps / force mains, culverts, outfalls, manholes, catch basins, and storm water inlets. Special asset information about hydraulic controls (e.g. weirs and orifices) will be noted in the geodatabase and expanded on in the model.

In the planning area, more than 6,400 structures were identified (including pipe taps on major sewers and culvert end points on modeled reaches). Approximately 166.4 miles of enclosed public storm water conveyances were documented (including catch basins along with approximately 7.8 miles of modeled open channel conveyances). There are 65 outfalls to waters of the State as well as additional ‘planning area outfalls’ where a conveyance routes flow out of the planning area (e.g. the Neff Extension Drain sewers as it flows under US-127 and the Onion Creek Drain open channel flowing through a culvert under US-127). These outfalls are defined for the purpose of establishing a boundary for the model and planning efforts.

Storm water system assets are generally located in existing street rights-of-way or in easements dedicated for the assets’ use and maintenance.

An overview map of the planning area storm water collection system is presented as Figure A-1 in Appendix A. A large-format map detailing drainage areas and assets is available as Exhibit 1 in Appendix J.

3.1 Approach to Asset Inventory

The development of a storm water system asset inventory can be challenging. In many cases, visual inspection of the assets may not be possible or economically feasible. Therefore, development of the asset inventory must sometimes rely on existing information and indirect assessments. The process typically includes several steps and evaluates information provided through several sources. These sources include local knowledge, community records, record drawings, field surveys, assessments, hydraulic modeling, and analysis of the system.

3.1.1 Asset Identification & Location

Developing a comprehensive storm water collection system asset inventory includes a review of existing historical records (drawings, field notes, staff knowledge, etc.), supplemented with field survey work. Asset material, size and age were identified through the review of available historical record documents. Spatial orientation (pipe location), pipe depth, and invert elevations were determined through a combination of reviewing historical records and global positioning system (GPS) field survey. This information is organized into a updated geographic information system (GIS) database for archiving, mapping, and further evaluation purposes.

At the onset of this project, the City had a robust geospatial database with the location of most assets within the City limits located (excluding some non-City storm sewers on the CMU campus)[17]. Many of these assets were detailed with information provided from the City’s large collection of utility records. CMU also had a digital layer that included location and size information for many assets on campus. In most cases, assets within the planning area but outside of the City were added based on available plans and project-specific survey if the assets were to be utilized in the model. Some non-modeled assets observed in the field or from available imagery, and for which plans were not located, were added to the database with location and other obvious characteristics only.

[17] The City owns / operates numerous storm sewers within the CMU campus boundaries in the public ROW and easements. The ICDC and ICRC also have some ROWs / easements within the campus boundaries.

In developing a comprehensive mapping / database project for the entire planning area, the following information was utilized:

- City – provided primary GIS database (based largely on surveying done in 2014-2015 and 2018) and plans (as requested) for City utilities and private developments within City limits as well as some non-City public assets within City limits;
- CMU – provided spatial data for most storm water assets on campus as well as utility plans as requested;
- Township – provided digital and paper plans for most requested private developments[18] within the planning area (many road assets for private developments are ceded to ICRC jurisdiction following construction when the road control is transferred to the public);
- ICRC – provided digital plans for many requested road utilities;
- ICDC – provided digital plans and paper plans for most requested information on county drains;
- MDOT – provided digital plans for most requested information on state rights-of-way; and,
- SCIT – provided digital plans for most requested information on tribal lands.

Thus, the final mapping/database product is based mostly on previously surveyed data for City assets and plan-derived information for some City assets and most assets outside of the City. Numerous assets throughout the planning area were surveyed as needed during the project for modeling (including some owned by the City, CMU, ICRC, ICDC, and MDOT) and are indicated to have been surveyed in the database.

Quality review of the data was ongoing throughout the project and efforts were made to fill in the gaps through locating plans and surveying (which was focused on those assets of interest for modeling purposes). Surveying obviously does not provide a construction year, which is used in assessing assets for which previous condition assessment data was not available, and in these cases a construction year was estimated typically based on pipe material and information for available information for adjacent assets (and this is indicated as such in the database). A special layer is provided that highlights areas where relevant plans were not available.

Where additional detailed information was needed, field surveys were performed to accurately locate storm manholes, catch basins, culverts, pipes, open channels, and ponds. This included not only areas where data was missing, but also assets to be modeled where the information from previous surveys did not agree or where significant disagreement between existing survey data and available plans required in person investigation.

Data obtained during the survey phase included the top elevation of each structure, rim-to-invert measurements (to establish an invert elevation for each pipe), and pipe diameter and material. Where required, open channel cross-sections were measured and pond structure and storage elevations documented. In some areas, ‘connectivity surveys’ were done simply to locate assets and to determine drainage and routing paths / asset connectivity.

A pipe and node network was then constructed from all synthesized information and the elevations and sizes of these assets were reviewed in profile (using SSA software) to highlight any problems with the database. The issues were corrected through examination of available information or additional surveying, if required. The data generated during modeling and assessment has been integrated into the final database. The SSA model is provided as a separate product, as requested, but a naming relationship has been maintained between the SSA model assets and those in the database for ease of use.

The data provided in this GIS base map are as complete as was possible using non-invasive assessment and survey techniques. There are numerous blind-tap connections between structures and sewer whose starting, ending, and other intersection points could not be explicitly observed for obtaining elevation and material information. In these cases, best estimates were made using available plan information and engineering judgment. In some cases, manholes may have been buried and in these cases a node has been added to the database and flagged as ‘buried’. Nodes have also been defined for blind taps and flagged accordingly.

[18] Private developments are not generally included in the modeling or assessment, but the site assets were drawn in many cases to assist in developing the runoff catchments utilized in modeling efforts.

3.1.2 Condition Assessment

To provide comprehensive and consistent field-based inspections, the National Association of Sewer Service Companies (NASSCO) has developed industry standards for the assessment and rehabilitation of underground infrastructure:

- Field Based NASSCO-MACP manhole (and other storm water structure) field-based inspections; &
- Field Based NASSCO-PACP pipeline field-based inspections.

The City provided geodatabase included NASSCO structural quick ratings for approximately 36 miles of City-owned storm sewer. Additional NASSCO evaluations are included as part of O&M recommendations moving forward and are based on previous inspection dates, age of asset (in consideration of expected life of asset), road work schedules, and other considerations.

3.1.2.1 Asset Terminology

Storm sewer systems generally consist of conveyances and structures. Conveyances include open channels, pipes, and culverts (and in some cases pumps and force mains). Open channels and culverts route flow above ground to structures while pipes route flow below ground between structures. Culverts are generally short pipe stretches (typically with exposed ends) that allow surface or channelized flows to pass through obstructions. Some culverts may have several inlets or catch basins connected along its length but generally do not connect to a larger pipe network.

Structures include manholes, catch basins, inlets, and outfall structures. All of them connect the ground surface to the sewer network. Catch basins are usually shallow structures, with a sump below the pipe inverts to allow for the accumulation of sediment and debris that is removed on a scheduled basis. Most have a cover designed for the intake of storm water but those converted for the purpose of sewer extension or designed to serve multiple storm inlets may have a solid cover. Manholes are generally deeper structures with no sumps although some may be shallow. They may have inlet grate covers or solid covers (or with some vent holes), depending on location and purpose. Storm water inlets (may have a grate depending on location and purpose) and outfall structures are the starting and ending points, respectively, of sewer lines where the pipe meets the ground surface, and where storm water enters or discharges out of the system. Complex and/or non-standard manholes are generally referred to as chambers and may serve multiple purposes including routing other utilities through or around storm sewer pipes, providing specialized routing controls (e.g. siphon pipe interfaces), connecting large diameter pipes, and providing hydraulically pipe connection and flow conditions.

3.1.2.2 Conveyance Assessments

The City has previously undertaken the task of inspecting most major storm sewer pipes using closed-circuit televising (CCTV). These inspections were previously processed using NASSCO pipeline defect rating methods to generate structural condition scores, operations and maintenance (O&M) condition scores, and combined condition scores for every asset that was assessed. In a typical operation, the CCTV truck is set up at the upstream structure and the vacuum truck stationed two to three structures downstream. A basket is placed in the flow line to catch any debris and lines are cleaned to allow the camera to pass through the pipes and record defects. A camera records video as it travels downstream in the pipe. As the camera travels down the sewer, a certified technician makes notes and takes pictures of everything within the pipe. This information includes any sort of defect such as joint offsets, root intrusion, cracked or broken pipes, as well as construction information including sewer taps, pipe material changes, and pipe size changes. This NASSCO scoring information was imported to the asset database for use in the current project condition assessment. Assets without inspections were assessed based on material and year of construction information.

There is no standardized practice for the evaluating the conditions of open channel conveyances but the minimal data for such a purpose would include the channel shape and dimensions (compared to planned features), the presence of artificial obstructions (man-made infrastructure not for storm water purposes), amount of natural growth within the channel (affecting its general ability to convey flows), and the presence of natural obstructions (e.g. deadfall and sediment deposits). The Center for Watershed Protection (CWP) has two manuals that provide metrics and standards that can be used in scoring conveyance conditions and data collection and calculation templates for putting these assessments into practice. The manuals are:

- Urban Subwatershed Restoration Manual Series #4: Urban Stream Repair Practices; and,
- Urban Subwatershed Restoration Manual Series #10: Unified Stream Assessment.

3.1.2.3 Structure Assessments

Structures are important components of the storm water collection system since they are the primary means of access to pipes for maintenance, inspection, and renovation. As main access points to the system, they must be accessible from the ground surface and extend to the pipe connections.

Structures must be structurally capable of resisting damage caused by machinery, weather conditions including frost heave in colder climates, and constant traffic in street installations. A comprehensive assessment is completed to determine the overall condition of each structure by identifying what defects, if any, need to be corrected.

In lieu of having detailed condition data about storm structures, the conditions of structures for the purposes of this project are assumed to be related to the condition of the pipes which they connect. MACP inspections are recommended in areas where storm sewer work is recommended to be done in the future.

3.2 Asset Identification

The storm water collection system in the planning area is comprised of conveyances and structures that are owned, maintained, and operated by the City, CMU, SCIT, ICRC, ICDC, and MDOT. Natural channels not legally structured as a 'county drain' by the ICDC are subject to State of Michigan regulations as 'Waters of the State' and the United States as 'Waters of the United States'. Most of the storm water collection system is located within street ROWs and easements dedicated to the various stakeholder agencies. Private entities in the City, in the Township, and on CMU's campus have additional assets that connect to the collection system network. Many private entities in these areas may connect to public storm water assets in the ICRC, ICDC, or MDOT ROWs or easements (through which public assets may cross or be located on private property). Refer to Exhibit 1 in Appendix J for detailed asset locations and ownership information. Appendices A and B also contain maps that highlight several characteristics of the pipes in the planning area.

3.2.1 Storm Sewer System Description

In general, more densely developed City and Township areas (including the northern portion of the CMU campus), and the ICRC and MDOT ROWs through these areas, are served by curb and gutter streets with catch basins directly in the roads and most conveyances located underground. Less densely developed areas rely on road ditch conveyances with culverts and generally fewer inlets or catch basins that are within these ditches.

Most catch basin and inlet connections to storm sewers are done through connection to manholes. However, there are numerous locations, particularly along the path of larger storm sewers, where catch basins and inlets (as well as some smaller sewers) are connected to the larger sewer through blind taps.

Many older county drains were constructed as tiles but some of the very old pipes in the developed areas of the City also utilized this construction method[19]. Over time, these pipes can accumulate sediment due to the breakdown of filter materials; have lower hydraulic capacities due to sediment accumulation, water infiltration during wet soil conditions, and offset pipe segments (if segments are fixed to each other) and have lower structural integrity as the segments shift orientation underground. To the extent the information was available, these types of pipes are identified in the database.

The planning area storm sewer system consists of multiple outfalls for numerous independent drainage networks (and some that are interconnected) as described in Section 2.0. Numerous outfalls from private lands also exist and these have been documented where identified but are not within the scope of this project. There are also a considerable number of jurisdictional storm water transfers where a conveyance owned by an agency discharges into a conveyance from a different agency (e.g. an ICRC sewer discharges into an adjacent ICDC county drain). These 'jurisdictional outfalls' have been flagged in the structure database layer as this information is useful for planning purposes and the identification of such will likely become a regulatory necessity as the management of storm water becomes more structured in the future. This has been done based on best available information and may contain some errors and omissions.

[19] 'Tile' construction methods are employed to allow infiltration but keep out sediment. To this end, the pipe ends are butted together (or not hydraulically sealed if bell and spigot pipe) and wrapped in pervious materials (which tend to break down faster than the pipes).

3.2.1.1 Chippewa River Outfalls

Most discharges are directly to the Chippewa River (or its adjacent lowland / floodplain area within the Mission Creek – Chippewa River Drainage Basin) through City, ICDC, MDOT, or ICRC outfalls. The ICDC outfalls in this area are physically and legally (based on the actual definition of a given county drain) a short distance upstream of the actual Chippewa River so, for example, the Recker Drain technically discharges into Recker Creek before flowing into the Chippewa River. The same is true of most other drain outfalls although these short 'creek' sections are still considered WoS and thus are not functionally different in real-world terms.

3.2.1.2 Hance Drain

The Hance Drain (in the Hance Drain Sub-Basin of the Dice Drain – Chippewa River Drainage Basin) serves the northeast portion of the planning area (serving Township and City areas, some SCIT lands, and MDOT and ICRC ROWs) and carries flows by pipe and open channel to the Chippewa River east of Leaton Road near its intersection with Airport Road. The Quarterline Drain along Airport Road serves the northern section Sub-Basin and discharges to the Hance Drain where it crosses Airport Road.

3.2.1.3 Onion Creek

The southeast portion of the planning area is served by the Onion Creek (a county drain) Drainage Basin. Most of this area (including Township and City areas and MDOT and ICRC ROWs) is part of the Onion Creek Sub-Basin which drains under US-127 through the Onion Creek open channel / culverts south of Corvallis Drive (extended). The large parcel of SCIT land in the southeast corner of the planning area discharges east under US-127 through a 12-inch culvert into the drainage ditch that conveys flow north to the Onion Creek.

3.2.1.4 Potter Brodie Drain/Potter Creek

The remainder of the drainage basin (including Township and City – primarily CMU - areas and MDOT and ICRC ROWs) is part of the Potter Brodie Drain / Potter Creek Sub-Basin which is drained under the US-127 Business Route and adjacent railroad via the Potter-Brodie Drain open channel / culverts approximately 1,100 feet west of Isabella Road. The remainder of the SCIT parcel is in the Potter Creek Sub-Basin.

3.2.1.5 Johnson Creek

The small portion of the Johnson Creek (a county drain) Sub-Basin of the Johnson Creek – Chippewa River Drainage Basin is an area excluded from assessment and modeling although most assets in this small area are included in the database.

3.2.1.6 Overall Collection System Statistics

There is a total of approximately 108 miles of publicly owned storm sewer within the planning area[20].

Approximately 54% of the pipe network consists of diameters between 12-inch and 24-inch. 10-inch and smaller pipes account for roughly 13%. While pipes 27-inch and larger account for around 28%. The remainder of the pipes had undocumented diameters. This information is summarized in Figure 3.

Approximately 76% of the system consists of concrete pipe types. These are mostly reinforced concrete pipe (RCP). Clay pipes account for approximately 13% and plastic pipes account for 9%. CMP accounts for approximately 3%. Refer to Figure 4.

The oldest parts of the storm water collection system were installed in the early decades of the 1900s. Significant system upgrades were undertaken in the 1970s within the City with county drains also being modified to accommodate City expansions. Much of the work in the 1980s involved upgrading older sewers in concert with road work. Since the 1990s, the ICDC has engaged in significant county drain upgrades while the City, CMU, and the ICRC install new infrastructure as the planning area develops. Refer to Figure 5 for a summary of asset install dates. Note that some dates are estimated based on best available information.

About 62% of the pipe length in the planning area is owned by the City. The ICDC owns about 19%, CMU owns about 14%, and the ICRC and MDOT each own about 7%. This information is summarized in Figure 6.

[20] As well as excluding private sewers (including building roof drain and sump leads) and open channels, this and other presented statistics do not include short culvert pipes which are not modeled nor single branch catch basin leads less than 60-feet in length.

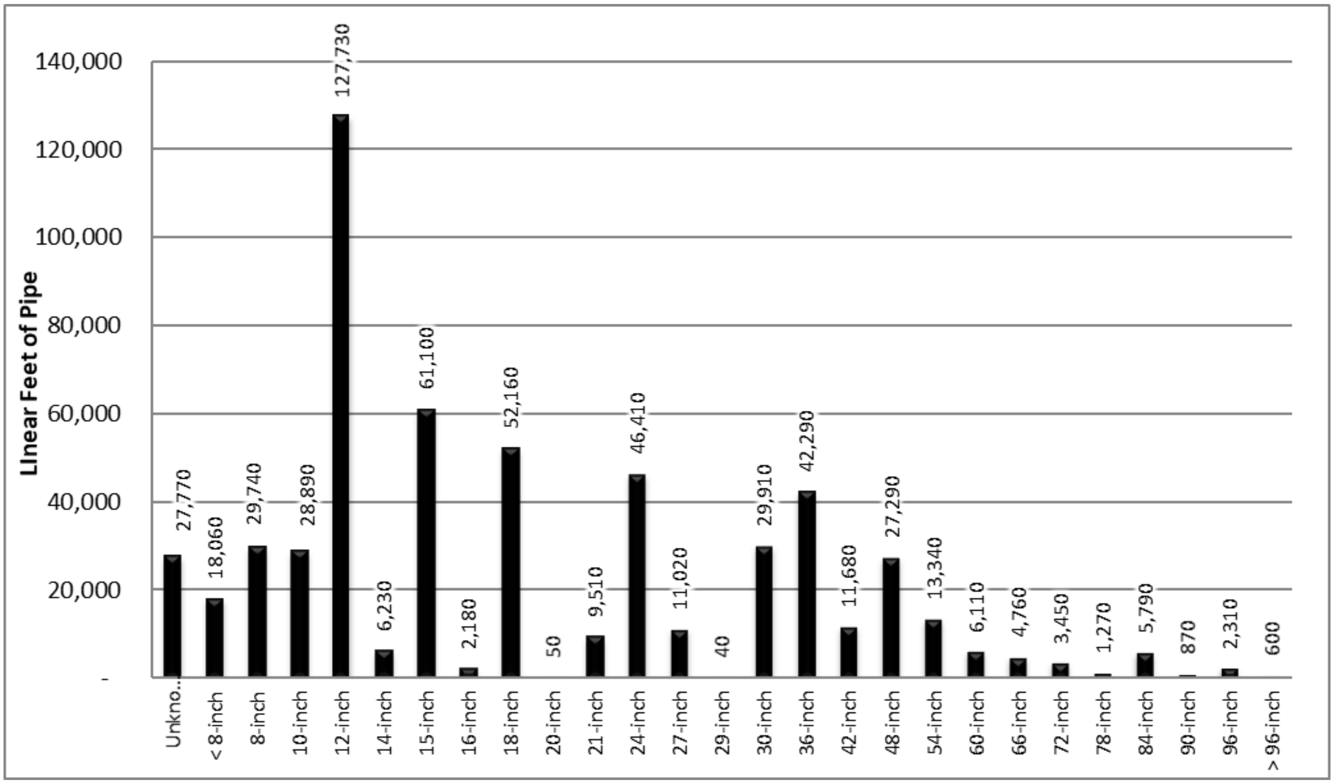

Figure 3. Storm Sewer System Pipe Length by Pipe Diameter

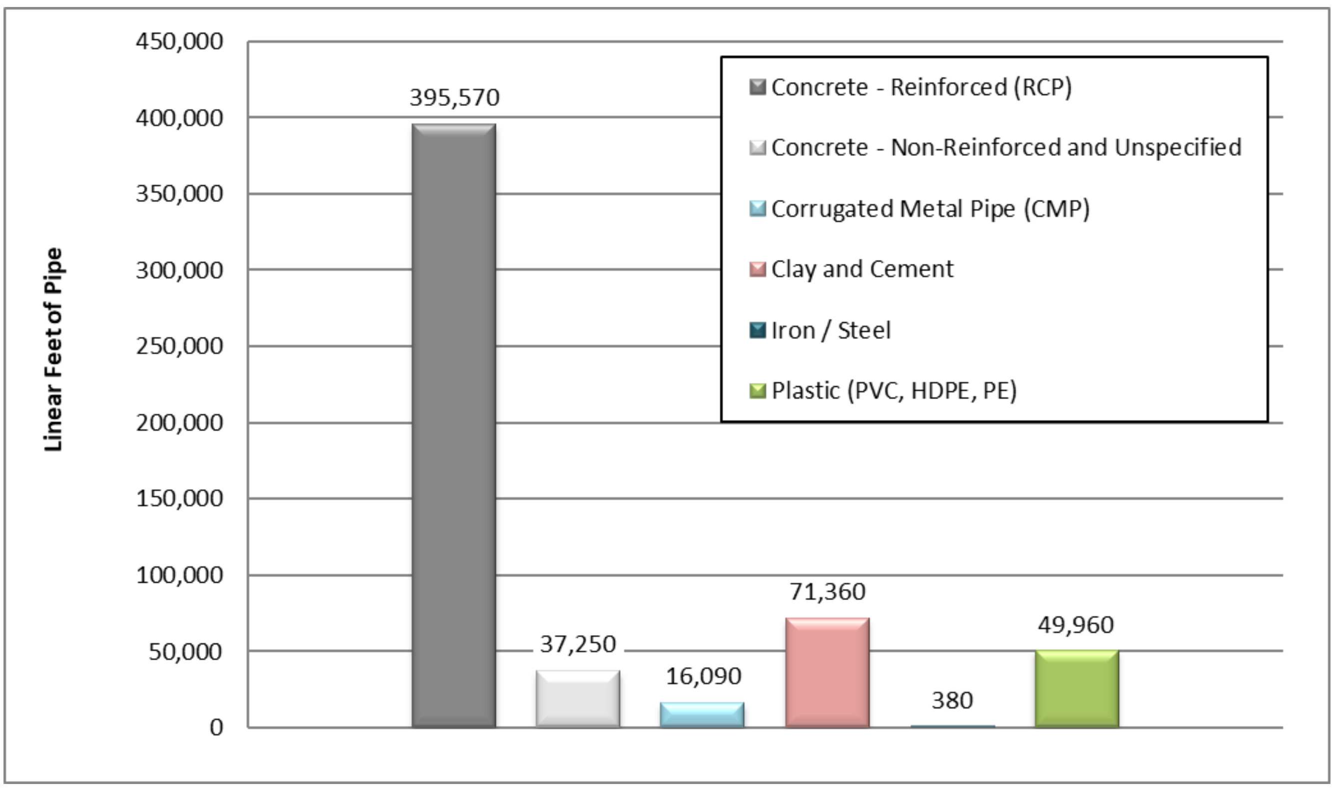

Figure 4: Storm Sewer System Pipe Length by Pipe Material

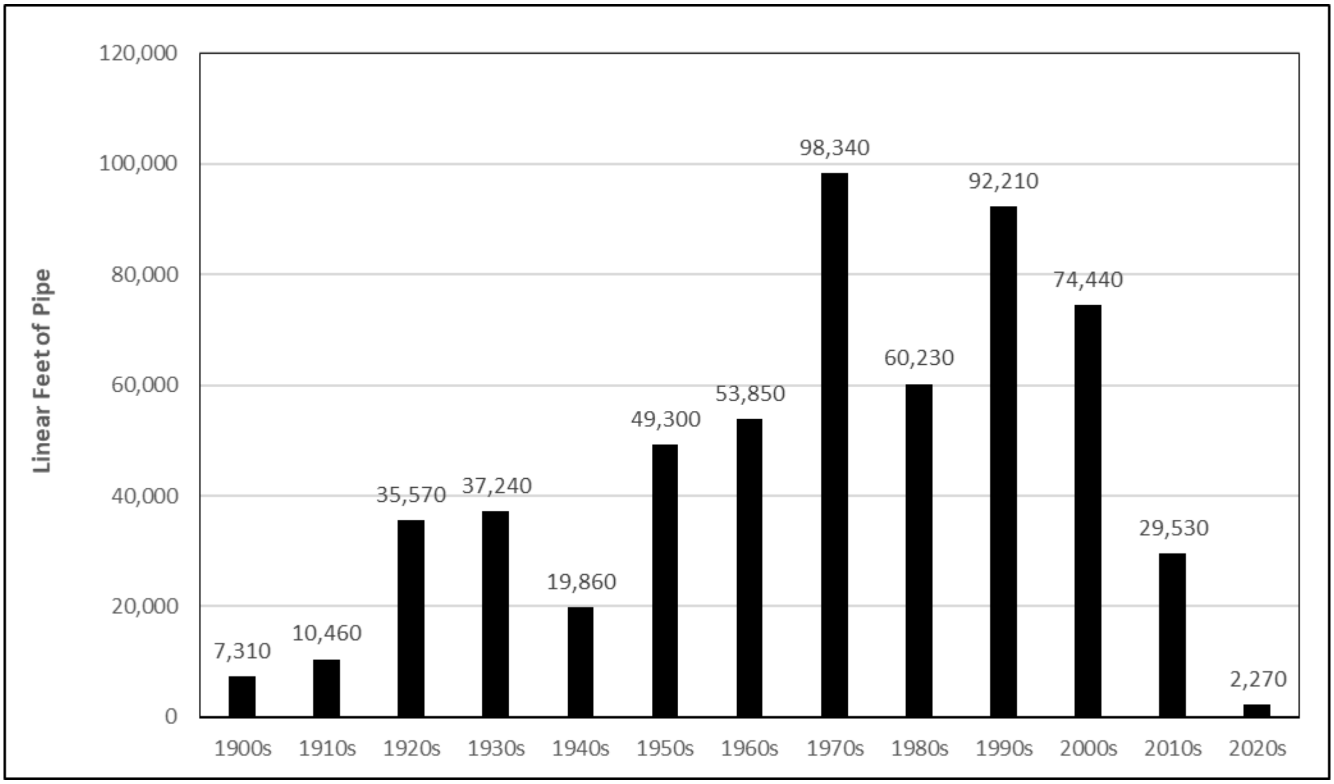

Figure 5: Storm Sewer System Pipe Length by Pipe Install Date

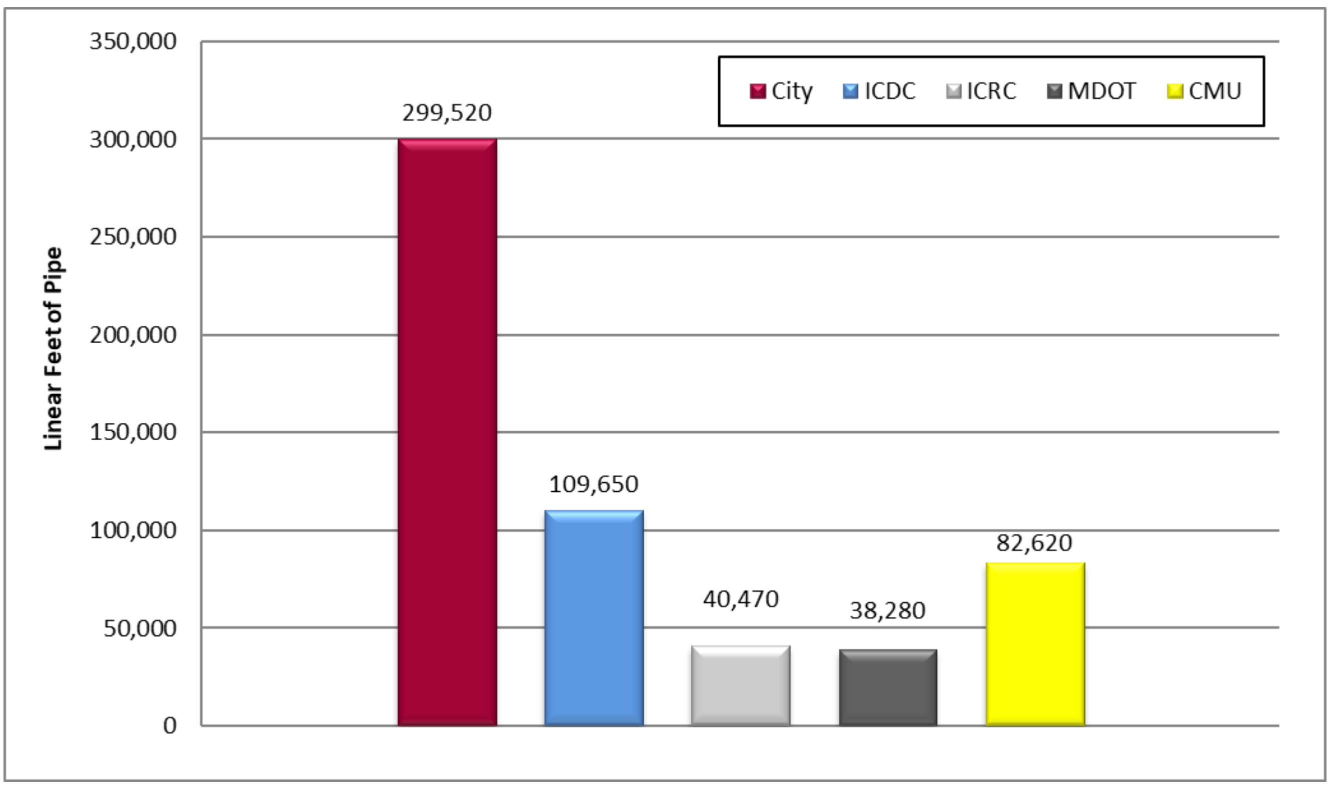

Figure 6: Storm Sewer System Pipe Length by Pipe Ownership

Maps of these pipe characteristics can be found in Appendix B: Figures B-1 through B-4.

3.3 Asset ID and Condition Assessment Summary

A summary of the assets for each major stakeholder in the planning area is presented as Table 5.

Table 5. Asset information by agency.

Agency / Entity	Modeled Open Channel Miles[1]	Total Sewer / Culvert Miles	Major Storm Water Pump Stations	Total Structures[2]	Outfalls to WoS	Structures Allowing SW Inflow
City	0.11	69.73	0	3,217	53	2,019
CMU	0.00	26.46	0	1,324	0	896
ICRC	0.21	20.10	0	742	4	539
ICDC	4.98	39.42	0	574	2	211
MDOT	0.77	10.68	2	557	6	336
State of Michigan	1.72	0	0	0	n/a	0

[1] open channel miles only include those assets identified in the database (i.e. roadside drainage is not included unless specifically modeled) and does not include the Chippewa River; State of Michigan number only includes those channel reaches that were modeled
[2] the structures number includes blind-tap locations and some culvert end sections

Of the planning area and assets within it, the hydraulic model developed for this project utilized 876 runoff basins (catchments), 1,872 pipes / culverts, 46 open channel conveyances, 2 pumps / force mains, 5 weirs, 1,809 manholes / catch basins, 67 outfalls, and 35 storage nodes (i.e. ponds, underground storage, wet wells). The physical attributes of the model assets came from the database assembled as part of this project.

3.3.1 Manhole, Catch Basin, & Outfall Assessments

There was no NASSCO-compatible structure assessment data available for this project and performing such assessments was not within the scope of the project.

3.3.2 Pipeline CCTV Inspection

Pipeline Cleaning and CCTV televising were performed in the years preceding this project for approximately 36 miles of City pipes. The CCTV assessment data was uploaded and linked to the GIS database and are available to review through the GIS mapping product. A structural quick-rating conditions scoring map including location and rating is provided in Appendix B: Figure B-5.

3.3.3 Open Channel Details

As requested, a table listing the modeled open channel reaches and some basic characteristics is provided as Table 6. Additional information can be found in the asset database and in the model.

Table 6. Open Channel Details.

Open Channel	Description	Agency	Method
Hance Drain	East of US-127 along ditch and 36-inch Crossing; 1 culvert modeled	ICDC	Plans
Forest Ln. Culvert Channel	Orchard Drive to Forest Lane culvert; 1 culvert modeled	SoM *	Plans & Survey
Upton Drain	Wendrow Way upstream to West Campus Drive;4 culverts modeled	ICDC	Plans & Survey
Lowlands Branch	Upton Creek channel south past Highland Street	SoM *	Survey
Upton Drain	Downstream of West Campus Drive pond to Broomfield Road	ICDC	Plans & Survey
Upton & Cole Drain	W. Campus Dr.: Three Leaves Dr. to Pond; 2 sets of culverts modeled	ICDC	Plans & Survey
Quarterline Drain	Airport Road to Grewes Lake; 6 culverts modeled; 1 u/s not modeled	ICDC	Survey
Potter-Brodie Drain	From railroad west of Isabella Rd u/s to Mission Rd; 6 culverts modeled	ICDC	Plans & Survey
CMU Pond Drainage	SE Ponds to Mission Road; 3 sets of culverts modeled	CMU	Survey
US-127 BR Ditch	Bluegrass Road to Potter-Brodie Drain; 1 culvert modeled	MDOT	Plans & Estimated
ICRC Channel	Indian Hills Pond to Potter-Brodie Drain; 1 culvert modeled	ICRC	Survey
Chipp-A-Waters Drainage	From west of Henry Street to Chippewa River; 2 culverts modeled	City	Survey
Grewes Drain	US-127 culverts north to Chippewa River; 4 culverts modeled	SoM *	Survey
US-127 Ditch	Isabella Road northwest to US-127 Culverts; 1 culvert modeled	MDOT	Survey & Estimated
ICRC Ditch	Isabella Road: National Drive to US-127 Ditch	ICRC	Plans
Onion Creek	Isabella Road to east side of US-127; 2 culverts modeled	ICDC	Plans & Survey
US-127 Ditch	North of Broomfield Road to Onion Creek	MDOT	Plans & Survey
ICRC Channel	Broomfield Road to US-127 Ditch; 2 culverts modeled	ICRC	Survey

* SoM denotes 'State of Michigan'

4.0 Capacity Analysis

This section presents the approach and provides the results of hydraulic modeling and analysis (HM&A) conducted for the planning area storm water collection system. The purpose of the HM&A is to provide an overview of the hydraulic capacity of the system and evaluate assets for capacity concerns based on a range of rainfall conditions and provide recommendations based on these results.

4.1 Approach to Capacity Analysis

Hydraulic modeling and analysis (HM&A) is used to identify the scope and extent of storm sewer system capacity issues. HM&A can be used to verify future pipeline sizing, and to guide pipeline replacement or rehabilitation needed to achieve capacity required to eliminate the potential for flooding

As requested, the model was constructed in AutoCAD Civil 3D using Autodesk's® Storm and Sanitary Analysis (SSA) software. SSA includes an easy to use and graphical user interface to provide an advanced graphical output. Results can be easily imported and exported, which allows preparation of custom reports and figures. The following steps are included in HM&A:

- Creating a network that represents the collection system assets from the GIS database.
- Verifying and editing the data.
- Calibrating and validating the model.
- Defining the analysis options and running the analysis.
- Reviewing the analysis output results.

In general, HM&A was performed on 12-inch and larger sewers. In some cases, smaller pipes were included to properly capture flows from distinct areas. Some 12-inch or larger pipes were excluded if warranted (e.g. at the upstream end of a sewer network branch for a series of pipes with the same size and slope only the final segment attached to the main sewer network is modeled).

The model utilized 876 runoff basins (catchments), 1,872 pipes and culverts, 46 open channel conveyances, 2 pumps / force mains, 5 weirs, 1,809 manholes / catch basins, 67 outfalls, and 35 storage nodes (i.e. ponds, underground storage, wet wells). All the physical dimensions of the structures and pipes came from the asset database assembled as part of this project[21]. Note that there are differences between the asset database and model due to the way certain hydraulic situations are modeled in SSA.

Important limitations of the model include:

- The Chippewa River and the various obstructions (e.g. road crossings, dams) through the planning area were not modeled during this project as this was done recently for the purpose of defining FEMA floodplains – the results of this previous modeling effort provide the boundary conditions at the outfalls of the model done for the current project (i.e. water surface elevations for various storm scenarios)
    - This being the case, the areas that drain directly to the river without significant storm water network flow routing are also excluded from areas for which detailed catchment boundaries were drawn
- The Mission Creek and the various obstructions (e.g. road crossings, dams) were not modeled during this project as this was done recently for the ICDC (which has jurisdiction over most of the Mission Creek Sub-Basin as it is a legal county drain west of Bamber Road)
- Inlet capacities of individual catch basins or storm water inlets (e.g. flow limits due to grate configuration or pipe headwall impacts) were not considered nor were the limits of the individual catch basin pipes (e.g. where four catch basins at an intersection with 10-inch leads connect to a manhole on a 12-inch, the model assigns the flow to the 12-inch manhole directly)
- Most private ponds were not directly modeled although the areas observed to be served by private ponds were limited in the hydrologic model layer to discharge no more than 0.15 cfs/acre in accordance with local ordinance stormwater pond design requirements
    - These areas can be seen in Exhibit 2 in Appendix J

[21] The two MDOT pump stations were modeled as inflow = outflow pumps to provide a functional pumping capacity in the results that can be check against the current PS configuration (as opposed to evaluating the current operational regime).

- The discussion of flows and capacities in this section relies on a modeling of the current real-world conditions of sewer sizes and configurations that may restrict flows in upstream areas. The flows from aa model run of the 10-year storm with these routing limitations removed is provided in the database as a reference for future design projects.

4.1.1 Hydraulic Calculations

Calculations within SSA are made using the following equations:

- Manning's Equation for open channel (free flowing) conditions:

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} \sqrt{S}$$

where *Q* = flow rate (cfs)
n = Manning roughness coefficient
A = wetted cross-sectional area (ft^2)
R = hydraulic radius (ft)
S = energy slope (ft/ft)

- Hazen-Williams equation for pressure sewer:

$$Q = CAR^{2/3} S^{1/2}$$

where *Q* = flow rate (cfs)
C = Hazen-Williams C-factor, which varies inversely with surface roughness
A = pipe cross-sectional area (ft^2)
R = hydraulic radius (ft)
S = energy slope (ft/ft)

- The hydrodynamic calculation method for surcharged pipe and manhole conditions. The hydrodynamic routing method solves the complete one-dimensional Saint-Venant equations, consisting of continuity and momentum equations for each conduit and a volume continuity equation for each node. The hydrodynamic routing method allows for pressurized flow, such as an adverse slope within the gravity collection system, and it can account for channel storage, backwater, entrance/exit losses, flow reversal, and surcharging. SSA can calculate the maximum hydraulic grade line (HGL), energy grade line (EGL), critical depth, peak flow rate, maximum flow depth, and maximum velocity in a sewer pipe for a given event.

More detailed hydraulic calculation information can be found in SSA documentation.

4.1.2 Hydrologic Calculations

For this project, the Soil Conservation Service (SCS) TR-55 method was used to model the relationship between rainfall and storm water entering the sewer system. This method requires four basic input parameters:

- the area of land draining to a particular entry point to the system,
- a rainfall pattern,
- the conversion of rainfall to runoff, and
- the time delay between the most intense period of precipitation and the maximum rate of storm water discharge into the system.

The following text summarize these hydrology and infiltration methodologies and how the parameters used in them were determined

An estimated existing ground surface of the planning area was created using a National Resources Conservation Service (NRCS) / United States Geological Survey (USGS) Digital Elevation Model (DEM)[22]. This surface was used in conjunction with the location of storm water structures to determine the catchment boundaries. Aerial imagery and street view imagery tools such as Google Earth and Street View were used (where available) to visualize the various inlet locations and elevation-defined flow paths to account for any localized elements (e.g. roofs) that could impact the specific runoff routes.

Four rainfall simulation scenarios (referred to as 'design storms')[23], 1-year (2.23 inches), 10-year (3.55 inches), 25-year (4.15 inches), and 100-year (5.10 inches), were employed to assess the system's ability to handle storm water flows[24]. For all scenarios, SCS (Soil Conservation Service) type-II, 24-hour rainfall distributions were utilized. A figure showing these rainfall distributions is presented as Figure 7.

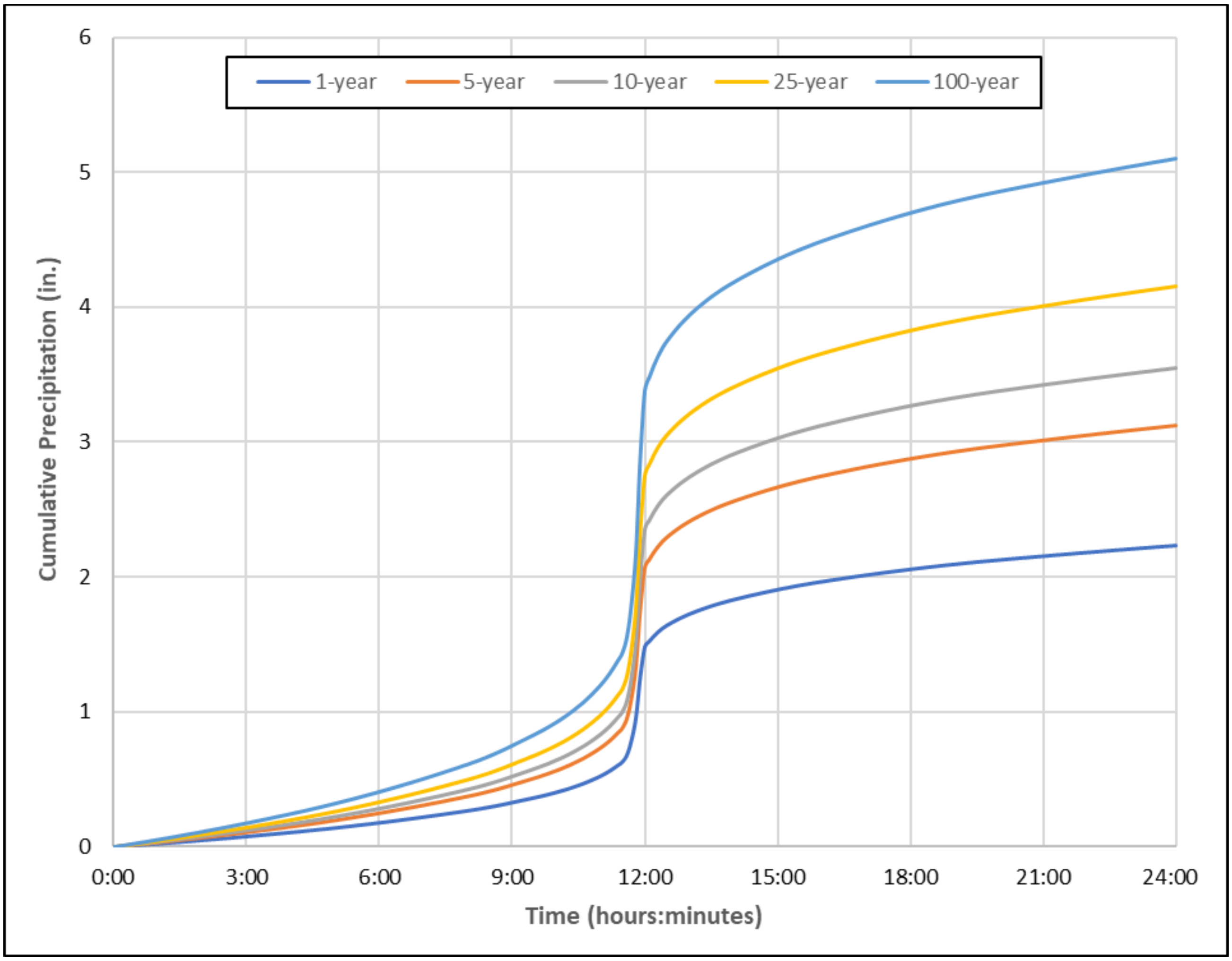

Figure 7. Design storm rainfall distributions.

[22] This is based on 2016 remotely-sensed light detection and ranging (LIDAR) data collected under the aegis of the State of Michigan and is suitable for generating 1-foot elevation contours.

[23] The naming convention for storm frequency is based on historical rainfall data and is explained:
- a 1-year storm is a storm with total rainfall that has occurred in 100% of years in the data;
- a 10-year storm is a storm with total rainfall that has occurred in 10% of years in the data;
- a 25-year storm is a storm with total rainfall that has occurred in 4% of years in the data; and,
- a 100-year storm is a storm with a total rainfall that has occurred in 1% of years in the data.

[24] The scope and proposal originally called for the modeling of the 5-year, 10-year, 25-year, and 100-year storms. The 1-year storm was substituted for the 5-year storm to get a wider range of scenarios and provide a 'sharper' cut-off point for determining which assets should be upgraded in the early phases of proposed future work.

In general, the 10-year storm is the modern standard for the design of storm sewers to convey flows while the 25-year storm is the modern standard for the design of detention facilities. The smaller storms help focus the planned work in the early stages of capital improvement efforts by identifying the assets with more severe capacity problems. The 100-year storm is useful to examine a very extreme flooding scenario, one which corresponds to the storm for which FEMA does its standard floodplain mapping.

Storm water flows entering the system were calculated by determining the drainage area of each structure and from various hydrologic data for each area of land. This data included ground surface impervious cover and elevation data from the United States Geological Survey (USGS) and soil data from the Natural Resources Conservation Service (NRCS) of the United States Department of Agriculture (USDA).

To estimate runoff resulting from the storm, SCS uses the runoff curve number (CN) method, a simple, widely used, and efficient method for determining the fraction of precipitation depth that gets converted to runoff. The CN is based on the drainage area's hydrologic soil group, land use, and hydrologic condition[25]. CNs range from 1 to 100, with pervious land (e.g. forest) corresponding to smaller numbers and impervious land (e.g. parking lots) corresponding to larger numbers. The more impervious the land, the more precipitation that is converted to runoff. Some areas with low perviousness are still classified with higher curve numbers if the dominant soil groups are poorly drained during saturated conditions (e.g. the Thiers Drain drainage area that serves the airport has an impervious coverage of only 16% but consists of soils in hydrologic group A/D – where the D denotes the 'poorly-drained' saturated conditions drainage class – and this accounts for a curve number that is higher than expected based on the impervious coverage in the area). Runoff curve numbers for the current land coverage are presented in Figure 8.

Specifically, in the SCS method, runoff is calculated using the following equation:

$$R = \frac{\left[P - 0.2(\frac{1000}{CN} - 10)\right]^2}{P + 0.8(\frac{1000}{CN} - 10)}$$

where R = runoff (inches)
P = precipitation (inches)
CN = runoff curve number

Runoff depth is calculated for each increment of time using the above equation. The runoff depth is then multiplied by the drainage area and convoluted with the SCS curvilinear unit hydrograph to generate the runoff flow rate vs. time relationship for each subbasin.

The SCS TR-55 velocity method was used to determine each catchment's time of concentration (TOC), the estimated time for a water drop from the most distant point of the area to reach the corresponding model node. The calculations involved were performed in AutoCAD Civil 3D. In this method, TOC is calculated using the following equation:

$$T_C = T_{sf} + T_{scf} + T_{cf}$$

where T_C = time of concentration (hours)
T_{sf} = travel time of sheet flow (hours)
T_{scf} = travel time of shallow concentrated flow (hours)
T_{cf} = travel time of channel flow (hours)[26]

[25] Land use and condition was determined using planning documents and the most recent imagery available. Hydrologic soil group was determined using the NRCS's Web Soil Survey. CNs corresponding to these can be found in many sources, including most hydrology textbooks and in SSA itself.
[26] Channel flow would be used if water were flowing as a creek or larger body. This does not include such pathways as overland ditches along roadways, which are considered shallow concentrated flow. Most channelized flow lengths in the model area were modeled explicitly and the intra-basin flows were modeled as either shallow or shallow concentrated flow.

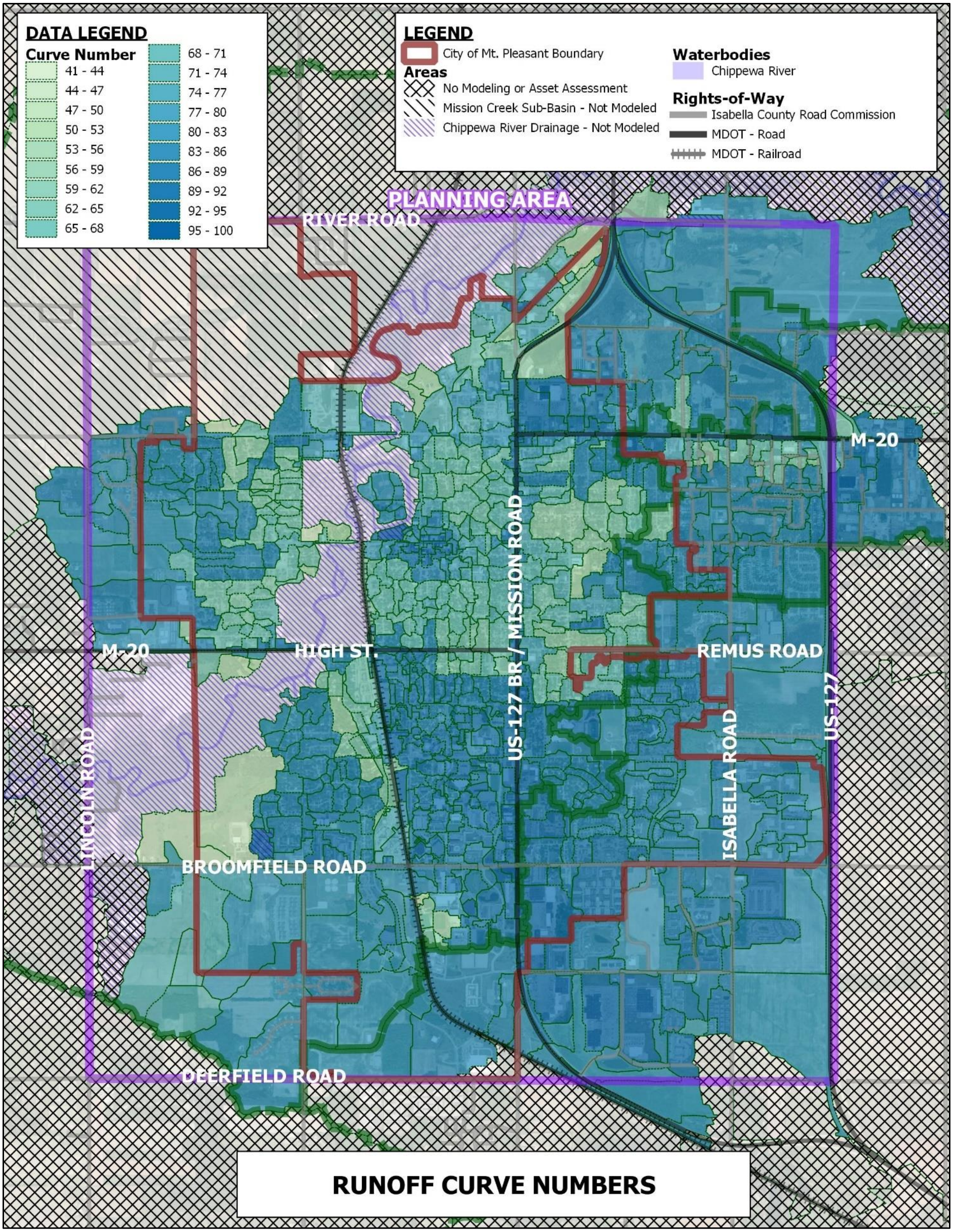

Figure 8. Runoff curve numbers.

The equations for the travel times of these components are as follows:

$$T_{sf} = \frac{0.007(nl)^{0.8}}{(P_2)^{0.5}S^{0.4}}$$

where n = Manning's roughness coefficient[27]
l = sheet flow length (feet)
P_2 = 2-year, 24-hour rainfall (inches)[28]
S = slope of land surface over sheet flow portion (ft/ft)

and

$$T_{scf} = \frac{l}{3600(aS^{0.5})}$$

where l = shallow concentrated flow length (feet) (remaining length of the subbasin's flow path)
a = coefficient, depending on the land type[29]
S = slope of land surface over shallow concentrated flow portion (ft/ft)

and

$$T_{cf} = \frac{L_{ch}}{3600\left(\frac{1.49}{n}\right)R^{2/3}{S_{ch}}^{1/2}}$$

where L_{ch} = channel flow length (feet)
n = Manning's roughness coefficient
S_{ch} = channel flow slope (feet/feet)
R = channel hydraulic radius (feet)
= flow cross-sectional area (feet^2) / wetted perimeter (feet)

Where appropriate, exfiltration from storm water structures was modeled. Exfiltration was assumed to be constant, and the exfiltration rate was calculated based on the hydraulic conductivity of the surrounding soil, as listed on the NRCS's Web Soil Survey, multiplied by the area of the structure bottom.

Differences in hydrology between modeling scenarios are discussed further below.

4.1.2.1 Existing Conditions Scenario

Runoff curve numbers in this project were calculated based on percentages of impervious and pervious land and the type of pervious land. Specifically, the curve number for each subbasin was calculated as a weighted average of the curve numbers corresponding to each land type, by area, as described in Equation 1. In the SCS method, impervious land is always assigned a curve number of 98, while the curve number for the pervious land depends on the land type. The lower the curve number, the more pervious the land (and the more rainwater that gets absorbed into the soil)[30].

$$CN = p_{imp}CN_{imp} + p_{per}CN_{per}$$

[27] Taken from Tables 15-1 and 15-2 in the Natural Resources Conservation Service (NRCS) National Engineering Handbook (NEH) Part 630, Chapter 15.
[28] 2.27 inches for this region of Michigan (Huff, Floyd A. and James R. Angel. "Rainfall Frequency Atlas of the Midwest". Table 5 of Part 2).
[29] Table 15-3 of NRCS NEH Part 630, Chapter 15.
[30] It should be noted that curve numbers do NOT represent the percentage of rainfall that gets converted to runoff, even though curve numbers range from 1 to 100.

where CN = the curve number for a particular subbasin
p_{imp} = the portion (by area) of impervious land in the subbasin (as a decimal value)
CN_{imp} = the curve number for impervious land (98)
p_{per} = the portion (by area) of pervious land in the subbasin (equal to 1 – p_{imp})
CN_{per} = the curve number for the pervious land

Areas of land that drain to a detention pond[31] before discharging to the sewer system were not included in subbasin areas in the model, since model subbasins represent land draining *directly* to the sewer system. Flows from each detention pond were instead entered as an 'External Inflow' at the node (i.e. structure) that the pond discharges to. At each node receiving flow from detention ponds, a constant external flow was assumed, equal to the maximum allowable flow specified in the City's stormwater ordinance, which is 0.15 cfs per acre of land draining to the pond[32]:

$$q = 0.15A_{det}$$

where q = the flow rate entered as an External Inflow at a node (cfs)
A_{det} = area of land draining to the detention pond that discharges to the node (ac)

4.1.2.2 Future Conditions with Storm Water Ordinance

The future-conditions with stormwater ordinance scenario was created to represent flow conditions following the completion of known future land developments. This scenario assumes that the City's stormwater ordinance would be enforced for these developments; in other words, they would include a detention pond with a maximum discharge rate of 0.15 cfs per receiving acre of land.

For subbasins containing land to be developed in the future, the future development area was subtracted from the existing area entered in the model:

$$A_{dir,fut} = A_{dir} - A_{dev}$$

where A_{dir} = the area entered into the model for the existing-conditions scenario, which represents existing land draining directly to the sewer system
$A_{dir,fut}$ = the area entered into the model for the future-conditions scenario, which represents the total land draining directly to the sewer system in the future
A_{dev} = the area to be developed in the future

In other words, since model subbasins represent land draining *directly* to the sewer system, the area to be developed was subtracted out since it would no longer drain *directly* to the sewer system. Flows from the detention ponds were, in turn, adjusted to reflect the increased areas of land discharging to them. As in the existing-conditions scenario, at each node receiving flow from detention ponds, a constant External Inflow was assumed, based on the total future land area discharging to the detention pond and the City's maximum allowable discharge to the sewer system of 0.15 cfs per acre:

$$q_{fut} = 0.15(A_{det} + A_{dev})$$

All subbasins in this scenario had the same curve number they had in the existing-conditions scenario because, even though less land discharges *directly* to the sewer system, the hydrologic characteristics of the remaining land would not change between the present and the future. The newly developed land would become impervious; but recall that this land would first drain to the detention pond as required in the ordinance.

4.1.2.3 Future Conditions without Storm Water Ordinance

The future-conditions without stormwater ordinance scenario was created primarily to provide a comparison between future flows resulting from enforcement of the City stormwater ordinance and those that would result without it. In other words, this scenario was created to demonstrate the effectiveness of the City stormwater ordinance in reducing future sewer capacity issues.

[31] That is, a detention pond that was not itself included in the model.
[32] Even though the City ordinance pertains to the 25-year storm, this same flow rate was used for all the modeled design storms. It should be noted that in most areas, the External Inflow does not consume a very large portion of downstream sewer capacity.

Since future development areas would discharge *directly* to the sewer system in this scenario, the curve numbers for subbasins containing the development areas were re-calculated to account for increased impervious area:

$$CN_{fut} = p_{imp,fut} CN_{imp} + p_{per,fut} CN_{per}$$

where CN_{fut} = the future subbasin curve number assuming no enforcement of the City stormwater ordinance
$p_{imp,fut}$ = the future portion of impervious land (by area)
$p_{per,fut}$ = the future portion of pervious land (by area)

and

$$p_{imp,fut} = \frac{p_{imp} A_{dir} + A_{dev}}{A_{dir}}$$
$$p_{per,fut} = 1 - p_{imp,fut}$$

It should be noted that, to provide for a direct comparison between simulation results from this scenario and those from the existing-conditions scenario, *existing* areas that drain to detention ponds were assumed to do so in this scenario as well.

4.1.3 Model Calibration / Validation

Predicted model flows were checked against those predicted by EGLE's 'Small Ungaged Watershed' method to ensure flows were reliably estimated. A continuity check was then made to determine if the model output matched the expected runoff flowing into the modeled pipe network. Once the model results matched what was expected, flow analysis for the system was completed. Flooded areas from 2017 were also compared to model capacity and flooded structure predictions to as an additional conceptual validation.

4.2 Model Results

HM&A results are intended to identify specific areas of the storm sewer system that are 1) likely to experience surcharging and capacity issues in response to larger precipitation events occurring frequently and 2) possibly under-designed based on various design storms[33].

For this project, the model results, particularly modeled flow vs. capacity, are processed during later steps of this planning process to help identify critical assets and the formulation of an overall Capital Improvement Plan (CIP) and individual CIPs for each stakeholder agency.

For visualization purposes, the sewers were grouped into five categories based on the maximum percentage of flow capacity that simulated flow rates reached during each simulation:

- < 25%
- 25-50%
- 50-75%
- 75-100%
- > 100%

Structures were also grouped into these five percentage categories based on the percentage of total depth that the projected water surface elevation reached during a given simulation (i.e. > 100% indicates surface flooding).

Surface flooding presents a safety, maintenance, and soil erosion and sedimentation control concern. During large storm events, manhole covers that are not bolted down can also "float" during overflows, causing a safety concern for vehicles, bicycles, and pedestrians.

Figure 9 shows how the length of sewer in the system that is under-capacity increases as the design storm total rainfall increases from the 1-year to the 10-year storm to the 25-year storm. Figure 10 shows the same for water surface elevation in the system structures.

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[33] The results of HM&A are not intended to form the basis for the design of any sewer or storage structure upgrade recommendations at this point. The baseline modeling results involve existing system restrictions that may not reflect ultimate flows to specific assets for different design storms. To assist in specific design efforts in the future, modeling results for 'unrestricted' conditions (which assume the same routing but with no upstream restrictions) are included in the asset database.

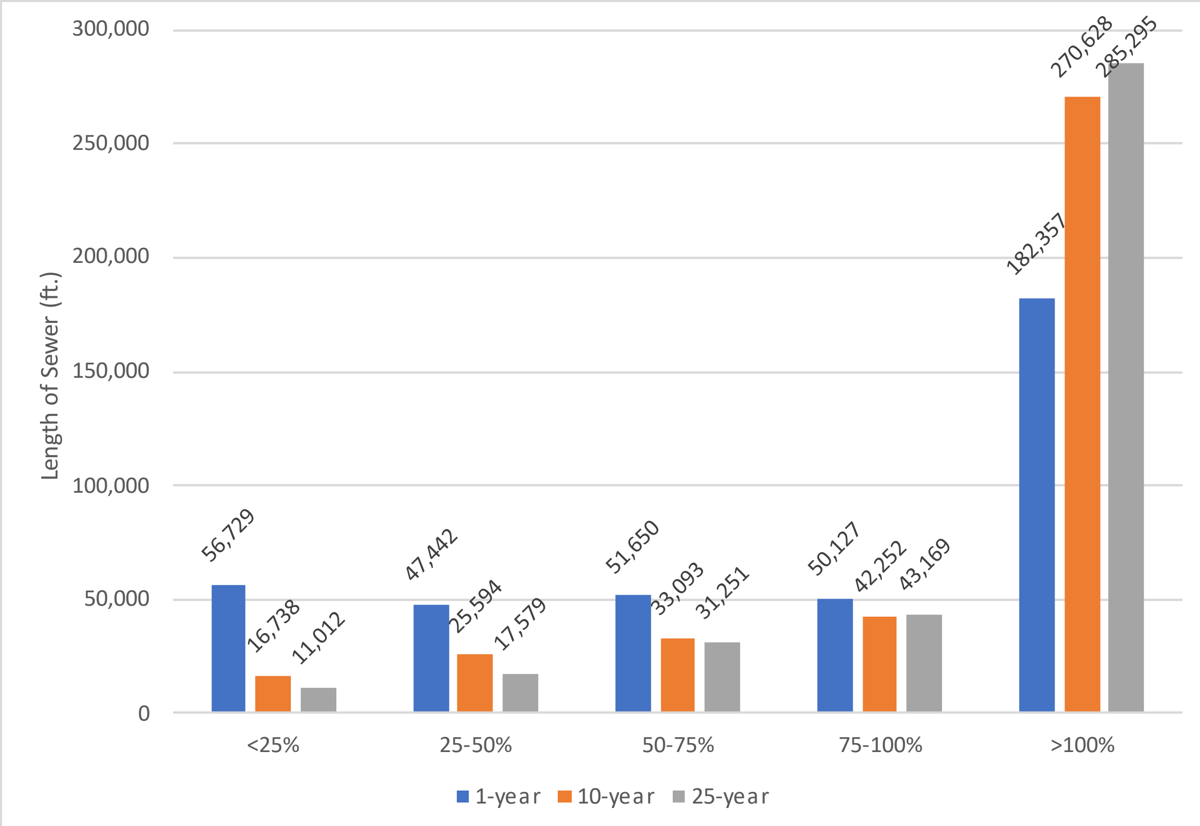

Figure 9. Length of sewer falling into maximum percent of capacity categories during the design storms.

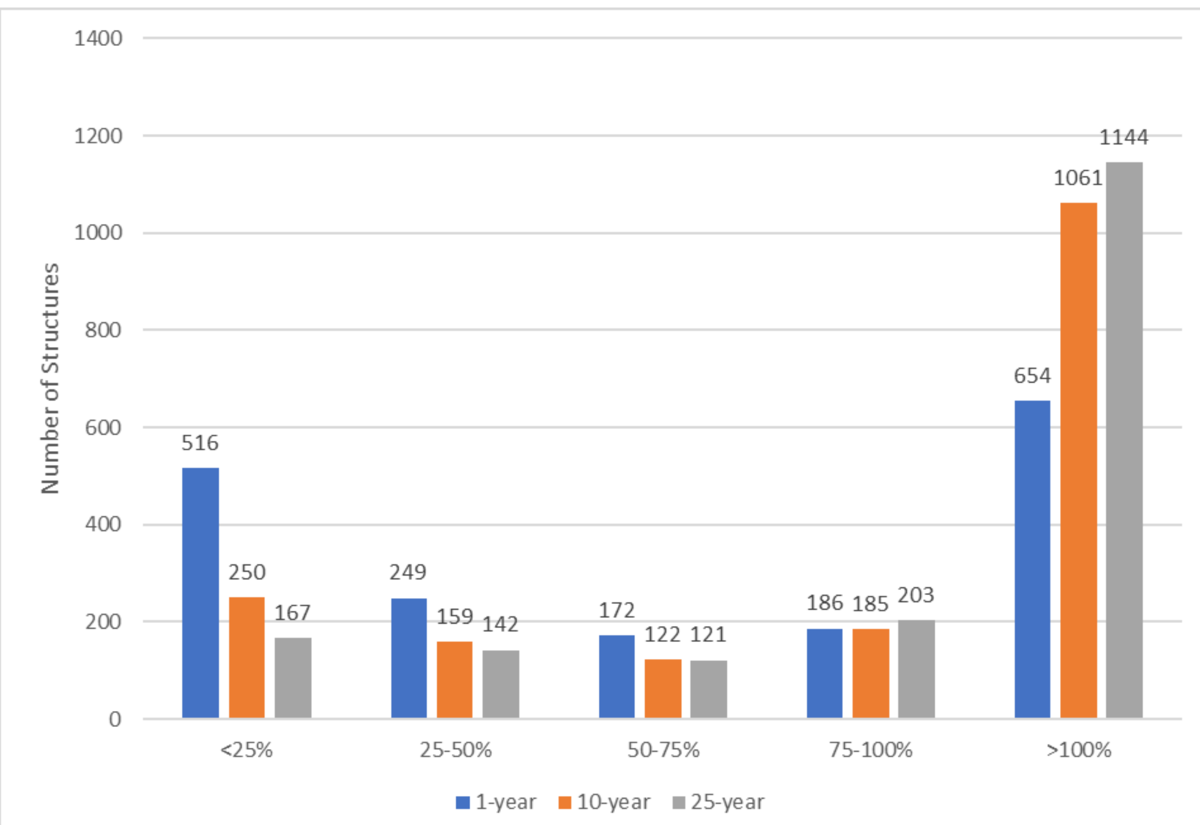

Figure 10. Number of structures falling into maximum percent total structure depth categories.

Each design storm simulation has a corresponding map in Appendix C that shows pipe flow/capacity and node depth/water surface. Figure C-1 is the Existing Conditions scenario at the 1-year storm. Figure C-2 is the Existing Conditions scenario at the 10-year storm. Figure C-3 is the Existing Conditions scenario at the 25-year storm.

4.3 Discussion of Modeling Results

The various design storm simulations reveal specific and general shortcomings of the storm water system in the planning area. This discussion examines conveyance projected flows compared to pipe capacities and flooding potential. Possibly under-performing storm water ponds are also discussed where appropriate.

The locations of pipes predicted to have inadequate capacity and structures predicted to surcharge for the 1-year, 10-year, 25-year, and 100-year events are shown in Figures C-1 through C-4.

The simulation results indicate that the following percentage of modeled pipes are over capacity during the:

- 1-year storm: 40%
- 10-year storm: 62%
- 25-year storm: 69%
- 100-year storm: 75%

The simulation results indicate that the following percentage of nodes will surcharge to ground surface (for at least 10 minutes) during the:

- 1-year storm: 15%
- 10-year storm: 35%
- 25-year storm: 43%
- 100-year storm: 51%

The following sections present capacity and conveyance issues by sub-basin in major aggregated regions of the planning area. This allows for an easier consideration of regional solutions where significant upgrades to the storm water conveyance system may be required (e.g. siting of storage facilities and regional intercepting sewers to alleviate widespread capacity issues). The discussion focuses on the 1-year and 10-year events as the design standards for storm water conveyances generally target the 10-year event but includes comments with respect to other storms as warranted. The performance of modeled ponds includes assessment related to the 25-year storm (the typical design target). Surface flooding along over-capacity sewers can be assumed to be minimal unless explicitly discussed. All event discussions are based on existing runoff conditions utilizing existing pipe networks[34].

> *Potential large-scale / multi-jurisdictional alternatives to simple pipe upsizing or general rehabilitation considerations are presented in an indented, italicized format in the most appropriate sub-section.*

The references to flooding in 2017 are presented visually in Exhibit 2 of Appendix J. Note that the flooding shown is non-comprehensive (in that it is limited to the City areas), is based only on reported damage and is on a parcel basis (and thus does not pinpoint damaged structures on parcels where multiple structures exist).

This section focuses on enclosed conveyance assets (i.e. pipes). Capacity and discharge information for open channel conveyances and operational assessments of ponds are in separate sub-sections. References to ‘flooding’ are specifically defined to refer to conditions when the water surface elevation (hydraulic grade line) extends to the rim elevation of sewers (or above the banks of open channels) and indicates that surface flow and/or flooding may occur at this location (but whether significant flooding of an area occurs depends on topography and availability of surface flow paths and is not generally considered).

It should be noted that the modeled performance of an asset is only one factor in determining how serious a potential problem is and the proposed schedule for dealing with a problem. For example, there may be underperforming assets that serve very small areas (and thus receive lower risk ratings) and may not appear in the planned 20-year schedule due to realistic budget limitations. The issues with these assets can still be addressed on an ad-hoc basis (e.g. if the road over the asset is being re-worked in the future, the asset can be replaced at that time even if it is not explicitly scheduled for work according to the CIP).

[34] The adequacy of the capacity of certain pipes to handle different storm events may change if the control structures in interconnected basins are modified or if upstream flow restrictions (e.g. due to undersized pipes) are alleviated. The pipe database contains ‘unrestricted’ flows for the 10-year and 25-year events and should be consulted with respect to storm improvements involving new pipes.

4.3.1 Hance Drain Sub-Basin

This subsection discusses the predicted performance of the assets modeled in the Hance Drain Sub-Basin. This includes the Quarterline Drain along Airport Road west of Grewes Lake and the Hance Drain upstream of the end of its enclosure west of Summerton Road (before entering the culvert under the road).

4.3.1.1 Quarterline Drain Area (ICDC)

The two downstream 24-inch culverts (at the west edge of Grewes Lake and the SCIT campground entrance driveway) and the 12-inch culvert west of the Maranatha Baptist Church have adverse grades and corresponding reduced capacities. Such alignments may also allow for the collection of sediment and debris that further reduces the capacity of these culverts. The model predicts capacity issues at these locations for the 1-year storm and larger. These culverts should be re-configured when the drain is next scheduled for maintenance or when Airport Road is next scheduled for work. If flooding problems have been noted upstream of these culverts, rehabilitation actions should be prioritized.

4.3.1.2 Hance Drain Area

Moving upstream from its planning area outlet west of Summerton Road, the Hance Drain connects with an ICRC sewer serving Enterprise Drive (not modeled) and then an MDOT sewer serving M-20 (Pickard Road). At US-127 (east side) there is an open channel from the south that serves both the original 36-inch Hance Improvement Drain crossing and the newer 96-inch crossing at the Kay Street alignment. The original 18-inch Jeffords' Drain crossing comes in from the west where the open channel enters the enclosed portion.

ICDC: East of US-127 to Planning Area Outfall

These 84-inch to 96-inch portions of the Hance Drain east of US-127 have sufficient capacity during all modeled storm events.

ICRC: Enterprise Drive Storm Sewer

This area is modeled for runoff to assess the downstream reaches of the Hance Drain but the ICRC sewer in this area is not explicitly modeled. No plans were available for the portion downstream of Pickard Road. There is also an interconnection to the Hance Drain open channel extending from Parkway Drive west (just south of the Venture Way ROW) for which no plans were located.

MDOT: Pickard Road Storm Sewer

The MDOT sewer serving Pickard Road is generally at more than 50% capacity along its length from west of Belmont Drive to the Hance Drain during the 1-year storm. Projected flows exceed capacity along this entire stretch for the 10-year storm and larger events.

The portions downstream of the pond in the US-127 off-ramp ROW are smaller than the pipes upstream of the pond and may be sized as such as a pond discharge control mechanism. If the pipes upstream and/or the pump station into the pond are upsized in the future, the hydraulics of the entire stretch of conveyance and storage would need to be considered.

> *An alternative opportunity exists to re-route or provide relief flow to the north into the Grewes Drain Sub-Basin (which flows past US-127 to the north through large MDOT culverts and into a channel through private land which drains most of the MDOT ROW in the north portion of the project area to the Chippewa River). Such an approach would be a joint project with either the ICDC (if routing along Belmont Drive) or the ICRC (if routing along Isabella Road). These areas north of Pickard have considerable open space and wetlands available to establish open channel conveyances and/or storage. The ICDC sewers that serve the area date from 1909 to 1973 and lack conveyance capacity for the 1-year storm, strengthening the argument for a cooperative project. See Project #1 in Table 16 and Appendix J: Exhibit 2 for additional information.*

ICDC: Hance Improvement Drain Alignment

The older southern Hance Improvement Drain route along Broadway Road and through the 36-inch US-127 crossing is projected to be nearing capacity for the 1-year storm and over capacity for the 10-year storm and larger events. Flooding of less than 30-minutes is projected during the 10-year storm with projected flooding duration increasing for larger storm events.

The upstream end of this sewer alignment is interconnected to the newer sewers (i.e. along Broadway Rd, Ruby Rd, etc. and through the 96-inch Kay St highway crossing) so the flooding potential may be alleviated by through minor drainage or sewer modifications (e.g. installing a sewer along the backlot line between Drive In Lane and Honey Bear Lane as opposed to replacing/upsizing the existing sewer along this alignment).

ICDC: Hance Drain Modern Alignment

The main Kay Street sewer performs well during the 1-year and 10-year storms aside from isolated sections (largely due to isolated slope problems introduced during construction to avoid utility conflicts).

The northern branches that intercut the Ward and Jeffords Drains generally perform well during the 1-year storm. Isolated capacity concerns exist for the 10-year storm for the First Street and Second Street sewers. The Isabella Road sewer (primarily north of Kay Street) and its branches (i.e. the school backlot sewer and its connected sewers on Carter Street, Betty Lane, and Yats Drive) lack capacity for 10-year and larger storms with some projected flooding of 30 minutes duration or less along these sewers.

The Ward Drain and Jeffords Drain are essentially intercut and relieved by the newer Hance Drain sewers. The Ward Drain has numerous segments nearing or exceeding capacity during the 10-year design storm, but flooding is not a concern due to the frequent interconnections with the larger sewers. The old Jeffords Drain crossing does not receive a significant amount of flow during the 1-year storm but is projected to be nearing capacity during the 10-year storm (and exceeding capacity for larger storms) based on current sewer configurations. Field observations showed this crossing has significant levels of sediment in it and should be cleaned (and possible changes made to sewer connections to ensure flow more regularly passes through it).

The western-most northern branch (between the East Drive and West Drive alignments flowing south to the Crosslanes sewer) that relieves the headwaters area for the Hance Extension Drain (a large impervious area on the south side of Pickard Street) has segments exceeding capacity for the 1-year storm and the entire stretch exceeding capacity during the 10-year storm and larger events (note that this might be due partially to the fact that the ponds serving these parcels are not modeled). There is extensive low-lying open land in this area that could serve as additional flow storage for this area if desired. The capacity issues extend down-stream and encompass most of the sewer in Crosslanes Street during the 10-year storm and larger events. Flooding of 30 minutes duration or less is projected along the sewer from the upstream connection downstream to Isabella Road (along Crosslanes Road) during the 10-year storm.

The Ruby Road branch off the Kay Street Storm Sewer approaches 50% full during the 1-year storm but has most segments projected to be nearing or exceeding capacity during the 10-year storm. The upstream sewers along Broadway Road to the west of Ruby Road perform similarly to the Ruby Road branch but those to the east reach capacity during the 1-year storm (likely as the flow from the older Hance Improvement Drain sewers relieve flow into these pipes – see discussion above). Flooding of less than 30 minutes duration is projected near the Ruby Road / Bertshire Drive intersection during the 10-year event with flooding duration extending to 1 to 4 hours during the 100-year event (and with flooding locations expanding from the intersection to include along the Bertshire Drive and Ruby Road sewers).

The Isabella Road branch south off the Kay Street Storm Sewer has sufficient capacity to serve the 1-year storm but the portion south of Broadway Street are projected to exceed capacity during the 10-year storm (as well as the sewers that connect to it MacKenzie Lane – see the MacKenzie Lane Storm Sewer discussion below). The Broadway Road branch west off the Isabella Road sewer generally performs similarly (as well as the sewers that connect to it at Williams Street – see the Hance Improvement Drain Branch No. 2 discussion below). Some flooding of less than 30 minutes is projected along these sewers during the 10-year storm with the duration only extending to upwards of 60 minutes during the 100-year storm – likely indicating that the flooding impacts are held in the upstream sewers due to the size issues discussed).

City: Williams Street and Broadway Street west of Williams

The local sewers serving Williams Street north of Broadway Street and Broadway Street west of Williams Street are projected to have flows that exceed capacity during the 1-year storm and larger. Some flooding is projected for these branches beginning with the 10-year storm (1 to 4 hours in duration with flood times extending during larger storms).

ICDC/City: Hance Improvement Drain Branch No 2

The local sewers serving the City area of Williams St, Michigan St, Greenfield Dr, and Smalley Dr exceed or are approaching capacity during the 1-year storm (except for the much larger 36-inch outlet from this area). Flooding of up to 4 hours is projected in parts of this area during the 1-year storm with flooding duration increasing and extent expanding for larger events. Minor flood damage in this area during the 2017 flooding supports the model-based determinations of capacity and surface flooding concerns in this area.

> *There are significant vacant lands adjacent to this area to provide storage opportunities. See Project #2 in Table 16 and Appendix J: Exhibit 2 for additional information.*

City: Mackenzie Lane Storm Sewers

The model projects that the Mackenzie Lane Storm Sewer and branches, that flow to the Isabella Road branch south of Broadway Road, are all projected to exceed capacity during the 1-year storm. Flooding of up to 4 hours in duration is projected in this area during the 10-year storm with durations at all projected flooding locations increasing for larger events (but not exceeding 4 hours at any location). No flood damage was noted during the 2017 flooding in this area, however.

4.3.2 Northeast Sub-Basins

The northeast sub-basins are largely Township areas that are less developed and utilize a significant number of open channel conveyances, older county tile drains, and have significant low-lying areas and open spaces.

4.3.2.1 Thiers Drain Area (ICDC and ICRC)

The observed conditions of Thiers Drain assets during field surveys precluded modeling of the area although the runoff from the area was still modeled to provide flows to guide future improvements / designs. Structures connecting to the drain branches along Isabella Road and River Road were full of debris and some pipe breakages were noted along its length. The drain largely serves undeveloped areas but does serve a large area of airport land and portions of the developments at the intersection of Isabella Road and River Road. It is suspected that most of the flow uses shallow overland channels along the roads and over the drain tile itself.

> *This area should be investigated to develop a long-term solution to address the current conditions. It is possible that the portions west of Isabella Road may be better served if routed to alternate conveyances, including: the existing ICRC sewer and channel serving River Road west of Isabella Road, the Grewes Drain crossing under River Road west of this area, or a new Chippewa River floodplain outlet that is closer than the current Thiers Drain outfall. See Project #8 in Table 16 and Appendix J: Exhibit 2 for additional information.*

4.3.2.2 Grewes Drain Area and River Road Storm Sewer Area

The Grewes Drain under and north of US-127 (under the jurisdiction of the State of Michigan) has sufficient capacity for the 1-year storm. The portion of the channel south of River Road and the culvert under River Road are projected to have flows that exceed capacity during the 10-year storm. Flooding of up to 4 hours is projected to occur near River Road during the 10-year storm with duration extending and flooding extending upstream along the channel during larger storms.

Given the amount of MDOT area that this channel drains, it may be warranted to obtain an easement on the property this conveyance traverses to ensure that channel conditions and culverts (which are currently privately owned) continue to provide sufficient capacity to properly serve the area.

ICDC: Quarterline, Quarterline Relief, and Quarterline Extension Drains

The Quarterline Drain sewers that serve areas of the Township near Belmont Drive, National Drive, and Corporate Drive east of Packard Road, are projected to be nearing or exceeding capacity for the 1-year storm and exceeding capacity for the 10-year storm and larger events. Flooding of greater than 4 hours duration is projected at some locations during the 1-year storm and for all manhole locations during the 10-year storm and larger events.

The area served by these sewers is generally low-lying with some residential development and there is significant adjacent natural storage and flood buffering available near this area. The age of the assets, the capacity concerns, and the potential for future development (as well as the possibility for easing capacity concerns in MDOT Pickard Street sewers) make this area a target for improved drainage infrastructure.

> *This area is targeted for potential upgrades as part of a regional project that improves flows in nearby City and MDOT sewers. See Project #1 in Table 16 and Appendix J: Exhibit 2 for additional information.*

ICRC: Isabella Road Storm Sewer

The storm sewer in Isabella Road north of Pickard Street is projected to be 50% to 75% full during the 1-year storm with the segments south of National Drive projected to have flows that exceed capacity during the 10-year storm (and larger events). Flooding is projected to occur near National Drive of up to 4 hours duration with some shorter duration flooding upstream along Isabella Road. Projected flooding duration at these locations is extended during larger events.

The projected flow rates and flooding problems may be mitigated by the low-lying areas adjacent to Isabella Road. Dedicated infrastructure may be warranted \ to ensure upstream runoff is stored (and infiltrated if possible) and does not flow to the road ROW except during extreme events. The downstream portions have adjacent low-lying areas that would tend to buffer flows and provide significant storage during intense events.

> *Projected problems in this area can be alleviated as part of a regional multi-agency drainage project. See Project #1 in Table 16 and Appendix J: Exhibit 2 for additional information. The project as presented does not address issues in Isabella Road but can be modified to include assets and drainage modifications to do so.*

ICRC: River Road Storm Sewer – East of US-127

The downstream section of the River Road Storm Sewer west of Isabella Road appears to have sufficient capacity to serve up to the 25-year storm and serves a relatively small area. Most of the sewer was not modeled due to a lack of data and its small relative service area.

> *Additional study is warranted if portions of the existing sewer are used to route Thiers Drain flow (as is considered in that section – see discussion above) as considered as part of Project #8 presented in Table 16 and Appendix J: Exhibit 2.*

4.3.2.3 River Road Storm Sewer and Culvert (ICRC) – West of US-127

The River Road Storm Sewer outlet and culvert (both west of US-127) each appear to have sufficient capacity for all modeled storm events. The upstream portion of the culvert drainage area is a low-lying natural depression along the City / Township boundary that receives runoff from Township parcels and some City parcels. The depression appears to drain overland but the proximity to some buildings is concerning. Additionally, other utilities traverse this alignment (including sanitary sewer assets) so there may be numerous benefits to providing better drainage in this area. If modified, there is considerable low-lying downstream areas that can buffer the increased flows if the capacity of the culvert becomes an issue.

> *Project #10 in Table 16 and Appendix J: Exhibit 2 proposes drainage modifications that would increase flows that discharge through the River Road culvert.*

4.3.2.4 Mission Road Storm Sewer Area (ICRC and MDOT)

The ICRC sewers north of US-127 BR are generally projected to be flowing at 50% to 75% of capacity during the 1-year storm and generally to have flows that exceed capacity during the 10-year event (and larger). Flooding of up to 30 minutes duration is projected near Industrial Avenue during the 25-year storm with similar duration flooding extending upstream during the 100-year storm.

The MDOT portion along US-127 BR to Pickard Street (M-20) has projected flows that range from 75% of capacity to exceeding capacity during the 1-year storm with all segments have projected flows that exceed capacity for the 10-year storm (and larger events). Flooding of less than 30 minutes is projected at the Pickard St / Mission Rd intersection during the 1-year storm with the duration extending and the extent of projected flooding moving downstream with larger storm events.

One alternative to pipe upsizing is likely to interconnect with City sewers to the west (which already serves MDOT drainage from further south on Mission Road). There was one documented incident of minor damage during the 2017 flooding which supports a conclusion that drainage capacity issues impact this area.

Project #1 in Table 16 and Appendix J: Exhibit 2 proposes drainage modifications that would drastically reduce flows in the East Side Storm Sewer (in Brown Street and its extended ROW north of Pickard Street) and there may be an opportunity to relieve flooding concerns associated with the Mission Road sewers through interconnections to the ESSS that take advantage of the resultant available capacity (through existing sewers in Corporate Drive or Pickard Street or directly to the Corporate Drive storm sewer pond, for example).

4.3.3 North and Central Sub-Basins

The north and central sub-basins comprise an area that is largely under the City's jurisdiction and ranges in land use / cover from the high intensity development of the City's downtown business district to the less intense areas north of Pickard Road.

4.3.3.1 East-Side Storm Sewer and Relief Sewer (City; CMU and MDOT as indicated)

The East Side Storm Sewer (ESSS) serves the east side of the City and routes flow north to the Chippewa River from areas as far south as Fairfield Drive. The main sewer was put into service in 1959. A relief sewer (RS) and storm water pond were installed / connected in 1975 (from Crosslanes Road north to the pond north of Corporate Drive).

There are two upstream interconnections with the Onion Creek Drainage Basin and one interconnection which receives excess flow from the MDOT sewer in Mission Road (at Fairfield Drive).

Due to the significant capacity concerns along the entire ESSS&RS that are projected during even the 1-year storm event (these concerns are discussed in the appropriate sub-sections, below), consideration of a regional project that removes flow from the ESSS&RS is warranted. A conceptual proposal would involve a large diameter sewer in Preston Road from the ESSS to the Onion Creek Channel (parallel and interconnected to the existing 84-inch pipe downstream east of Crapo Street). This would disconnect upstream portions of the ESSS and create capacity in the downstream areas. See Project #3 in Table 16 and Appendix J: Exhibit 2 for additional information.

City: ESSS South of Bellows Street (MH 2081)

The main ESSS sewer from its southern terminus (where it cross-connects with the Onion Creek Drainage Basin north of Abbey Court) to Bellows Street is projected to have flows generally from 75% of capacity to exceeding capacity during the 1-year storm with most segments exceeding capacity during the 10-year storm (and larger events). Flooding of up to 30 minutes of duration is projected along the upstream segments and branches (as discussed below) during the 1-year storm with the duration extending and extent of flooding expanding during larger storm events.

The inter-connection point at MH 3065 routes flow into both the ESSS and a sewer in the Onion Creek Drainage Basin (in Abbey Court) but it would not be recommended to disconnect this cross-over point as the Abbey Court sewer is also approaching capacity and the drainage area directly upstream of this location experienced major damage during the 2017 floods.

The local branches in Glenwood Place and Fairfield Drive are projected to have flows that exceed capacity for all modeled events. The 12-inch portion of the Preston Rd sewer (west of the ESSS) lacks capacity to serve projected flows for the 1-year storm while the whole branch lacks capacity for the 10-year storm (and larger).

Minor flood damage occurred to a handful of parcels along these sewers during the 2017 flooding, most heavily concentrated in the lower elevation areas near the ESSS ROW.

The sewer in Fairfield Drive west of the ESSS serves an interconnection point with the Upton Drain Sub-Basin in the MDOT sewers in Mission Road. Removing this interconnection would provide benefits to this sewer and downstream in the ESSS. This action would send more flow through the Cross Campus Storm Sewer (generally 54-inch in diameter) to the Upton Drain and it should be

> *explicitly modeled when considering regional projects #3 and #7 (as presented in Table 16 and Appendix J: Exhibit 2.to fully understand the impacts and any changes necessary to accommodate the increased flow rates.*

At MH 2081, flow is divided between a 54-inch sewer to the east that flows into the Onion Creek Drainage Basin and the 42-inch ESSS which continues north. The diversion is controlled by the pipe elevations, water surface elevations, and large orifice restriction in the ESSS 100 feet downstream in MH 2067. This pipe to the Onion Creek is projected to be flowing at 75% to greater than 100% of capacity during the 1-year storm and generally lacks proper capacity for larger storms (refer to the appropriate discussion in the Onion Creek section below).

City: Bellows Street Sewers Upstream of ESSS Orifice

At Bellows Street and Brown Street, three sewers connect to the ESSS between the Onion Creek diversion pipe (54-inch along Bellows Street, Crapo Street, and Preston Road) and the ESSS orifice.

The Bellows Street sewers west of Brown Street (north alignment and south alignment) are generally projected to have flows that exceed capacity for the 1-year storm (and larger events). The northern alignment Bellows Street sewer extends across Mission Road and serves portions of campus (discussed in appropriate sub-section below). Flooding concerns along the northern sewer alignment generally do not emerge until the 100-year storm.

Flooding is projected to occur for up to 4 hours during the 10-year event in Elizabeth Street (connected to the southern alignment Bellows Street sewer) with the duration extending and extent expanding during larger events. There is an area of 2017 flood damage to parcels along Eastwood Drive and Elizabeth Street that may be due to inlet concerns and the size of the 12-inch sewer (not modeled) serving Elizabeth Street at and south of Eastwood Drive.

> *An inter-basin relief / reroute option exists to construct a large diameter sewer on Kinney Avenue from Bellows Street to Maple Street where a 66-inch sewer in the Lincoln Street Storm Sewer Sub-Basin exists (the 48-inch starting at Cherry may be a suitable ending point, but the two upstream 48-inch segments have flatter slopes and are projected to have flows that are nearing the pipe capacity during the 10-year storm. Refer the Kinney Street Storm Sewer for additional discussion about capacities in this area. This option would reduce flows in portions of the Bellows Street sewers, the ESSS, and the Onion Creek (all with current capacity concerns). See Project #5 in Table 16 and Appendix J: Exhibit 2 for additional information.*

The Bellows Street sewer east of Brown Street (27-inch) is projected to have flows that exceed capacity during the 1-year storm (and larger events). Flooding of up to 1 hour is projected at the upstream end of the sewer during the 1-year storm with the flooding duration extending and the extent of flooding moving downstream during larger storm events. The apartments located at the northwest corner of Bellows Street and Crapo Street experienced major damage during the 2017 flooding. This site has an underdeveloped and undersized drainage layout and on-site underground storage would be beneficial. The site is also served to the north into Gaylord Street which has better capacity in its downstream sections and should be considered when upgrades are done in this area.

CMU: Storm Sewers Tributary to the City's Bellows Street Storm Sewer

The East Campus Dr and Lot 8 west (including Chippewa Trail) and east sewers are projected to have flows that exceed capacity for the 1-year storm (and larger events). Flooding of up to 4 hours is projected along the Lot 8 west sewers during the 1-year event with the projected duration extending and the extent moving upstream during larger events. Flooding of up to 30 minutes is projected along the Lot 8 east sewer during the 10-year event with the projected durations extending and the extent expanding during larger events. Flooding of up to 30 minutes is projected at the upstream end of the East Campus Dr sewer during the 1-year event with the projected duration extending and the extent moving downstream during larger events.

The Lot 8 central sewer is generally projected to have flows that exceed capacity upstream of the parking lot swales during the 1-year storm (and larger events). Isolated short-duration flooding is projected during the 25-year storm (and larger events).

City: ESSS Bellows Street to Crosslanes Street

The ESSS from Bellows Street to Crosslanes Street is projected to be flowing at 50% to 75% of capacity north of Broadway during the 1-year storm and at 75% to exceeding capacity south of Broadway Street. The entire reach is generally projected to have flows that exceed capacity during the 10-year storm and larger events. Short-duration flooding of up to 4 hours (with most locations flooding up to 30 minutes) is projected during the 10-year storm along the sewer alignment with additional flooding projected along various sewer branches (as discussed below). The projected flooding extends its duration and expands its extent during larger events. The 2017 flooding includes sporadic flood-damaged parcels along the entire ROW and some along smaller side branches.

From south to north, the status of the various side branches are as follows:

- Gaylord Street west of Brown Street – projected flows exceed capacity for 1-year storm and larger events and 30-minute duration flooding projected beginning with the 1-year storm
    - There are two 2017 flood-damaged parcels in this area
- Gaylord Street east of Brown Street – the downstream pipe segments have sufficient capacity to handle projected flows from the all of the modeled storm events, but the upstream segments have flows projected to exceed capacity and cause flooding of up to 4 hours in duration during the 1-year storm with flooding duration extending and flood locations expanding for larger storms;
    - The upstream area experienced a considerable number of flood damaged buildings during the 2017 flood event (flooding in this area is compounded with under-sized pipes in the sewers on all adjacent roads, which resulted in a large contiguous area of flood damage)
- High Street west of Brown Street – projected flows exceed sewer capacity for all modeled storm events with short duration flooding projected for the 1-year storm and flood durations extending for larger storm events
- South Drive east and west of Brown Street – projected flows exceed sewer capacity for all modeled storm events with up to 30-minute duration flooding projected for the 10-year storm and flood durations extending for larger storm events
    - Some 2017 flood minor damage in this area
- North Drive west of Brown Street – projected flows exceed sewer capacity for all modeled storm events with up to 30-minute duration flooding projected for the 10-year storm and flood durations extending for larger storm events
    - Some 2017 flood minor damage in this area
- North Drive east of Brown Street (including upstream Crapo St and South Dr sewers) – projected flows generally exceed sewer capacity for all modeled storm events with up to 4-hour duration flooding projected for the 10-year storm and flood durations extending for larger storm events
    - Numerous 2017 flood major and minor damage instances in this area
- Illinois Street west of Brown Street – projected flows exceed capacity during the 10-year storm event (and larger events) with flooding of up to 1 hour duration projected during the 100-year storm
- Illinois Street east of Brown Street – projected flows generally exceed capacity during the 1-year storm event with flooding of up to 4-hour duration projected during the 1-year storm and projected flooding of up to 4-hour duration during the 10-year storm with projected flooding duration extending and extent expanding during larger storms
    - Extensive major and minor flood damage along and in upstream service area in 2017
    - A large regional storage pond was recently installed to serve several upstream parcels in this area (pond not included in model hydraulics)

There exist large tracts of available land in the upstream of this area and along its length a bit to the south. There is the potential for regional storage to serve the ESSS directly and/or the Illinois Street sewer. There also exists the potential to utilize the upstream storage areas in concert with the sewers in the Hance Drain Sub-Basin to provide a relief outlet or a re-route and utilize some of the capacity further downstream in the Hance Drain (although some upstream sections may need additional capacity. See Project #2 in Table 16 and Appendix J: Exhibit 2 for additional information.

- Broadway Street east and west of Brown Street – projected flows exceed capacity during all modeled storm events with projected flooding of up to 4-hour duration during the 10-year event and projected duration of flooding extending during larger storm events
    - No flooding is reported to have impacted these areas during 2017

- Chippewa Street east of Brown Street – projected flows do not exceed capacity for the 1-year storm but do exceed capacity for the 10-year storm with projected flooding of up 30-minutes in duration along the sewer (with the duration of flooding extending during larger storm events)
  - Flood damage in 2017 was documented in the upstream portions of this drainage area and at the corner of Russell Street and Chippewa Street.
- Lincoln Street west of Brown Street – this branch is not modeled but there was minor flood damage upstream in 2017 indicating the pipe and or inlets are undersized

City: ESSS&RS Crosslanes Street to Corporate Drive Pond

The ESSS&RS generally have sufficient capacity for the 1-year and 10-year storm projected flows from Crosslanes Street to Pickard Street. North of Pickard Street, the sewers are projected to be flowing at 75% capacity to having flows that exceed capacity during the 1-year and 10-year storm events with nearly all segments experiencing flows that exceed capacity during the 25-year storm. Flooding of up to 4-hours in duration is projected near Corporate Drive during the 10-year storm with the flooding durations extending and the flooding locations expanding upstream to Andre Avenue during larger storm events. There was no reported flood damage in 2017 along the ESSS&RS ROW.

The Corporate Dr sewer west of the ESSS is projected to have flows that exceed capacity during the 1-year storm (and all larger events) with flooding of up to 30-minutes in duration projected during the 1-year storm (with duration extending for larger events). No 2017 flood damage was reported in this area but an alternate outfall to the pond to the north could relieve some capacity issues / surcharging in the ESSS Relief Sewer.

The Corporate Drive sewer east of the ESSS (extending up Packard Road) is projected to have flows that exceed capacity during the 1-year storm (and all larger events) with flooding of greater than 4 hours in duration projected along the Packard Road branch during the 1-year storm (with the flooding duration extending for larger events and expanding to the Corporate Drive sewers downstream).

> *Issues with the ESSS&RS and its branches in this area (including the MDOT branches discussed in the next sub-section) could possibly be considered in a multi-jurisdictional project that reconfigures / reroutes the drainage through a new flow path that utilizes the Grewes Drain and rebuilds the Quarterline Drain branches (Belmont Drive, National Drive, and eastern Corporate Drive area) that feed into it along the MDOT drainage ditch south of US-127. MDOT drainage along Pickard Street could be included. Details are discussed under the MDOT: Pickard Road Storm Sewer section of the Hance Drain Area section. Alternatively, or in concert with such a project, flow from the Township / ICRC areas of Airport Road / Corporate Way could be routed from the City pond and into the Grewes Drain Sub-Basin. Such a project could also alleviate capacity issues in the upstream portions of the Hance Drain and Andre Avenue drainage areas (discussed below). See Project #1 in Table 16 and Appendix J: Exhibit 2 for additional information.*

The Andre Avenue branch east of Brown Street (except for the downstream 36-inch section) and all of its upstream branches are projected to have flows that exceed sewer capacity during the 1-year storm (and all larger events) and are projected to experience flooding of up to 4-hours in duration in the upstream areas during the 1-year storm (with projected flooding durations extending and the flooding locations expanding downstream during larger storm events). Flood damage in 2017 along W Grand Avenue can likely be attributed to these capacity issues.

MDOT: Pickard Street sewers to ESSS&RS

The MDOT sewers serving Pickard Street to the east and west of Brown Street (ESSS&RS) have projected flows that are at least 75% of capacity (with some exceeding capacity) during the 1-year storm. All modeled sewers have projected flows that exceed capacity during the 10-year storm (and larger events) with flooding of up to 1-hour in duration occurring during the 10-year storm (with durations extending and flooding locations expanding during larger storms). There was no 2017 flood damage reported on along this ROW.

City: ESSS Corporate Drive Pond to Outfall

The ESSS from the pond to the City limit (the ESSS Relief Sewer ends at the Corporate Pond connections) is projected to be at 75% of capacity during the 1-year storm with most pipes at full capacity during the 25-year storm. The ESSS from the City limit to the outfall has sufficient capacity for all modeled storm events.

The branch sewer on the north side of US-127 BR extending to the west of the ESSS is projected to have capacity for the 1-year storm and 10-year storm. Flows are expected to exceed capacity during the 25-year storm with flooding of up to 30-minutes in duration occurring during the 25-year event (and flooding durations extending during larger events).

The Industrial Drive sewer is projected to experience flow rates during the 1-year storm that exceed capacity with some flooding of up to 30-minutes in duration expected at the upstream end of the sewer. The flooding duration is projected to extend for larger storm events with flooding locations expanding downstream towards the pond. No flood damage was reported in the area during 2017.

> *The Industrial Drive drainage could be re-routed to utilize the ICRC culvert to the northeast, removing some flow from the ESSS. If this drainage was disconnected from the storm surge pond on the north side of US-127 BR, the pond would have more capacity to handle equalization for the ESSS. See Project #10 in Table 16 and Appendix J: Exhibit 2 for additional information.*

The county recycling facility north of the City boundary is modeled as connected to the ESSS but the outlet from the large on-site pond could not be located in the field. It may be that this facility is meant to retain storm water, but this connection should be investigated and the model modified as appropriate.

4.3.3.2 Fancher Street, Pickard Street, Andre Street, and Lincoln Street Storm Sewers Interconnected Sub-Basins (City; MDOT as indicated)

The Fancher Street Storm Sewer, Pickard Street Storm Sewer, Andre Street Storm Sewer, and Lincoln Street Storm Sewer have multiple interconnections and while they are discussed separately it should be kept in mind that the performance of the various main storm sewers can be influenced by changing the interconnection characteristics.

There were relatively few instances of 2017 flood damage in this entire network of interconnected sub-basins. Those that did occur are not concentrated in a particular area and may have been due to localized inlet or hydraulic issues and are not indicative of the capacity of the sewers in this area in general.

> *The available capacity in the Lincoln Street Storm Sewer is significant and should be utilized to provide relief for adjacent areas where capacity concerns exist These efforts should consider the impacts of Project #5 in Table 16 and Appendix J: Exhibit 2 on the available capacity in the Lincoln Street Storm Sewer.*

City: Fancher Street Storm Sewer

The Fancher Street Storm Sewer (from Pickard Street / Kinney Avenue intersection – where it interconnects to the Pickard Street Storm Sewer – to the outfall at the Chippewa River) is projected to have sufficient capacity to handle flows from the 1-year storm event with most of the segments expected to have flows exceeding or otherwise greater than 75% of the sewer capacity during the 10-year storm event. Projected flooding of up to 30-minutes is expected to occur at one location along this sewer reach and only during the 100-year storm event (or larger).

The Industrial Avenue and Washington Street ROW branches are also projected to have flows that exceed capacity during the 10-year storm with flooding of up to 30-minutes in duration projected along Industrial Avenue during the 10-year storm and along Washington Street ROW during the 25-year storm (with projected flooding durations extending for larger storm events).

The main sewer along Kinney Avenue and Arnold Street is projected to have capacity for the 1-year and 10-year storm events, while the Palmer Street section (connecting to MDOT's Mission Road Storm Sewer) is projected to not have sufficient capacity for any modeled events. Flooding of up to 30-minutes in duration is projected along these sewer segments during the 100-year storm event.

The Palmer Street branch west of Arnold Street is projected to receive flows that exceed capacity during the 1-year storm (and larger events). Flooding of up to 1 hour in duration is projected at the upstream end of this sewer during the 10-year storm with flooding durations increasing during larger events.

The Arnold St branch (south of Palmer St) that interconnects to the Andre Avenue Storm Sewer has sufficient capacity to handle flows projected for up to the 25-year storm with the downstream segment lacking capacity for the 100-year storm. Flooding is projected for up to 30 minutes at Bennett Ave during the 100-year storm.

There was no flood damage reported in these areas during 2017.

MDOT: Mission Road Storm Sewer from Palmer Street to Lincoln Street (in the Fancher Street SSSB)

Between Palmer St and Lincoln St the sewers are generally projected to have capacity for the 1-year storm flows with all but one segment lacking capacity for the 10-year storm. Flooding is projected to occur for up to 30-minutes in duration at Palmer St, Bennett Ave, and Andre St during the 25-year storm and at Crosslanes St during the 100-year storm. There was no 2017 flood damage reported along the Mission Rd Storm Sewer.

City: Pickard Street Storm Sewer

The Pickard Street Storm Sewer have sufficient capacity to handle the projected flows for the 1-year and 10-year storm events. Most sewer segments are projected to have flows that exceed capacity (or are flowing at 75% of capacity) during the 25-year storm.

The Franklin Street north and Fancher Street (north and south) branches are projected to receive flows that exceed capacity during the 1-year storm with flooding of up to 1-hour projected at the upstream end of the Franklin Street north sewer during the 1-year storm (with the duration of flooding extending for larger storm events). Flooding of up to 1-hour in duration is projected along the Fancher Street branches during the 10-year storm with projected durations of flooding extending for larger storm events.

The Main Street, University Avenue, and Franklin Street south branches are projected to have sufficient capacity to convey the flows from the 1-year storm. The Main Street sewer is projected to receive flows that exceed capacity during the 10-year storm while the University Avenue and Franklin Street south sewers having half of their respective pipe segments receiving projected flows that exceed capacity during the 10-year storm (with all segments receiving flows that exceed capacity during the 100-year storm). Flooding is projected for less than 30-minutes along the Main Street sewer and for up to 1 hour along the University Avenue / Bennett Avenue sewers during the 10-year storm. The duration of flooding is extended for larger storms along these two branches while the extent also expands for larger storms along Main Street.

City: Andre Street Storm Sewer

The Andre St Storm Sewer, which has an upstream interconnection to the Fancher St SSSB at Arnold St /Andre Ave intersection, is projected to have sufficient capacity for the 1-year storm. The sewer east of University Ave (upstream portion) is also projected to have sufficient capacity during the 10-year storm. About half of the sewer segments are projected to have flows that exceed capacity during the 25-year storm.

The small Kinney Avenue branches to the north and south are projected to have sufficient capacity to serve up to the 25-year storm event. The Arnold Street sewer that connects to the Lincoln Street SSSB at the Lincoln Street / Arnold Street intersection has sufficient capacity to serve the projected 10-year storm flows (with the northern segment having the capacity to also serve the 25-year storm).

The small diameter / high-level interconnect with the Lincoln Street SSSB (at Lincoln Street / University Street) routes no flow between the basins during any model scenarios.

The only flooding projected in this area is for less than 30 minutes during the 100-year storm at the intersection of Kinney Avenue and Crosslanes Avenue (this is on the Kinney Avenue south branch to the Andre Street Storm Sewer). There was one documented case of minor flood damage during the 2017 flooding, and it is in the general area where the model predicts flooding, although not directly adjacent to the sewer.

City: Lincoln Street Storm Sewer

The Lincoln Street Storm Sewer from its outfall at the Chippewa River to the Kinney Avenue / Cherry Street intersection (generally 84-inch to 66-inch in diameter) is projected to have sufficient capacity to handle all modeled storm events. Two 48-inch pipes along Kinney Avenue south of Cherry Street lack capacity for 25-year storm (and larger events). Flooding along this sewer is only projected during the 100-year storm for a duration of up to 1 hour at Illinois Street.

The Arnold Street sewer is parallel to the large sewer in Kinney Avenue and the Mission Road Storm Sewer and interconnects to both sewers at numerous locations. Aside from one segment south of Wisconsin Street, it has the capacity to handle the projected 1-year storm flows and has sufficient capacity, north of Wisconsin Street, to handle up to the projected 100-year storm flows (except for one segment). Flooding of up to 1-hour in duration is projected to occur along this sewer at Locust Street and Cherry Street during the 100-year storm event.

Flood damage in 2017 was noted along Arnold Street from Lincoln Street to Chippewa Street although the model does not project this. This may be due to pipe conditions not included in the model or other factors.

The 30-inch sewer along Lincoln Street from Mission Road to Kinney Avenue is projected to have sufficient capacity to handle flows from the 1-year storm and 10-year storm.

The Mosher Street 36/30-inch sewer from Mission Road to Kinney Avenue has sufficient capacity to handle projected flows during the 1-year storm with one pipe section that lacks sufficient capacity to handle projected flows during the 10-year storm event and a second that lacks sufficient capacity to handle projected flows during the 25-year storm event.

The Illinois Street 36/30-inch sewer and Maple Street 48/42-inch sewer between Mission Road and Kinney Avenue each have sufficient capacity to handle flows projected for storms up to and including the 25-year storm event. One segment of the Maple Street sewer lacks capacity to handle the projected flows from the 100-year storm.

The older sewer along Chippewa Street and Court Street has about half of the pipe segments projected to receive flows that exceed the capacity during the 1-year storm and larger events with most segments lacking capacity to handle the flows projected for the 25-year storm event. Flooding is projected along Court Street for a duration of up to 4 hours during the 1-year storm event with durations extending for larger storm events. There was no 2017 flood damage reported and the relief sewer along Franklin Street (Chippewa Street to Lincoln Street) and the relief shunt pipe at Kinney Avenue / Chippewa Street have sufficient capacity to handle project flows for all modeled storm events.

The Michigan Street sewer west of Fancher Street (and its branches) appear to be undersized to handle projected flows from the 1-year storm event (and larger). The segments east of Fancher Street have sufficient capacity to handle the projected flows for up to the 25-year storm event. Flooding is projected to occur for up to 4 hours in duration along the Franklin Street branch during the 1-year storm event with isolated flooding projected along the western portion of the main Michigan Street sewer for durations of up to 1 hour. The flooding projected along the main sewer is projected to increase in duration and expand in locations during larger storms with the flooding on the Franklin Street branch increasing in duration during larger storms. Flooding on the Fancher Street branch is projected at Wisconsin Street during the 25-year storm (and larger). There was no flooding damage in these areas reported in 2017 but two incidences of minor damage in upstream areas indicate a potential problem (possibly with inlet capacity or unmodeled branches).

The Broadway Street sewer flowing from west of Arnold Street and connecting to the MDOT sewer in Mission Road is projected to have sufficient capacity to handle flows for the 1-year storm but not for larger events. Flooding is projected for a duration of up to 30 minutes between Kinney Avenue and Arnold Street during the 10-year storm (and larger events).

The sewer flowing from Mission Road to Kinney Street between High Street and Gaylord Street has sufficient capacity to handle all modeled storm events.

MDOT: Mission Road Storm Sewer from Lincoln Street to Bellows Street (in the Lincoln Street SSSB)

The Mission Road sewers south of Maple Street generally are projected to receive flows that exceed capacity for the 1-year storm event and larger. Flooding of up to 4-hours is projected to occur north and south of Bellows Street along these sewers with the duration of flooding increasing and the extent expanding from High Street to Preston Road for larger storms.

North of Maple Street the sewers are generally projected to have capacity for the 1-year storm flows with about half of the pipe segments exceeding capacity during the 10-year storm and nearly all exceeding capacity during the 25-year storm (and larger events).

There was no 2017 flood damage reported along the Mission Road Storm Sewer. The numerous sewers from Mission Rd to the sewers in Kinney Ave and Arnold Ave (in the Lincoln Street SSSB) likely alleviate much of the flooding potential that is caused by the sewers in Mission Road lacking capacity for larger storm events.

City: Branches to Mission Road Storm Sewer (east side of Mission Road) – Andre Street and Lincoln Street SSSBs
The Bennett Avenue branch sewer is expected to receive flows that exceed capacity during the 1-year storm and larger events. The Crosslanes Street sewer and Wisconsin Street sewer are expected to receive flows that exceed capacity during the 10-year storm and larger events. The Maple Street sewer east of Mission Road has capacity to handle the projected flows for all modeled storm events. During the 10-year event, flooding is projected for up to 4 hours at the upstream end of the Bennett Avenue sewer and for up to 30 minutes at the upstream end of the Crosslanes Street sewer. During the 25-year event, flooding is projected for up to 1 hour at the upstream end of the Wisconsin Street sewer. The duration of projected flooding is extended, and locations expanded downstream along Bennett Avenue and Crosslanes Street, during larger storm events

The Gaylord Street sewer flowing from Arnold Street to Mission Road is projected to have insufficient capacity to handle the flows for the 1-year storm event (and larger). Flooding is projected to occur along this alignment for a duration of over 6 hours during the 1-year storm (and larger).

4.3.3.3 Cherry Street, Maple Street, and Mill Street Storm Sewers Interconnected Sub-Basins (City)
The Cherry Street Storm Sewer, Maple Street Storm Sewer, and Mill Street Storm Sewer have multiple interconnections and while they are discussed separately it should be kept in mind that the performance of the various main storm sewers can be influenced by changing the interconnection characteristics.

City: Mill Street Storm Sewer
The Mill Street Storm Sewer and its branches are projected to have sufficient capacity to handle flows generated during the 1-year storm and 10-year storm. The Oak Street branch and the main sewer segments upstream of Pine Street / Illinois Street also appear to have capacity to handle the projected flows from the 25-year storm. The Pine Street branch north of Illinois Street is projected to have capacity for only the 1-year storm and none that are larger. Flooding of up to 30-minutes of duration is projected at the north end of Pine Street during the 25-year storm with the flood duration increasing and additional locations (on the Oak Street branch, Illinois Street branch, Wisconsin Street branch, and along the main sewer near these streets) projected to flood during the 100-year storm event. There was no documented 2017 flood damage reported in this area. The interconnection point with the Maple Street Storm Sewer appears to be appropriately sized for all modeled storm events.

City: Maple Street Storm Sewer
The Maple Street Storm Sewer and most of its branches along the Maple Street and Franklin Street main sewer alignments are projected to have sufficient capacity to handle flows from the 1-year storm. The Oak Street north branch and Franklin Street north branch are the exceptions. Most of the main sewer segments on the Maple Street alignment are projected to be to be flowing at 75% full to over capacity during the 10-year storm. The University Avenue branch does not have capacity to handle the flows projected during the 10-year storm. The May Street (Franklin Street to Fancher Street) and Fancher Street segments (Maple Street to May Street) – Including the Lansing Street branch, May Street / Main Street branch, and Fancher Street branch south of May Street – are all projected to receive flows the exceed capacity during the 1-year storm (and larger events). The Franklin Street main sewer alignment is projected to have sufficient capacity for all modeled storm events and should likely be utilized to better serve the area to the south that has significant capacity and flooding concerns (as described below). The Cherry Street branch to the Franklin Street sewer alignment has sufficient capacity to handle projected flows for up to the 10-year storm event.

Flooding is projected along the May Street sewer segments and its branches during the 1-year storm for durations that exceed 6 hours (at two locations on the University Drive branch). at the upstream ends of the Oak Street, Franklin Street north, and University Avenue branches during the 10-year storm for durations of up to 4 hours. Projected flooding durations are extended, and locations are expanded, for larger storm events. Minor flood damage in 2017 along these sewers may be indicative of these capacity and projected flooding concerns. The sewer in Franklin Street from Maple Street to May Street has sufficient capacity for either scenario.

City: Cherry Street Storm Sewer

The Cherry Street Storm Sewer from its outfall to Franklin Street is generally projected to have sufficient capacity to handle up to the 10-year storm (one segment east of Washington Street has sufficient capacity only for the 1-year storm). The segments downstream of Pine Street lack sufficient capacity to handle flows projected for the 25-year storm (and larger events). The Washington Street branch and most upstream branches do not have sufficient capacity to handle flow projected for the 1-year storm (the High Street branches have sufficient capacity for the 1-year storm but not the 10-year storm). The 18-inch interconnection sewer along Pine Street between Cherry Street and Maple Street is not projected to receive flow during any modeled storm events.

Flooding is projected along the Washington Street sewer alignment, May Street branches, and Clayton Street branch during the 1-year storm for durations that may exceed 4 hours. Flooding durations are extended for larger events with flooding locations expanding to High Street for the 100-year storm. Minor flood damage in 2017 along these sewers may be indicative of these capacity issues.

4.3.3.4 Minor Sub-Basins (City)

The performance of other Sub-Basins in the north and central portions of the planning area are discussed briefly:

- WWTP Storm Sewer – projected to have capacity to serve all modeled storm events;
- Washington Street Storm Sewer – the main 24/30-inch branch from the outfall south towards Broadway Street is projected to have sufficient capacity to handle all modeled storm events:
    - The Mosher Street branch is projected to have sufficient capacity to handle flows from the 1-year storm but not the 10-year storm (and larger events) except the segments downstream of Main Street that can handle flows projected for the 25-year storm:
        - Flooding is projected at the eastern end of the sewer for durations of up to 30 minutes during the 25-year storm (with durations increasing and an additional downstream location flooding for larger events) and one instance of flooding damage in 2017 was recorded in this area
    - The Broadway Street branch does not appear to have capacity to handle the flows generated during the 1-year storm event (and larger):
        - Flooding is projected at the east end of the sewer for up to 30 minutes during the 1-year storm with durations and at Washington Street during the 10-year storm with flooding durations increasing at both locations during larger events but there were no incidences of 2017 flood damage reported in this area
- Broadway Street East Storm Sewer – the main sewer has sufficient capacity for all modeled storm events except the upstream 10-inch sewer that lacks capacity to handle the flows from any modeled storm events
    - Flooding of up to 30 minutes in duration is projected during the 25-year storm upstream of the 10-inch sewer with the duration increasing for larger storm events

4.3.4 Northwest Sub-Basins

The northwest area is largely comprised of City area with Township areas served by the ICRC and ICDC passing through City sewers to the Chippewa River.

4.3.4.1 Ward Avenue, Cemetery, Fessenden Avenue, and Broadway Street Storm Sewers Interconnected Sub-Basins (City and ICRC as indicated)

The Ward Avenue Storm Sewer, Cemetery Storm Sewer, Fessenden Avenue Storm Sewer, and Broadway Street Storm Sewer have multiple interconnections and while they are discussed separately it should be kept in mind that the performance of the various main storm sewers can be influenced by changing the interconnection characteristics.

A major initiative to relieve capacity concerns and address flooding issues in this area would be to install a new major storm sewer from the Beltnick Drain / Bradley Road Storm Sewer connection at Broadway Street and Bradley Road, that then runs along W. Michigan Street, Livingston Street, and Gratiot Court and parallels or replaces the existing 36-inch sewer that discharges to the Chippewa River. This pipe would relieve the Bradley Road Storm Sewer (discussed in a following sub-section) where the Beltnick Drain connects and could be interconnected with the Ward Avenue, Cemetery, and Fessenden Avenue Sub-Basins as needed. This pipe could be extended north along Bradley Avenue to provide better service along north Bradley Road and the ICRC sewer that connects at Pickard Street. See Projects #6 and #9 in Table 16 and Appendix J: Exhibit 2 for additional information.

City: Cemetery Storm Sewer

The Cemetery Storm Sewer and some of its branches are generally projected to lack capacity to convey the 1-year storm (and larger events), including: the main conveyance through the Cemetery, along Harris Street and along Bruce Street, Cooley, Elm and Whitney, the Harris Street branch north of Bruce Street (and its branches on Robert Avenue and Harold Avenue), The Cooley Street branch south of Bruce, Henry Street branch south of Bruce, and Adams Street branch (north and south of Bruce).

Flooding of up to 1 hour in duration is projected during the 1-year storm along Harris Street north of Harold Avenue, along the adjacent Robert Avenue branch, at Adams Street / Harold Street, along Henry Street south of Bruce Street, and along Cooley Street north of Broadway Street. The duration of flooding is extended and incorporates additional locations (e.g. Adams Street near Pennsylvania Avenue, Neier Road, and Whitney Street) for larger storm events. Some flooding in 2017 validates some of the model-projected problems but the numerous interconnections throughout the area are likely alleviating the problem somewhat.

City: Ward Avenue Storm Sewer

The Ward Avenue Storm Sewer crossing the cemetery has sufficient capacity to handle flows for all modeled storm events. The stretch from Henry Street to Harris Street has sufficient capacity to handle flows projected for the 1-year storm as do the segments west of Bradley Road to the City boundary. These segments, however, generally lack the capacity to handle the projected flows from 10-year storm (or larger events). The Cooley Street north branch (and its branches) lack sufficient capacity to handle projected flows for the 1-year storm (and larger events). The north Bradley Road branch (to Pickard Road) and the branch along the Elm Street ROW west of Bradley Road are projected to receive 10-year flows that are nearing or exceeding pipe capacity (with these segments generally being able to handle the flows for the 1-year storm).

Flooding of up to 30 minutes in duration is projected during the 1-year storm on Bradley Road north of Woodland Drive and of up to 1 hour in duration along the branches to the Cooley Street north branch (near Pickard Street). Flooding with increasing durations is expected during larger storms at more Bradley Road locations, along Beech Street and Oakland Street, and for the Cooley Street north branch (and its branches). There was major and minor damage reported during the 2017 floods near all these model-projected flooding locations.

The Cemetery Storm Sewer interconnection to the Ward Avenue Storm Sewer at Harris Street and Ward Avenue is at capacity but the Ward Avenue Storm Sewer east of Harris (to the River) has significant capacity (and has a retired CSO/SSO[35] 15-inch pipe parallel to it that is still physically capable of carrying flow and can provide even more discharge capacity). Routing more flow east could help alleviate capacity concerns and flooding issues in downstream areas of the Cemetery Storm Sewer.

The interconnection between the Ward Avenue and Cemetery Sub-Basins could be reconfigured to divert more flow into the Elm Street sewer flowing east but the first segment downstream of this crossover appears to offer some restriction. Flooding just upstream of this area is likely related to this problem and the capacity issues in both the basins' sewers in Elm Street.

[35] CSO – combined sewer overflow; SSO – sanitary sewer overflow. These are discharge points from combined / sanitary sewer systems that allow for the discharge of flows to surface waters when the respective sewer system lacks capacity to convey the flow that is entering the system.

The interconnection between the Ward Avenue and Cemetery Sub-Basins at Elm Street and Adams Street has a small capacity and relieves only a small amount of flow from the Cemetery Sub-Basin to the Ward Avenue Sub-Basin during the 10-year storm. A possible reconfiguration would be routing a large diameter pipe from Bruce Street to Elm Street Along Adams to provide better flow equalization.

ICRC: Flagstone Court / Cornerstone Drive (in the Ward Avenue Storm Sewer Sub-Basin)

The sewers serving the roads in this area are projected to lack capacity to handle the flows from the 1-year storm event (and larger events). Flooding of up to 30-minutes in duration is projected during the 1-year storm event with flooding durations extending for larger storm events. This has value for protecting downstream sewers and may not be an issue related to actual flooding but if any damage was reported in these areas during the 2017 flooding, these areas should be considered for reconfiguration (note that these areas are outside of the City and therefore do not have information reported related to the 2017 flood damage that may have been incurred).

ICRC: Pickard Street west of Bradley Road (in the Ward Avenue Storm Sewer Sub-Basin)

The Pickard Street sewer is projected to have sufficient capacity to handle the 1-year storm with most segments having sufficient capacity to handle the 10-year storm. The relief outfall path running north from Pickard Street at Parkland Drive (and ultimately routing flows along Bamber Road north to the Mission Creek) is projected to lack sufficient capacity to handle the 10-year storm flows (and larger events). Modeling of this sewer to its Mission Creek outfall is recommended to better understand the capacity issues in this area and to develop more accurate solutions to alleviating capacity concerns.

> *An alternative to better serve this area and relieve capacity issues downstream in the developed City areas would be to route all flow down a new conveyance along Bamber Road, which is much less developed, that flows north to the Mission Creek. Such a conveyance could make use of the City lands east of Bamber Road for open channel conveyance and/or storage. The headwater areas of the sewers in Bradley Street and Cooley Street could be interconnected to provide overflow relief. See Project #9 in Table 16 and Appendix J: Exhibit 2 for additional information.*

City: Fessenden Avenue Storm Sewer

The Fessenden Avenue Storm Sewer and its branches upstream (west) of Henry Street are projected to generally have sufficient capacity for events up to and including the 10-year storm. The main sewer downstream (east) of Henry Street, as well as the Henry Street sewer and its branches, generally lack sufficient capacity to handle flows projected during the 1-year storm and larger events. The Adams Street south branch is projected to have capacity to handle the 1-year storm (but not larger events).

The two interconnections between the Cemetery Storm Sewer Sub-Basin and the Fessenden Avenue Storm Sewer Sub-basin are projected to be nearing or at capacity during the 1-year (and lacking capacity for larger events). Changes to relief between these two sub-basins is unlikely to alleviate any capacity concerns due to the existing capacity issues in both sewer systems.

Flooding of up to 4 hours in duration is projected during the 1-year storm along the Henry Street / Broadway Street / Michigan Street areas. Flooding of up to 1-hour in duration is expected along the Wood Street branch. The duration of flooding at these locations extends for larger storm events while projected flooding locations extend to Fessenden Avenue and Adams Street north of Fessenden. There were instances of 2017 flooding reported along the Henry Street branch to the north (including Michigan Street and Broadway Street) as well as the Wood Street branch to the south. There was no flood damage reported in 2017 in the downstream areas along Fessenden Avenue but three instances upstream of Henry Street (near Wood Street).

City: Broadway Street Storm Sewer

The Broadway Street Storm Sewer is projected to have sufficient capacity to handle flows for the 1-year storm. The sections east of Harris Street (18-inch) have capacity to handle the projected flows for all modeled storm events, but the sections between Adams Street and Harris Street lack the capacity to handle projected flows for the 10-year storm (and larger events). Additional capacity along this stretch (which acts in part as a diversion from the Fessenden Avenue Storm Sewer Sub-Basin) could better utilize the downstream sewer segments and reduce flooding in the Fessenden Avenue SSSB.

4.3.4.2 Upton Avenue Storm Sewer (City; MDOT as indicated)

The Upton Avenue Storm Sewer is projected to have capacity to handle the 25-year storm with most segments also being able to handle storms up to the 100-year storm. All of the branches are projected to have sufficient capacity for all modeled storm events except for the Granger Street branch that does not have capacity for the 25-year storm (and larger events) and the Burch Street branch that does not have capacity for the 10-year storm (and larger events).

Flooding is projected for a duration of up to 1-hour along Burch Street during the 25-year storm (with flooding duration extending for larger storm events). Two instances of flood damage in 2017 occurred in this Burch Street area. Five other instances of flood damage in areas not projected to flood (in the Henry Street / Upton Avenue / Belnap Street area) may be due to local issues (e.g. storm inlet capacities) or undocumented obstructions in the sewers.

MDOT: High Street Storm Sewers

The MDOT sewers west of Henry Street are projected to have sufficient capacity to handle flows for all modeled storm events except for the western most two segments that only have sufficient capacity to handle the projected flows for the 1-year storm (and no larger modeled events). The two sewer segments east of Henry Street also only have sufficient capacity to handle the projected flows for the 1-year storm (and no larger modeled events). Flooding is projected at the east end of the High Street sewers for a duration of up to 30 minutes during the 10-year storm and at the west end of the High Street sewers for up to 30 minutes during the 100-year storm (with durations of flooding increasing for larger events). There was no flood damage reported in 2017 in these areas along High Street.

4.3.4.3 Adams Street Storm Sewer

The Adams Street Storm Sewer and its branches are projected to have sufficient capacity to handle the 1-year storm event with only the Burch Street branch having capacity to handle projected flows from larger storms (all modeled events). Flooding of up to 30 minutes in duration is projected along the Granger Street and Burch Street branches during the 25-year storm with flooding durations extending for larger storm events. There were no instances of flood damage reported in 2017 along these sewers.

4.3.4.4 Bradley Road Storm Sewer (City; ICDC as indicated)

The Bradley Road Storm Sewer is generally projected to lack capacity for flows generated from the 1-year storm except for the segments north of Fessenden Avenue which have sufficient capacity for the 1-year storm (but not for larger events). The Fessenden Avenue west branch is projected to have insufficient capacity to handle the 1-year storm (and larger events) while the Betsy Lane branch and the main branch sewer extending south to Broadway Street generally have capacity to handle the projected flows from the 10-year storm (but generally not larger events).

Flooding is projected for up to 4 hours along the Fessenden Avenue west branch during the 1-year storm event. Flooding is projected along Bradley Road for up to 4-hours during the 10-year storm event. Projected flooding durations are extended during larger storm events and flooding of up to 30-minutes in duration is projected along the Betsy Lane branch during the 25-year storm event (similarly with durations increasing for larger events). Two (2) instances of 2017 flood damage (1 minor and 1 major) were reported northeast of the Bradley Road / Broadway Street intersection. There is significant on-site storage in many adjacent properties that may reduce peak flows in the sewer. Additionally, the western portions of this basin are undeveloped and the flow from these areas may be significantly slower than modeled.

> *A major initiative to relieve capacity concerns in the Bradley Road Storm Sewer would be to install a new major storm sewer from the Beltnick Drain / Bradley Road Storm Sewer connection at Broadway Street and Bradley Road, that then runs along W. Michigan Street, Livingston Street, and Gratiot Court and parallels or replaces the existing 36-inch sewer that discharges to the Chippewa River. This pipe would relieve the Bradley Road Storm Sewer where the Beltnick Drain connects and could be interconnected with the Ward Avenue, Cemetery, and Fessenden Avenue Sub-Basins as needed. This pipe could be extended north along Bradley Avenue to provide better service along north Bradley Road and the ICRC sewer that connects at Pickard Street. See Project #6 and #9 in Table 16 and Appendix J: Exhibit 2 for additional information.*

ICDC / ICRC: Beltnick Drain and Sandstone Drive

The Beltnick Drain and the Sandstone Drive Storm Sewer are generally projected to lack capacity to handle flows for the 1-year storm (or larger events). Flooding is projected for up to 4 hours in duration at the upstream ends (at Lincoln Road) of both the north and south branches of the drain. The flooding durations extend during larger storm events and expand downstream along both branches and along the main branch to Bradley Road. Most of the developed service area is Township land so there is no 2017 flood data to use for comparison. There are a number of on-site detentions and undeveloped areas that may result in the peak flows reaching the sewer being the lower than estimated.

4.3.4.5 Minor Basins

The small basin sewers along Michigan St and Lyons St are projected to have sufficient capacity to handle flows for all modeled storm events (although the upstream segment in the Michigan St Sub-Basin only has capacity to handle projected flows for up to the 25-year storm). Flooding of up to 30 minutes in duration is projected upstream of this segment during the 100-year storm. Some 2017 flood damage in the upstream portion of the Lyons St Sub-Basin may be indicative of inlet restrictions or undocumented sewer obstructions.

The Chipp-A-Waters area flow structures appear to have sufficient capacity to handle all modeled events.

The Pickard Street / Railroad Area sewer is projected to have sufficient capacity for the 1-year storm but to be experience flows that are greater than 75% of capacity or exceeding capacity for the 10-year storm (and larger events). No flood damage was reported in 2017 in this small area.

Around half of the Island Park outfall sewers appear to have sufficient capacity to handle the 1-year storm event with only one having capacity to handle larger events. This park is in the floodplain and the area is largely fields and parking lots. Those outfalls serving areas with buildings should be investigated to be sure structural protection is maintained during these storm events.

The outfalls north of the Island Park area serving the adjacent park and Pickard Street appear to be appropriately sized to handle all modeled storm events. No flood damage was reported in 2017 in this small area.

4.3.5 Southwest Sub-Basins

The southwest sub-basins largely cover most of the CMU campus, the southwest corner of the City, and less / developed areas of the Township adjacent to the City.

4.3.5.1 Recker Drain (ICDC)

As two parallel pipes, the main drain from Broomfield Road to the outfall is projected to have sufficient capacity to handle all modeled storm events. Flooding occurs along this alignment during the 1-year storm and larger events but there is a flow channel that accommodates these flows.

As two parallel pipes, the branch extending south is projected to have insufficient capacity to completely handle any modeled storm events. Some flooding occurs along this alignment during the 1-year storm and larger events but there is a flow depression that accommodates these flows.

The single pipe branch serving Broomfield Road west of Crawford Road is projected to generally have capacity to handle the 1-year storm but to have projected flows during the 10-year storm that range from 75% of capacity to exceeding capacity. Flooding of up to 4 hours is projected along this sewer during the 10-year storm with the flooding durations extending for larger storm events and encompassing additional upstream and downstream locations along the sewer.

The area served by the drain is largely agricultural (the south branch) or undeveloped and there are significant opportunities for adjacent storage adequate storm water controls associated with future development. Any capacity issues in this area are not currently likely to lead to significant property damage and no flood damage in 2017 was reported in the City areas of this basin.

4.3.5.2 Forest Lane Culvert Area (City)

The outlet culvert from this area is projected to have sufficient capacity for all modeled storm events.

In the headwaters of this area (Orchard Drive and Country Way area), the sewers are generally lacking sufficient capacity to handle the flows from the 1-year storm (and larger events). Flooding of up to 4 hours in duration is projected near the pond and extending up Country Way and Crestwood Drive and on the sewer extending northeast to Center Drive. The duration of flooding is extended during larger events with projected flooding locations activating further northeast and further south along Orchard Drive. Flooding damage in 2017 was reported primarily near the pond at the outlet of this area with two instances of upstream flood damage (on Crestwood Drive and on Center Drive).

Regional storage or an alternate outfall can likely be installed upstream near Center Drive and Tomah Drive to alleviate flooding upstream and reduce flows in downstream sewers. Additional storage, conveyance capacity, or an alternate outlet will likely address issues with pipe capacity and flooding on the downstream side of the pond. The channel conveying flows from the upstream discharge downstream to the culvert does not have capacity concerns for any modeled events and is in a low-lying undeveloped area where flood damage is not generally a concern.

4.3.5.3 Upton Drain (ICDC; City, CMU, ICRC, and MDOT as indicated)

The Upton Drain open channel and its culverts from Wendrow Way upstream to the enclosure at West Campus Drive are projected to have sufficient capacity to handle all modeled storm events. Flooding in 2017 along the drain channel appears to be due to the open channel drain hydraulics and the elevation of the Chippewa River downstream.

The enclosed section downstream of the cross-campus sewer and Sunset Drive connections is projected to lack the capacity to handle the 1-year storm event (and larger events)

> *The portion of the Upton Drain Enclosure downstream of the Cross-Campus Storm Sewer / Sunset Drive sewer connections should be enlarged or flows re-routed to enter the drain downstream of the existing enclosure. Alternatively, if upgrades are done to the cross-campus and or Sunset Drive sewers, rerouting flow around the enclosure may be an option. See Project #7 in Table 16 and Appendix J: Exhibit 2 for additional information.*

Upstream to Broomfield Road, the enclosed Upton Drain appears to have capacity to handle all modeled storm events except for a section near the Towers and the section crossing Broomfield Road which are projected to have capacity issues for all modeled storm events.

<u>City: Minor Sewers along Upton Drain</u>

The Kent Drive and Gordon Street/Watson Road north outfall culverts are projected to have sufficient capacity to handle the flows for all modeled storm events. The upstream end of the Kent Drive culvert indicates flooding of up to 1 hour in duration during the 1-year storm (with durations extending for larger events). No 2017 flood damage was reported in either area.

The Vernon Drive sewer has sufficient capacity to handle flows projected for the 10-year storm (and smaller events). The Glen Avenue sewer (east of the drain, north of Hopkins Street) is projected to have sufficient capacity to handle flows projected for the 25-year storm (and smaller events). The Hopkins Street sewer (west of the drain) has sufficient capacity to handle the flows projected for all modeled storm events. There is flooding projected at the upstream end of the Vernon Drive sewer of up to 1-hour in duration during the 1-year storm with the duration extending for larger events. All three of these areas have adjacent 2017 flood damage recorded but the proximity to the Upton Drain channel makes it difficult to determine if the flood damage was due to the local sewer capacities or flooding in the drain.

The Preston Road sewer to the west of the drain is projected to have insufficient capacity to handle flows projected for the 10-year storm (and larger events). Flooding of up to 1-hour in duration is projected at the upstream end of this sewer during the 10-year storm with flooding durations extending during larger storms. No 2017 flood damage was reported in this area.

<u>City: Watson Road Storm Sewer south of Upton Drain</u>

The Watson Road Storm Sewer that extends along Hopkins Street is projected to generally lack capacity to handle the flows from the 1-year storm (and larger events). Flooding of up to 4 hours in duration is projected south of Highland Street during the 1-year storm (with durations extending for larger events). No 2017 flood damage was reported in this area.

City: Hopkins Street / West Campus Drive Storm Sewer

The Hopkins Street / West Campus Drive Storm Sewer (to the first manhole in the Northwest Apartments parking lot) is projected to have sufficient capacity to handle the 1-year storm event and all but the downstream Hopkins Street segment have sufficient capacity to handle the projected flows from the 25-year storm. There is no flooding projected downstream of the Northwest Apartments parking lot and no flood damage reported during 2017.

CMU: Northwest Apartments and Lot 1

The Lot 1 sewer passing under the railroad lacks sufficient capacity to convey the flows projected for any of the modeled storm events. However, this area (on either side of the railroad, has storage area along the railroad ROW and can eventually outlet to the north, if necessary, via the railroad ditch. Flooding occurs along this sewer upstream of the railroad (and into Lot 1) for up to 4 hours in duration during the 1-year storm with durations extending for larger storm events. During the 100-year storm event, flooding of up to 1-hour is projected in the Northwest Apartments parking lot.

City: Preston Road Storm Sewer east of Upton Drain

The Preston Road Storm Sewer east of the Upton Drain (as well as its branches serving the University Center and the east side of the Library) are projected to have insufficient capacity to handle the flows from the 1-year storm. Flooding is projected primarily along the Preston Street sewer for durations up to 4 hours during the 1-year storm with durations extending and flooding locations expanding to the branches during larger events.

> *A regional project is proposed to replace or supplement the sewers currently in Preston Road. See Project #7 in Table 16 and Appendix J: Exhibit 2 for additional information.*

City: Crescent Drive Storm Sewer

Downstream (east) of Highland Street, the Crescent Drive Storm Sewer is projected to have sufficient capacity to handle flows from all modeled storm events. The portion upstream (west) of Highland Street (and the sewer branches) are generally projected to lack sufficient capacity to handle flows from the 1-year storm (or larger events). Flooding of up to 4-hours in duration is projected at the western (upstream) end of the sewer during the 1-year storm with durations extending and flood locations expanding downstream during larger storm events. Flood damage was recorded in 2017 at the downstream end of the sewer but the proximity to the Upton Drain channel makes it difficult to determine if the flood damage was due to the local sewer capacities or flooding in the drain.

City: Sunset Drive Storm Sewer

The Sunset Drive Storm Sewer from east of Stockman Road is projected to have pipe segments that range from 50% of capacity to exceeding capacity during the 1-year storm. The western branch and the Stockman Road branch generally are projected to be utilizing 75% to 100% of capacity during the 1-year storm (but the branches to these two branches are projected to lack capacity the handle flows from the 1-year storm). The western branch is projected to be utilizing 75% to 100% of capacity during the 10-year storm but the Stockman Road branch will exceed capacity during this storm event. The downstream most segments of the main sewer appear to have sufficient capacity to handle flows from all modeled storm events.

Flooding is projected near the Sunset Drive / Stockman Road intersection for up to 30 minutes and of up to 4-hours duration at the upstream ends of the branches to the branches during the 1-year storm event. The projected flooding extends in duration and expands in location to the main sewer, western branch, and Stockman Road branch for larger storm events. Flood damage was reported in 2017 north of the Sunset Drive / Stockman Road intersection and along Stockman Road south of the intersection.

City/MDOT/CMU: 54-inch Cross-Campus Storm Sewer

The downstream portion of the Cross-Campus Storm Sewer is projected to lack sufficient capacity to handle the flow from the 1-year storm. Approximately 30% of the upstream segments also lack sufficient capacity for the 1-year storm (or larger events). The remaining segments appear to generally have sufficient capacity to handle all modeled storm events. Flooding is projected near Sauk Trail for a duration of up to 1-hour during the 1-year storm with the duration of flooding extending during larger storm events.

> *The cross-campus sewer should be upgraded or an alternate conveyance built to carry flows to the Upton Drain. This could provide relief for sewers draining to the Upton Drain and would be useful to create capacity in other areas of the system (e.g. removing cross-connections to ESSS). As conceived, the current proposed project routes flow north along Washington St and utilizes Preston Rd to bypass the downstream capacity restrictions in the CCSS and in the Upton Drain enclosure. See Project #7 in Table 16 and Appendix J: Exhibit 2 for additional information.*

CMU: Branches to Cross-Campus Storm Sewer

The Sauk Trail branch, the western-most Lot 33 sewer, and the East Campus Dr sewer are projected to have insufficient capacity to handle flows from the 1-year storm (or larger events). The eastern-most Lot 33 sewer is generally projected to have insufficient capacity to handle flows from the 10-year storm (although the downstream-most segment appears to have capacity to handle all modeled events). Flooding is projected north of Lot 33 for up to 1 hour during the 1-year storm (and behind the library for up to 4 hours) with the projected flooding durations extending and the flooding locations expanding into Lot 33 during larger events.

> *A relief sewer is proposed as part of a regional project to provide additional capacity that bypasses flow restrictions in the cross-campus sewer, the Upton Drain, and the Preston Rd Storm Sewer while providing additional flow capacity for areas of campus with storm sewer capacity issues and potential flooding problems. See Project #7 in Table 16 and Appendix J: Exhibit 2 for additional information.*

City: Washington Street Storm Sewers

The Washington St Storm Sewer north of the CCSS is projected to have insufficient capacity to handle flows from the 1-year storm (and larger). The southern sewer is generally projected to have sufficient capacity to handle all modeled storm events. Flooding of up to 1-hour in duration is projected at the upstream end of the north branch and at Ojibway Court along the south branch during the 1-year storm. The projected duration of flooding at these locations is extended for larger storm events and expands south along the southern branch.

> *A regional project is currently conceived to address the capacity concerns for the north branch of the Washington St sewer. See Project #7 in Table 16 & Appendix J: Exhibit 2 for additional information.*

CMU: Washington Street Sewer Branches

The Ottawa Court Storm Sewer is projected to have sufficient capacity to handle the flows from the 1-year storm (but not for larger events). The Ojibway Court Storm Sewer upstream (east) of the Sauk Trail is projected to have insufficient capacity to handle flows from the 1-year storm (and larger events). The downstream portion has sufficient capacity to handle the flows projected for the 1-year storm but has segments that lack capacity for the 10-year storm (and larger events). Flooding is projected at the upstream end of the Ojibway Court Storm Sewer for a duration of up to 1-hour during the 1-year storm (with the duration extending for larger storm events and flooding locations extending downstream and emerging during the 10-year storm event). Flooding is projected along the Ottawa Court sewer for a duration of up to 30 minutes during the 10-year storm (with the durations extending for larger storm events).

MDOT: Mission Road Between Preston and East Campus Drive

The Mission Road Storm Sewer between Preston Road and East Campus Drive (south of Broomfield Road) is projected to generally lack sufficient capacity to handle flows from the 1-year storm (and larger events). Flooding is projected for up to 30 minutes in duration near Preston Road and for up to 1 hour in duration north and south of Broomfield Road during the 1-year storm. Flooding durations are extended and flooding locations expanding along Mission Road for larger storm events. No 2017 flood damage was reported along Mission Road in this sewer service area.

ICRC: Broomfield Road

For the Broomfield Road Storm Sewer west of the Upton Drain, most of the sewer segments are projected to range from 75% of capacity to exceeding capacity for flows during the 1-year storm. Most segments are projected to exceed capacity for the 10-year storm. Flooding is projected at Crawford Road (and to the east) for up to 30 minutes in duration during the 25-year storm.

For the Broomfield Road Storm Sewer east of the Upton Drain (northern alignment), the sewer segments upstream (east) of the Sauk Trail are projected to lack sufficient capacity to handle flows from the 1-year storm (those downstream have sufficient capacity in this scenario). The downstream segments (west of the Sauk Trail) are projected to lack sufficient capacity to handle flows from the 10-year storm (and larger events). Flooding is projected for up to 1-hour in duration during the 1-year storm at the upstream (eastern-most) reach. Flooding is projected to extend in duration and expand to downstream locations for larger events.

For the Broomfield Road Storm Sewer east of the Upton Drain (southern alignment), approximately half of the sewer segments are projected to be at greater than 75% capacity to exceeding capacity during the 1-year storm and 10-year storm. All segments are projected to be in this capacity range during the 25-year storm. Flooding is expected for greater than 4 hours near the pond during the 1-year storm with durations extending and locations extending downstream along the road alignment during larger storm events.

City: Crawford Road connecting to Broomfield Road and Deming Drive connecting to Broomfield Road
The Crawford Road Storm Sewer is projected to have insufficient capacity to handle flows from the 1-year storm. Flooding is projected for up to 1-hour in duration during the 1-year storm with durations extending and locations expanding for larger storm events. No flood damage in 2017 was reported in this service area.

The Deming Dr Storm Sewer is projected to lack sufficient capacity to handle flows from the 25-year storm (or larger events) with the upstream modeled segment also lacking capacity for the 1-year storm and 10-year storm. Flooding is projected along Deming Dr for a duration of up to 1-hour during the 1-year storm with the flooding durations extending for larger events. Flood damage in 2017 was reported adjacent to Deming Dr.

CMU: South Campus Storm Sewer
The South Campus Storm Sewer that runs parallel to the railroad on the east side (and connects to the Broomfield Road Storm Sewer east of the Upton Drain, southern alignment) is projected to generally have sufficient capacity during the 1-year storm (except for the reach east of the stadium). The sewer generally lacks sufficient capacity to handle flows projected for the 10-year storm. Flooding is expected across much of this sewer for durations of up to 30 minutes during the 25-year storm with durations extending and locations expanding for larger storm events.

The southern branch adjacent to the athletic fields is projected to have sufficient capacity for all modeled storm events. The new sewer serving the south side of the Student Activities Center is projected to have capacity for flows from events up to and including the 25-year storm.

ICDC: Upton Drain Open Channel south of Broomfield Road and Upton Drain West Branch and Cole Drain Sewers
The open channel / culvert portions of the Upton Drain and Cole Drain south of Broomfield and west of the railroad have sufficient capacity to handle projected flows from all modeled storm events. The flooding extents during 2017 in the south campus area are shown in Figure 11.

The western branch of the Upton Drain (flowing generally from Crawford Road to the west to the east side of West Campus Drive in the east and between Kewadin Village to the north and the baseball stadium to the south) is projected to lack capacity to handle flows during the 1-year storm and larger events (as well as its branches extending south towards the stadium). Flooding of greater than 4 hours in duration is expected in the upstream reaches and of duration of less than 30 minutes near the baseball stadium parking lot during the 1-year storm. This flooding extends in duration and expands to additional locations along this sewer for larger storm events. Parts of this reach can provide overland and/or channelized flow and this tends to alleviate flooding concerns as well as the fact that the area is generally agricultural / recreational open-space facilities.

The enclosed portions of the Cole Drain (flowing south from the north side of West Campus Drive east of Denison Drive) are projected to lack sufficient capacity to handle flows from the 1-year storm (and larger events). Flooding is projected for durations surpassing 4 hours during the 1-year storm at Three Leaves Drive with additional locations to the north flooding for up to 4 hours with increasing flood durations at all locations projected during larger storm events.

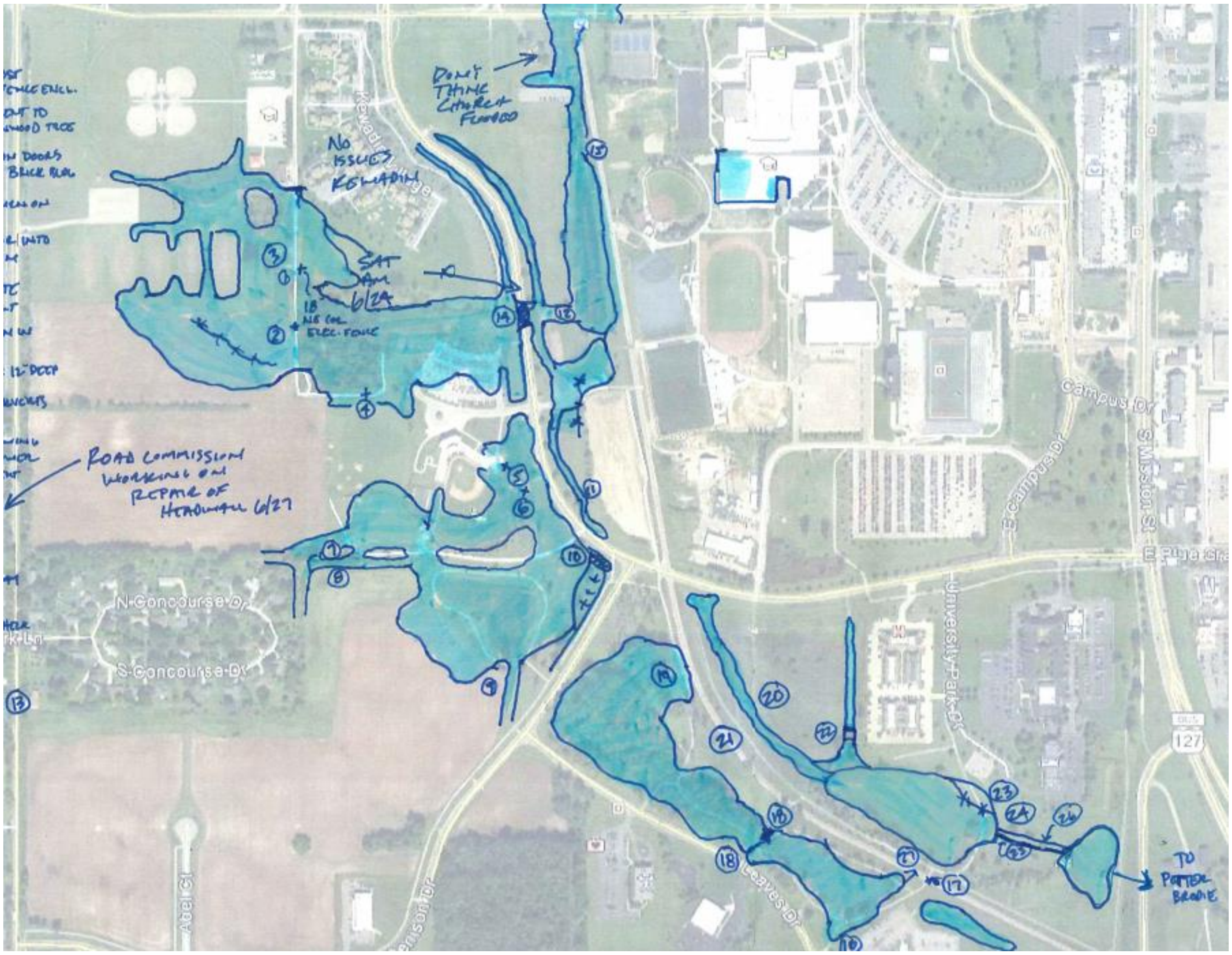

Figure 11. South campus flooding during 2017.

The discharge infrastructure for the ponds south of the stadium are projected to have sufficient capacity for all modeled storm events.

4.3.5.4 Minor Basins (City; MDOT as indicated)

The Highland Street / Wendrow Way sewer discharging to the Upton Creek Lowlands channel (parallel to Wendrow Way to the west of the street) is projected to lack capacity to handle flows from the 1-year storm. The Forest Lane sewer discharging to the same channel is projected to have sufficient capacity for the 1-year storm (but not for the 10-year storm or larger events). Flood damage in these areas in 2017 may be due to these capacity issues or because of the proximity to the Chippewa River floodplain.

The Greenbank Drive sewer discharging to a Chippewa River canal north of Wendrow Way is projected to lack capacity in its downstream segment to handle flows for the 1-year storm. The Canal Street sewer discharging to another Chippewa River canal near Riverview Court is projected to have sufficient capacity to handle flows from the 1-year storm but not the 10-year storm or larger events. The Riverview Court sewer discharging to the same canal is projected to have capacity for up to (and including) flow from the 25-year storm (but not for larger modeled events). It should be noted that the inverts for this sewer were estimated and the capacity estimate may be inaccurate.

Significant flood damage in 2017 in these areas (and on Riverview Court) is possibly due to proximity to the floodplain but the culvert sizes should be reviewed to prevent damage during less intense storms. This area would require significant flood protection efforts to mitigate flood damage from the Chippewa River and the short canals that extend towards the developed areas.

MDOT: M-20 / High Street at Chippewa River

All sewers discharging from this area to the Chippewa River floodplain are projected to have sufficient capacity to handle flows from all modeled storm events. The performance of the pump station was not assessed in the model; the input flow rate was set equal to the output flow rate. The pump station capacities should be evaluated in consideration of the flows projected by the model for the various storm events.

The sewer segment extending east of the railroad bridge is projected to have capacity for the 1-year and 10-year storms (but not for larger events) and flooding is projected at the upstream end of this sewer for a duration of up to 30 minutes during the 100-year storm. No 2017 flood damage was reported in this area.

City: Watson Street / May Street

The Water Road Storm Sewer that connects to an MDOT outfall on the north side of High Street is projected to have sufficient capacity to handle all modeled storm events except the two short segments at High Street lack capacity to handle flows projected for the 10-year storm (and larger events). Flooding is projected along this sewer for up to 1 hour in duration during the 10-year storm with durations extending for larger storm events. Flooding in 2017 was documented at the upstream (east) end of the May Street sewer.

4.3.6 Onion Creek Sub-Basin

The Onion Creek Sub-Basin covers the southeast portion of the planning area and is a mix of City and Township lands with ICRC corridors and ICDC drains. There was significant concentrated flooding reported in 2017 for two upstream areas in this Sub-Basin.

4.3.6.1 Onion Creek Headwaters: Primary Planning Area Outlet (ICDC) [Central]

The Onion Creek passing through culverts under US-127 is the major planning area outlet for flows from areas that are tributary to the Onion Creek.

The Onion Creek Drain open channel from Isabella Road to US-127 is projected to have sufficient capacity to handle flows from all modeled storm events. The culverts passing under US-127 are projected to have insufficient capacity to handle any of the modeled storm events. There is no documented flood damage from 2017 but data may be incomplete in this area. The significant undeveloped areas north of the drain provide ample space to create in-line storage if deemed necessary.

4.3.6.2 Onion Creek Headwaters: Neff Extension Drain (ICDC) – Additional Planning Area Outlet [North]

The Neff Extension Drain routes flow along Remus Road from the east side of Isabella Road to the east under US-127 (which is the boundary of the planning area). The drain is projected to lack capacity to handle flows from the 1-year storm and larger events. The peak flows experienced may be lower due to unmodeled storm water ponds in the developed areas that it serves.

Flooding is projected along Remus Road for durations of up to 1 hour during the 1-year storm with flooding durations extending during larger storms. The area to the south of Remus Road is low-lying agricultural land and the area north of Remus Road and west of US-127 is low-lying undeveloped wetland areas. Excess flows in these areas or in the drain will enter the US-127 ditch and flow south to the Onion Creek open channel where it passes under US-127, likely absorbing any excess flows that cannot be handled by the drain.

4.3.6.3 Onion Creek Headwaters: Isabella Road North (ICRC; City as indicated)

The Isabella Rd sewer north of Preston Rd is projected to have sufficient capacity to handle the 1-year storm and 10-year storm (although the southern-most segments are projected to have flows that exceed 75% of capacity or exceed capacity for the 10-year storm). Flooding is projected for durations of up to 30 minutes north of High St during the 10-year storm and for up to 1 hour north of Bellows St. Flooding duration is projected to extend north of High St for larger storms and to extend south of Bellows St to Preston Rd.

ICRC: High Street west of Isabella Road

The High Street Storm Sewer (west of Isabella Road) is projected to have insufficient capacity to handle flows from the 1-year storm (and larger events). Flooding is projected along High Street for durations of over 4 hours during the 1-year storm event with durations extending during larger storm events. Flood damage in this area in 2017 may be due, in part, to these capacity issues.

City: Bellows Street west of Isabella Road

The Bellow Street Storm Sewer (west of Isabella Road) is projected to have sufficient capacity for flows from the 1-year storm between Isabella Road and Sweeney Street (and along the Sweeney Street south branch), but not for larger events, while the branches continuing west along Bellows Street and along Sweeney Street / Gaylord Street (to the north) do not have sufficient capacity for the 1-year storm (or any larger events).

Flooding is projected along the Sweeney Street (north) / Gaylord Street sewer for durations of up to 4 hours during the 1-year storm with durations extending during larger storm events. Flooding, at the upstream end of the Sweeney Street south sewer and at the upstream end of the Bellow Street sewer, is projected during the 10-year storm event for durations of up to 1 hour (with durations increasing for larger storm events). Flooding at other locations along Bellows Street is projected for durations of up to 1 hour during the 25-year storm (with durations extending for larger storm events).

Flood damage in 2017 was reported for a high number of structures adjacent to the Sweeney Sweet / Gaylord Street sewer along its entire length and in the upstream area on the north side of Bellows Street. Flooding in this area is compounded by capacity issues in adjacent sewers also having capacity issues.

4.3.6.4 Onion Creek Headwaters: Preston Road Storm Sewer (City)

The Preston Road Storm Sewer from its discharge into the Onion Creek Drain upstream to the Preston Road / Crapo Street intersection is projected to have sufficient capacity to handle flows from the 1-year storm but not for larger events. The portion from the Preston Road / Crapo Street intersection to the Crapo Street / Bellows Street intersection is projected to have insufficient capacity for any modeled storm events. The portion from the Crapo Street / Bellows Street intersection upstream to the ESSS interconnection (at Bellows Street / Brown Street intersection) is projected to have sufficient capacity for storms up to and including the 25-year storm except for the upstream segment which has insufficient capacity for any modeled storm events.

Flooding is projected along Bellows St (at the Mt. Pleasant High School pond discharge) during the 10-year storm for durations of up to 4-hours with durations extending and locations expanding downstream along Bellows St / Crapo St for larger storm events. Major flood damage was reported in 2017 adjacent to Crapo St.

> *There are large tracts of public land adjacent to many of these areas (e.g. Mt. Pleasant High School, park east of Sweeney Street south of Preston Road) and some other undeveloped lands further downstream along Preston Road. The flooding damage reported in these areas is coincident with damage in adjacent areas that connect to the East Side Storm Sewer. Such a configuration would likely benefit from an additional sewer in Preston Road to the Onion Creek, like as is discussed as on option for the ESSS. See Project #3 in Table 16 and Appendix J: Exhibit 2 for additional information.*

City: Sweeney Street Storm Sewer and Branches

The Sweeney St Storm Sewer south of Preston Rd, and its branches, are generally projected to not have sufficient capacity to handle flows from any of the modeled storm events. Flooding of up to 1-hour in duration is projected along the Batson Pl sewer, the Eastpointe Dr / Somerset Dr / Morning Mist Ln sewer, the Abbey Ct / Heritage Way sewers, and the upstream (southern) segments of the Sweeney St Storm Sewer during the 1-year storm. Projected flooding durations are extended and locations expanding along the various branches and downstream along the Sweeney St Storm Sewer for larger storm events. Flood damage in 2017 was reported along Batson Pl, Morning Mist Ln, and at the corner of Eastpointe Dr and Sweeney St.

City: Oxford Row Area Sewers

The old Onion Creek sewer pipes through the Oxford Row area (Portabella Trail and Canterbury Trail) are projected to lack sufficient capacity to handle any of the modeled storm events. Flooding is projected along these sewers (including the Canterbury Trail branch) for up to 1-hour in duration during the 1-year storm. Flooding durations are extended and locations expanded (to include the entire sewer reach downstream to Preston Road) during larger storm events. Major and minor flood damage was reported in this area in 2017.

> *It seems likely that new drainage infrastructure will need to be provided for the Oxford Row area. Such a pipe / network could also help better serve the ESSS / Preston Road Storm Sewer interconnection and the adjacent areas that experienced flood damage in 2017. See Project #4 in Table 16 and Appendix J: Exhibit 2 for additional information.*

City: Crapo Street north of Bellows Street

The Crapo Street / Bellows Street / Flynn Lane sewers that connect to the Preston Road Storm Sewer at the Crapo Street / Bellows Street intersection are projected to have insufficient capacity to handle flows from any modeled storm event. Flooding is projected along all these sewers for durations of up to 4 hours during the 1-year storm with durations extending for larger storm events. Numerous instances of minor and major flood damage were reported along these sewers in 2017.

> *A proposed project to improve drainage in this area utilizes a new sewer through the Oxford Row area that extends north to Gaylord Street to provide additional flow capacity and flooding relief for this and adjacent areas. See Project #4 in Table 16 and Appendix J: Exhibit 2 for additional information.*

City: Crapo Street ROW south of Preston Road / Abbey Court Area Sewers

The Crapo Street ROW south of Preston Road is projected to have sufficient capacity for the 1-year storm. This includes the sewer along Abbey Court, the ROW west of Churchill Boulevard, McVey Street, and Johnson Street (to Broomfield Road). Most of these sewers do not have sufficient capacity to handle the 10-year storm (and larger events). The sewer in the ROW east of Brentwood Drive generally has capacity for the 10-year storm (but not for larger events).

Flooding is projected for durations of up to 4-hours between Abbey Ct and Broomfield Rd. Projected flooding locations extend in duration and expand to include locations along Abbey Ct, the ROW east of Brentwood Dr, and the Crapo St ROW during larger storm events. There were numerous instances of minor flood damage reported in these areas in 2017. There was major flood damage reported in 2017 upstream of the inter-connection with the ESSS that splits flow from the Appian Way area. The site's sewer / pond configuration is unable to handle flows during extreme events due to capacity issues in both this sewer and the ESSS.

4.3.6.5 Onion Creek Headwaters: Armstrong Drain and Mead Drain (ICDC; ICRC as indicated)

The Armstrong Drain along Isabella Road south of Preston Road is projected to generally have sufficient capacity for all modeled storm events except for two short segments south of Broomfield Road that lack capacity for the 10-year storm (and larger events) and one segment north of Broomfield Road that lacks capacity for the 25-year storm (and larger events). Flooding is projected for a duration of up to 4 hours during the 10-year storm south of Preston Road and for up to 30 minutes south of Broomfield Road. Projected flooding expands upstream from both locations and extends flooding durations during larger storm events.

The Mead Drain (along Chandler Road and west through apartments at Sterling Way) is projected to lack sufficient capacity to handle any modeled storm events. Flooding is projected along the length of the drain for durations of up to 4 hours during the 1-year storm with durations extending and locations expanding along the drain for larger storm events. This is mostly Township area so comparable 2017 flood damage data was not available. Peak flows in the drain may be lower than projected due significant on-site storage provided in the relatively modern adjacent developments. There are numerous areas of undeveloped, privately owned lands along the drain where additional storage could be provided if desired.

ICRC: The Broomfield Road Sewer west of Isabella Road

The Broomfield Road Storm Sewer west of Isabella Road is projected to generally lack capacity to handle the flows from any modeled storm events (the downstream two segments have capacity for the 1-year storm but not for larger events). Flooding is projected at the upstream (western) end of the sewer for a duration of up to 30 minutes during the 1-year storm with locations along most of the sewer flooding during the 10-year storm (with durations extending for larger storm events) except for the two most downstream manholes. No flooding was reported in this area in 2017 although data is only available for the north (City) side of the road. The sewer and most developments along this road are relatively modern and the peak flows into the sewer are potentially mitigated by the on-site detention at these locations.

ICRC: The Bluegrass Road Sewer west of Isabella Road

The Bluegrass Road Storm Sewer west of Isabella Road has sufficient capacity for the 1-year storm upstream (west) of Collegiate Way with the downstream segments lacking capacity for any modeled storm events. The next upstream segment is projected to lack capacity for the 10-year storm and 25-year storm with those further upstream having sufficient capacity for both. Segments west of Sweeney Road are projected to have capacity for all modeled storm events. The sewer and most developments along this road are modern and the peak flows into the sewer are likely mitigated by the on-site detention at these locations. Flooding is projected for durations of up to 4 hours during the 10-year storm (upstream and downstream of Collegiate Way). Projected flood durations are extended and flooding locations expanded upstream for larger storm events. This is Township area, so 2017 flood damage data was not available.

4.3.6.6 Onion Creek Headwaters: US-127 South of Bluegrass Rd ROW Additional Planning Area Outlet [South]

The culvert under US-127 serving the SCIT parcel in the southeast portion of the planning area is projected to lack sufficient capacity to handle flows from any modeled storm events. This area is undeveloped / agricultural land and excess surface water would tend to be relieved in the MDOT US-127 ditch and flow north to the Onion Creek. To accommodate increased flows from future development, the culvert would need to be upsized, significant detention / retention would need to be constructed, and/or excess flows would need to be reliably routed into the US-127 ditch.

4.3.6.7 Onion Creek Headwaters: Minor Basins (City / ICRC / MDOT as indicated)

Two small basins that flow to the open channel Onion Creek Drain west of US-127 are discussed below.

City: Industrial Park / Gover Parkway Sewer

The sewer serving Gover Parkway is projected to have sufficient capacity to handle the 1-year storm but is generally lacking sufficient capacity to serve the 10-year storm (and larger events). The peak flows area potentially lower than modeled due to the presence of numerous on-site detention facilities in the industrial park. Flooding along the road is projected for durations of up to 4 hours during the 10-year storm with locations expanding along the road and flooding durations extending for larger events. No flood damage was reported in this area during 2017.

ICRC / City: Broomfield Road east of Isabella Road / US-127 Ditch

The sewer serving Broomfield Road and the open channel between Broomfield Road and the US-127 ditch have sufficient capacity to handle all modeled storm events (except for the culvert at the downstream end of the open channel that lacks capacity for any modeled events and was also documented in the field to be significantly obstructed with sediment). Flooding is projected at the upstream end of the Broomfield Road sewer and at the open channel discharge culvert for durations of up to 4 hours during the 1-year storm with durations extending and locations expanding to between these two locations during larger storms.

4.3.7 Potter Creek Sub-Basin

The Potter-Brodie Drain in the headwaters area of the Potter Creek and largely utilizes open channels to route flow out of the planning area (south of US-127 BR / railroad).

4.3.7.1 Potter Creek / Potter-Brodie Drain Headwaters: Campus Area (CMU)

The sewer north of Three Leaves Drive intercepts the Cole Drain at Three Leaves Drive and splits some of the flow out of the Upton Drain Sub-Basin. The intercepting sewer is projected to lack sufficient capacity to handle the 1-year storm or larger storm events. Flooding is projected along its length for greater than 4 hours in duration during the 1-year storm with durations extending for larger storm events.

The outlet from this area (from west to east) under Mission Road is projected to have sufficient capacity for all modeled storm events. The downstream CMU culvert upstream of the ICRC ROW is projected to lack capacity for the 10-year storm event (and larger) but minor flooding in this area is not a problem (and should possibly be encouraged through design to reduce peak flows in the Potter-Brodie Drain).

> *It may be beneficial as to remove greater amounts of flow from the upstream areas of the Upton Drain. Low-lying areas on campus and downstream along the main Potter-Brodie Drain provide significant opportunities for storage without flood impacts that are not available along the developed Upton Drain corridor. The Potter-Brodie Drain open channel also has greater opportunity for channel / floodway expansion as it lacks the significant enclosed sections that limit the Upton Drain north of Broomfield Road. See Project #11 in Table 16 and Appendix J: Exhibit 2 for additional information.*

4.3.7.2 Potter Creek / Potter-Brodie Drain Headwaters: Branch No 3 Drain (ICDC)

The Potter-Brodie Branch No. 3 Drain is projected to have sufficient capacity to handle the 1-year storm. The segments upstream (north) of Commons Drive are projected to lack capacity to handle the 10-year storm (or larger events). The segments downstream of the Encore Drive pond connection are projected to have sufficient capacity for all modeled storm events while the segments along Commons Drive are generally projected to be able to handle the 25-year storm (but not larger events).

Flooding is projected along the upstream reaches of the drain for durations of up to 30 minutes during the 10-year storm with flooding projected to expand along the entire drain for extended durations during longer storm events. Actual flooding is likely alleviated by adjacent lowlands that provide in-line storage (and alternate overland flow paths to the east/south in the most upstream reaches into the Isabella Road south drainage area that was not included in the modeling). Some of these alternate and adjacent storage areas should be preserved to avoid drain problems that could come with future development.

4.3.7.3 Potter Creek / Potter-Brodie Drain Headwaters: Mission Road to Railroad Outfall (ICDC)

The culverts along the open channel drain are projected to have sufficient capacity to handle all modeled storm events except for the railroad crossing culvert that is projected to lack capacity to handle any of the modeled storm events. Portions of the main drain channel are projected to have insufficient capacity for the 1-year or larger events but the floodway width along the drain mitigates much of this concern. The channel can also be easily expanded by the ICDC to provide additional channel capacity.

The flow limiting nature of the railroad culvert may be useful in limiting flows downstream and maximizing flood storage along the upstream drain channel. However, if it is desired to retain this function while minimizing flooding of US-127 BR and the railroad, the flow-restricting mechanism should be on the north side of US-127 BR and incorporated into a berm (and possible additional high-level outlet – e.g. the Isabella Road south sewer) to keep high water levels under control. Regardless of the intent to store excess flow upstream of US-127 BR, the railroad culvert and downstream ICDC culvert are in less-than-ideal condition and upgrading them to prevent freeway / railroad overtopping during extreme flooding are recommended.

ICRC: Encore Drive and West Bluegrass / Shopping Mall

The Encore Dr and Walmart sewers are projected to have sufficient capacity to handle up to and including the 25-year storm while the Encore Dr sewer does not have sufficient capacity to handle the 100-year storm.

The west Bluegrass Road / shopping mall sewers are projected to have sufficient capacity for the 1-year storm but to generally lack capacity for the 10-year storm and larger events. The open channel downstream of the pond is projected to have capacity for all modeled storm events but the downstream parallel culverts have sufficient capacity only for the 1-year storm (and not for larger events). However, the culverts are in a location where flooding is not a concern and may serve to limit peak flows downstream in the Potter-Brodie Drain.

Flooding is projected along the Bluegrass Road sewers for durations of up to 30 minutes during the 25-year storm with durations extending during larger storm events.

MDOT: US-127 BR Drainage

The US-127 BR open channel drainage and downstream culvert have sufficient capacity to handle all modeled storm events. The sewers upstream of the channel, serving the Mission Rd / Bluegrass Rd inter-section, are projected to lack capacity to handle any modeled storm events. Flooding is projected near this inter-section for a duration of up to 30 minutes during the 1-year storm w/ durations extending during larger events.

4.4 Future Conditions Considerations

As new development and redevelopment and occurs throughout the planning area, stormwater management will be required to comply with the current Stormwater Ordinance, which specifies a discharge rate per acre at the 25-year storm. Zoning maps and future land use / development plans were utilized to identify areas of likely future development. These areas can be seen in Exhibit 2 in Appendix J.

The runoff characteristics from basins intersecting the parcels were modified to have imperviousness characteristics similar to existing developed areas. Refer to the discussion in Section 4.1.2.2 and 4.1.2.3 for additional detail regarding the hydrologic / hydraulic modeling parameters for the future condition scenarios. The maximum discharge was then capped at 0.15 cfs / acre to match ordinance requirements.

A hydraulic model scenario was simulated to compare the impact of compliance with this peak discharge rate for new developments and redeveloped areas to the projected hydraulic performance of the existing system assuming future developments do not comply with the Stormwater ordinance and compared to the projected hydraulic performance of the existing system (where onsite detention is achieved at certain locations).

In general, compliance with the Stormwater Ordinance site detention and peak discharge rates decreases the number of stormwater pipes with projected flowrates exceeding the pipe capacity and the number of structures experiencing surcharged conditions (i.e. HGL above the rim elevation) for ≥10 minutes. Figure 12 and Figure 13 on the following page show 25-year storm model results for the scenarios of current developments with detention, future developments without detention, and future developments with detention.

Figures C-5 and C-6 in Appendix C illustrate the over-capacity pipe modeling results at the 25-year storm considering detention/retention compliance with the Storm Water Management Ordinance compared with future development and redevelopment without compliance with the Ordinance.

4.5 Summary of Sump Pump Considerations

It is suspected that many sewer customers within the City who have basements discharge sump pump flows to the sanitary sewer. The City's Sewer Use Ordinance prohibits the connection of sump pumps (and other sources of clear water, e.g. roof drains, foundation drains, etc) to the sanitary sewer system because it takes up valuable wastewater capacity. As such, the City has implemented a sump pump disconnection program. Typical work in support of this program involves installing sump pump connection laterals from existing or new storm sewers in areas where utility or road work is occurring and installing new PVC storm sewers in parallel to existing storm sewers (or extending upstream from storm sewer manholes) to facilitate connections of existing sump pumps (those being removed from connection to the sanitary sewers) and new sump pumps.

A hydraulic modeling scenario was simulated to compare the system's current hydraulic performance at the 1-year, 24-hour design storm (which serves as the basis for the 1-5 Year Capital Improvement Plan – see Section 6.0) compared to a scenario where potential illicitly connected sump pumps are disconnected from the sanitary sewer and routed to the storm sewer. A sump pump only model was also run to determine a flow rate that can be expected in each pipe if all upstream sump pumps are rerouted into the storm sewer.

The following assumptions were used in the development of this modeling scenario:

- Each sump pump peak flow contributes 25 gpm;
- A sump pump was assumed to exist for each structure with a basement (based on information provided by the City) if that structure was built before 1985 (structures built after the 1985 sump pump ordinance language was adopted are assumed to have sump pump connected to the storm sewer and the existing model flows are considered to include this flow; and,
- Disconnections were not considered outside of the City as the Township has no disconnection program, has fewer houses w/ basements, and sewer plans do not indicate sump pump connections.

Although most information indicates that sump pumps for buildings on the CMU campus are connected to the storm sewer, some older buildings may have sumps connected to the sanitary sewer. For example, Rowe Hall, Foust Hall, and Anspach Hall drawings show mechanical room sumps connected to the sanitary sewer however the ability of these sumps to drain groundwater is not known. As such, potential future sump pump flows being routed to the storm sewers on campus is expected to be low (and thus not included in the model) and CMU should include such considerations when performing improvements to storm sewers on campus.

Sump pump flows were assigned based on the runoff catchments used in the model. The total number of estimated sump pumps to be connected to the storm sewer and the peak flow from these are included as fields in the catchment layer data. The estimated sump pump locations can be seen in Exhibit 2, Appendix J.

In general, the addition of these sump pump flows to the 1-year, 24-hr storm model add 53 pipe segments to exceed their capacity, of which 44 of these pipes would experience structure surcharging for >10 minutes.

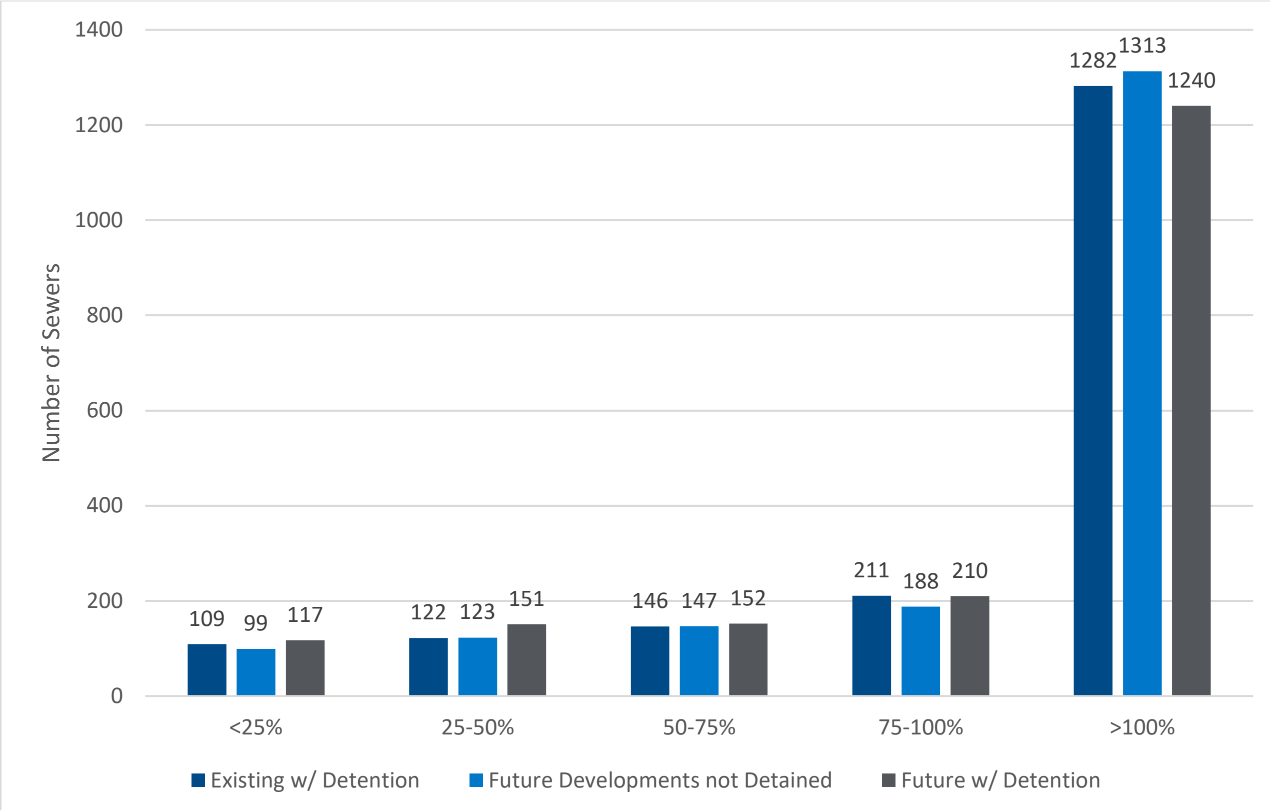

Figure 12. Number of Pipe Segments with Flow Rates at % of Capacity at the 25-year storm

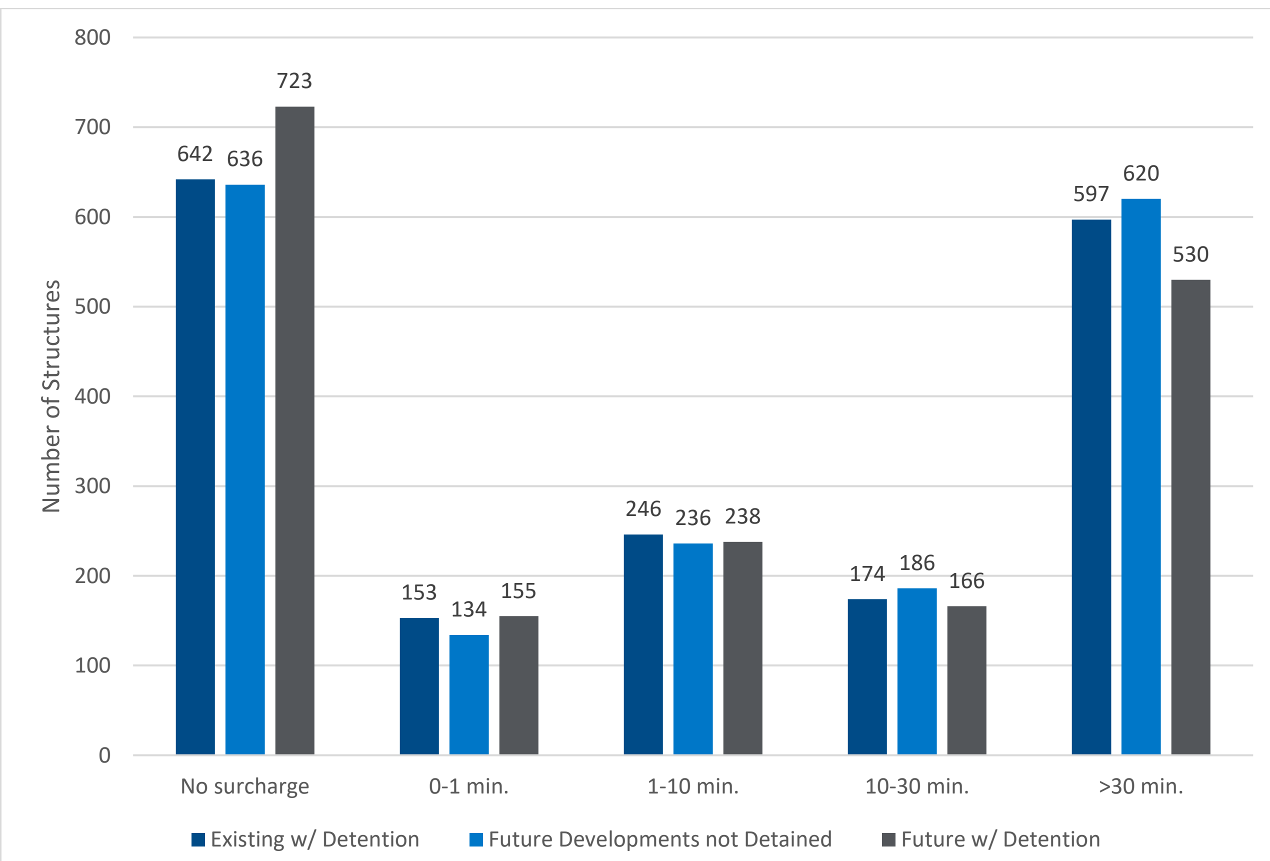

Figure 13. Number of Structures at each Surcharge Criteria (min.) at the 25-year storm

Figure C-7 in Appendix C is a map that illustrates the 1-year, 24-hr storm w/ sump pump modeling results.

4.6 Summary of Open Channel Performance

Most of the open channels that were modeled have sufficient main channel capacity to convey the flows generated by the storm events examined. Those where some concern exists include:

- The Hance Drain north of the 96-inch culvert crossing US-127 appears to be undersized for existing flows with capacity issues being exacerbated if the upstream storm network does not restrict flows;
- The Potter-Brodie Drain is marginally undersized for current storm network conditions but could be significantly undersized if upstream flow restrictions are eliminated from the storm network (this includes allowing significant flow to divert from the Cole Drain through the southern CMU ponds);
- Some portions of the Onion Creek open channel from Isabella Rd to its modeled outfall point on the east side of US-127 could have capacity problems if upstream flow restrictions are alleviated; and
- The flow channel from Broomfield Road to the US-127 Ditch is marginally undersized.

See Table 7 for open channel information.

Table 7. Modeled open channels.

Open Channel	Segment	Agency	Length (feet)	Slope	Manning's Values overbank channel	Method	Channel Capacity (cfs)	10-year Storm existing design	25-year Storm existing design	100-yr Storm existing
Hance Drain	North of 96-inch highway culvert	ICDC	470	0.00083	0.100 0.070	Plans	120	180 cfs 230 cfs	180 cfs 275 cfs	180 cfs
	South of 96-inch highway culvert	ICDC	660	0.00395	0.100 0.070	Plans	270	70 cfs 64 cfs	78 cfs 78 cfs	84 cfs
Quarterline Drain	Campground culvert to culvert	ICDC	320	0.00269	0.100 0.032	Survey	130	12 cfs 34 cfs	13 cfs 44 cfs	14 cfs
	Culvert to Camp-ground culvert	ICDC	170	0.00200	0.100 0.032	Estimated / Survey	34	12 cfs 33 cfs	12 cfs 43 cfs	13 cfs
	Airway Drive culvert to culvert	ICDC	220	0.00276	0.100 0.032	Survey	40	11 cfs 33 cfs	12 cfs 43 cfs	13 cfs
	Culvert to Airway Drive culvert	ICDC	200	0.00165	0.100 0.032	Estimated / Survey	30	11 cfs 33 cfs	12 cfs 43 cfs	13 cfs
	Culvert to culvert (adj. to church)	ICDC	100	-0.00610	0.100 0.032	Survey	58	10 cfs 33 cfs	10 cfs 42 cfs	11 cfs
Potter-Brodie Drain	Mission Road to culvert	ICDC	1,200	0.00085	0.100 0.070	Plans	23	44 cfs 175 cfs	46 cfs 245 cfs	47 cfs
	Culvert to Encore Drive pond	ICDC	1,000	0.00207	0.100 0.070	Plans	37	37 cfs 150 cfs	37 cfs 215 cfs	37 cfs
	Encore Drive pond to Encore Dr	ICDC	1,400	0.00032	0.100 0.070	Plans	14	25 cfs 135 cfs	22 cfs 165 cfs	19 cfs
	West of Encore Drive to tributary	ICDC	450	-0.00247	0.100 0.070	Plans	40	40 cfs 145 cfs	38 cfs 180 cfs	35 cfs
	East of Mission Road to tributary	ICDC	250	0.00502	0.100 0.032	Plans	125	46 cfs 71 cfs	47 cfs 89 cfs	57 cfs
	West of Mission Road to culvert	ICDC	300	0.00061	0.100 0.032	Plans	47	43 cfs 55 cfs	52 cfs 68 cfs	60 cfs
Potter-Brodie tributary	Pond to Potter-Brodie Drain	ICRC	650	0.00620	0.100 0.032	Estimated	185	115 cfs 111 cfs	135 cfs 135 cfs	155 cfs
Mission Road Channel	Old Mission Road to Potter-Brodie	MDOT	970	0.01227	0.100 0.032	Estimated	215	29 cfs 35 cfs	32 cfs 40 cfs	39 cfs
	Bluegrass Rd to Old Mission Road	MDOT	800	0.00200	0.100 0.035	Estimated	100	12 cfs 19 cfs	12 cfs 22 cfs	12 cfs
Upton Low-lands Creek	Highland Street to Upton Creek	State of Michigan	840	0.00186	0.100 0.032	Survey	1,240	31 cfs 37 cfs	37 cfs 48 cfs	46 cfs
	Forest Lane to Highland Street	State of Michigan	290	0.00162	0.100 0.032	Survey	60	14 cfs 17 cfs	16 cfs 22 cfs	20 cfs
Forest Lane Creek	South of Forest Lane	State of Michigan	1,650	0.00979	0.100 0.032	Survey	4,500	15 cfs 35 cfs	17 cfs 40 cfs	22 cfs
Upton Drain	Wendrow Way to Watson Road	ICDC	930	0.00296	0.100 0.032	Plans	1,200	335 cfs 735 cfs	365 cfs 900 cfs	405 cfs
	Watson Road to Highland Street	ICDC	1,000	0.00481	0.100 0.032	Plans	1,800	320 cfs 700 cfs	340 cfs 850 cfs	370 cfs

Open Channel	Segment	Agency	Length (feet)	Slope	Manning's Values overbank channel	Method	Channel Capacity (cfs)	10-year Storm existing design	25-year Storm existing design	100-yr Storm existing
	Highland Street to Preston Road	ICDC	620	0.00896	0.100 0.032	Survey	2,500	290 cfs 660 cfs	300 cfs 800 cfs	315 cfs
	South of Preston Road	ICDC	600	0.00216	0.100 0.032	Survey	940	260 cfs 600 cfs	270 cfs 720 cfs	280 cfs
	South of Broomfield Road	ICDC	600	0.00272	0.100 0.032	Survey	1,000	40 cfs 200 cfs	45 cfs 275 cfs	55 cfs
	Along West Campus Drive – N	ICDC	330	0.00357	0.100 0.032	Plans	275	14 cfs 67 cfs	19 cfs 100 cfs	20 cfs
	Along West Campus Drive - S	ICDC	470	0.00366	0.100 0.032	Plans	280	15 cfs 60 cfs	19 cfs 100 cfs	20 cfs
Grewes Drain	North of River Rd	MDOT	1,120	0.00899	0.100 0.032	Survey	530	100 cfs 190 cfs	100 cfs 220 cfs	105 cfs
	South of River Rd to private culvert	MDOT	180	0.00333	0.100 0.032	Survey	315	95 cfs 185 cfs	97 cfs 215 cfs	100 cfs
	North of US-127 to private culvert	MDOT	1,500	0.00130	0.100 0.032	Survey	120	140 cfs 185 cfs	160 cfs 215 cfs	170 cfs
US-127 Channel - N	Between US-127 Lanes	MDOT	180	0.00152	0.100 0.032	Survey	330	90 cfs 145 cfs	130 cfs 170 cfs	140 cfs
	Belmont Drive to US-127	MDOT	960	0.00173	0.100 0.032	Survey	265	45 cfs 100 cfs	42 cfs 120 cfs	47 cfs
	Isabella Road to Belmont Drive	MDOT	1,160	0.00118	0.100 0.032	Survey / Estimated	220	31 cfs 32 cfs	35 cfs 41 cfs	36 cfs
Isabella Rd Channel	National Drive to US-127 Channel	ICRC	460	0.00196	0.100 0.032	Plans	35	18 cfs 23 cfs	18 cfs 26 cfs	19 cfs
Onion Creek	Between highway lanes	ICDC	110	0.00815	0.100 0.032	Plans	560	510 cfs 550 cfs	600 cfs 630 cfs	600 cfs
	Overflow channel to highway	ICDC	260	0.00069	0.100 0.070	Plans	915	415 cfs 580 cfs	430 cfs 795 cfs	450 cfs
	Pond to overflow channel	ICDC	740	0.00042	0.100 0.070	Plans	710	410 cfs 670 cfs	420 cfs 840 cfs	430 cfs
	East of Isabella Road to pond	ICDC	1,430	0.00053	0.100 0.070	Plans	800	400 cfs 780 cfs	415 cfs 950 cfs	420 cfs
US-127 Channel - S	US-127 ditch to Onion Creek	MDOT	940	0.00612	0.100 0.032	Estimated	310	40 cfs 60 cfs	50 cfs 120 cfs	60 cfs
	Cross-parcel to ditch	State of Michigan	940	0.00612	0.100 0.032	Estimated	23	24 cfs 47 cfs	24 cfs 55 cfs	24 cfs
Chipp-A-Waters Swale	East of Henry St (extended)	City	400	0.01630	0.100 0.032	Survey	1,170	5 cfs 5 cfs	6 cfs 6 cfs	9 cfs

4.7 Summary of Pond Performance

Most of the ponds and underground storage structures appear to be sized sufficiently and to provide significant flow rate reductions during the 25-year storm. Those where some concern exists include:

- The Bluegrass Rd / shopping mall pond which does not appear to provide significant reduction in event peak flow;
- The Chipp-A-Waters pond/wetland does not provide significant flow reduction although it may not be designed to do so, given its proximity to the Chippewa River;
- The CMU SAC underground facility does not appear to provide significant reduction in peak flow;
- The Oxford Row pond does not provide significant reduction in event peak flow;
- The Mission Road and East Campus Drive pond does not appear to provide significant reduction in event peak flow; and
- The ESSS Surge Pond may not provide significant peak flow reduction for the current pipe network if upstream restrictions are eliminated but this will not likely be an issue if regional projects are implemented to address capacities concerns in the ESSS.

There are some minor flooding issues associated with some of the other ponds, as well as some concerns with peak flow reductions. Pond assessments can be seen in Table 8.

Table 8. Modeled ponds.

Pond	Agency	25-year Storm Existing Network Pond Performance	25-year Storm Unrestricted Network Pond Performance
Encore Drive	ICRC	Size Sufficient Significant Flow Reduction	Size Sufficient Significant Flow Reduction
Shopping Mall / Bluegrass Road	ICRC	Size Sufficient Peak Q Not Significantly Reduced	Size Sufficient Peak Q Not Significantly Reduced
CMU South / North of Railroad	CMU	Size Insufficient Significant Flow Reduction	Size Sufficient Significant Flow Reduction
Gover Parkway	City	Size Insufficient Significant Flow Reduction	Size Sufficient Significant Flow Reduction
Chipp-A-Waters	City	Size Sufficient No Significant Flow Reduction	Size Sufficient No Significant Flow Reduction
CMU Baseball South	CMU / ICDC	Size Sufficient Significant Flow Reduction	Size Sufficient Significant Flow Reduction
US-127 / Corporate Drive	City	Size Sufficient Significant Flow Reduction	Size Sufficient Significant Flow Reduction
Appian Way	City	Size Sufficient Significant Flow Reduction	Size Sufficient Some Flow Reduction
West Campus Drive	CMU	Size Sufficient, Minor Flooding Significant Flow Reduction	Size Sufficient Peak Q Not Significantly Reduced
Mt. Pleasant High School	City	Size Sufficient, Minor Flooding Significant Flow Reduction	Size Sufficient Significant Flow Reduction
CMU Baseball North	CMU / ICDC	Size Sufficient Significant Flow Reduction	Size Sufficient Significant Flow Reduction
CMU Softball Fields	CMU / ICDC	Size Sufficient, Minor Flooding Significant Flow Reduction	Size Sufficient Peak Q Not Significantly Reduced
Sterling Way / Mead Drain	ICDC / Private	Size Insufficient Significant Flow Reduction	Size Sufficient Significant Flow Reduction
CMU South / South of Railroad	CMU	Size Insufficient Significant Flow Reduction	Size Sufficient Significant Flow Reduction
US-127 at Pickard Road	MDOT	Size Insufficient, Medium Flooding Significant Flow Reduction	Size Sufficient, Minor Flooding Significant Flow Reduction
Orchard Drive – West	City	Size Insufficient, Medium Flooding Significant Flow Reduction	Size Sufficient Significant Flow Reduction
CMU SAC – Underground – W	CMU	Size Sufficient Peak Q Not Significantly Reduced	Size Sufficient Peak Q Not Significantly Reduced
Orchard Drive – East	City	Size Sufficient Significant Flow Reduction	Size Sufficient Some Flow Reduction
CMU Farm Pond	CMU	Size Insufficient Significant Flow Reduction	Size Sufficient No Significant Flow Reduction
CMU East Campus Drive – South	CMU	Size Sufficient Significant Flow Reduction	Size Sufficient Significant Flow Reduction
Sandstone Drive	ICRC	Size Sufficient Significant Flow Reduction	Size Sufficient Significant Flow Reduction
Oxford Row	City	Size Sufficient Peak Q Not Significantly Reduced	Size Sufficient Peak Q Not Significantly Reduced
Natural depression east of Mission at Industrial	City / Private	Size Sufficient Significant Flow Reduction	Size Sufficient Significant Flow Reduction
Mission and East Campus Drive	CMU / MDOT	Size Sufficient Peak Q Not Significantly Reduced	Size Sufficient Peak Q Not Significantly Reduced
CMU East Campus Drive – North	CMU	Size Sufficient Significant Flow Reduction	Size Sufficient Peak Q Not Significantly Reduced
Lot 8 Southeast Pond	CMU	Size Sufficient Significant Flow Reduction	Size Sufficient, Minor Flooding Significant Flow Reduction
Flagstone Pond	ICRC	Size Sufficient Significant Flow Reduction	Size Sufficient Significant Flow Reduction
ESSS Surge Pond / Industrial Drive	CMU	Size Sufficient Significant Flow Reduction	Size Sufficient Peak Q Not Significantly Reduced
Bellows / Douglas Underground Storage	CMU	Size Sufficient Significant Flow Reduction	Size Sufficient Significant Flow Reduction
Lot 8 Central Depressions	CMU	Size Sufficient, Minor Flooding Significant Flow Reduction	Size Sufficient Peak Q Not Significantly Reduced
Sports Fields Underground Storage	CMU	Size Sufficient Significant Flow Reduction	Size Sufficient Some Flow Reduction

5.0 Critical Assets (Business Risk Evaluation)

Business Risk Evaluation is the determination of criticality of each asset in the storm water collection system.

5.1 Approach to Critical Assets

Criticality is determined based on two factors: Likelihood of Failure (LoF) - also known as Probability of Failure – and Consequence of Failure (CoF).

Defining an asset's Business Risk allows for management of risk and aids in decision-making on where to allocate O&M and capital improvement funds. Consequence of Failure and Likelihood of Failure are described in greater detail below, along with the approach to define the Business Risk of an asset.

InfoAsset™ Planner (IAP), an ESRI® ArcGIS-based sewer asset management and capital planning software from Innovyze®, was used to compile, analyze, and assess Business Risk for each asset and to develop a Capital Improvement Plan for the storm water collection system assets.

5.1.1 Likelihood of Failure

Likelihood of Failure (LoF) is a measure of how likely an asset is to fail. Several categories have been chosen to quantify how likely an asset is to fail, including:

- Condition of the asset based on field assessments, including NASSCO-based pipe assessments (PACP)
- Remaining useful life with respect to an expected useful life, based on asset material and install year
- Service History - preventative maintenance procedures performed on the asset
- Operational status of the asset, including hydraulic capacity
- Proximity to flood damaged areas

For each asset, a LoF score is assigned in each category based on a scale of 1 (low) to 10 (high). Conditions leading to an increased LoF are scored high, while conditions leading to a decreased LoF are scored low.

Each LoF category is also given a weighting factor. Larger weighting factors are assigned to the categories that have the greatest effect on an asset's likelihood to fail, such as pipe condition (as observed during the CCTV work) and proximity to flood damage observed in June 2017.The total LoF score for an asset is determined by multiplying the score in each category by the weighting factor and summing the weighted category scores.

The LoF categories and weighting factors used for the storm water collection system components are shown in Table 9. This table uses a linear and exponential weighting to calculate weighting and also excludes from consideration any factors which cannot be determined for a given asset (e.g. if no condition data is available, that consideration is excluded from the final calculation).

The scoring formula for a general likelihood of failure (gLoF) is as follows:

$$gLoF = (2*C^{1}) + (4*R^{1.5}) + (0.5*S^{1}) + (4*O^{1.5}) + (4*D^{1.5})$$

The variables C and O are excluded from the gLoF calculation if they are missing, such that an asset with only R and D information would be scored as such:

$$gLoF = (4*R^{1.5}) + (4*O^{1.5}) + (4*D^{1.5})$$

The general maximum likelihood of failure (gmLoF) for a given asset is the maximum score based on the equation for that asset (with a value of 10 for each variable). For an asset with all 5 variables available, the gmLoF is 404.47. For the scenario where only R, O, and D information is available, the gmLoF is 379.47.

The LoF is then calculated for each asset as gLoF/gmLoF which normalizes the scores for the assets with different available information on a scale of 0 to 1 (although the minimum is not explicitly 0 as the minimum gLoF is calculated using a value of 1 for all variables – e.g. the minimum gLoF if all 5 variables are used is 14.5).

Table 9. Likelihood of failure (LoF) risk weighting.

Likelihood of Failure (LoF) Risk Weighting				
Category / Variable	**Criteria**	**Scoring Range**	**Linear Weight**	**Exponent Weight**
Condition (C) *excluded if never televised*	CCTV Assessments – PACP	1-10	2	1
Remaining Useful Life (R)	Age (assumed if missing) Material (assumed if missing)	1-10	4	1.5
Service History (S)	CCTV History	1-10	0.5	1
Operational Status (O) *excluded if not modeled*	Hydraulic Analysis – Projected Flow vs. Pipe Capacity	1-10	4	1.5
Flood Damage Proximity (D)	Proximity of asset to different levels of flood damage	1-10	4	1.5

The remaining useful life is based on the assets' material type and installation date. It is anticipated that 100% of PVC, concrete, ductile iron, and clay pipes will last at least 20 years. The survival probability decreases over time, with 80% of assets expected to last 50 years, and 20% expected to last 75 years for most pipe materials.

5.1.2 Consequence of Failure

Consequence of Failure (CoF) is a measure of the impact of failure of an asset within the collection system. Several categories have been developed to quantify the impact of failure for each asset, including:

- Location of asset (i.e., location with respect to commercial/downtown or residential/rural areas)
- Facilities served by asset (i.e., schools/hospitals, other critical facilities)
- Size and location of asset within the utility network (i.e., trunk line to outfall)

Each category is assigned a weighting factor. Larger weighting factors are assigned to the categories corresponding to more critical parts of the planning area (whether that be roads, sewers, buildings, etc.), where asset failure could cause especially adverse conditions. For the purposes of this plan, parts with large concentrations of people, or where an asset failure could cause widespread damage, safety hazards, or capital losses, are deemed highly critical. For example, portions of the storm system near outfalls are considered highly critical because an asset failure there could cause a backup in the remaining upstream portion of the sewer branch and lead to extensive surface flooding.

For each asset, a CoF score is assigned in each category, on a scale of 1 (low) to 10 (high), based on the magnitude of impact the asset's failure could have on the parts of the planning area in the category. The total CoF score is determined by multiplying the score in each category by the weighting factor and summing the weighted category scores.

The CoF categories and weighting factors used for the storm water collection system components are shown in Table 10.

Table 10. Consequence of failure risk weighting.

Consequence of Failure (CoF) Risk Weighting			
Category / Variable	**Descriptions**	**Scoring Range**	**Linear Weight**
Location of Asset (L)	Commercial / Downtown Proximity to Roadway, Railroad	1-10	0.44
Facilities Served by Asset (F)	School, Hospitals, or other Critical Facilities	1-10	0.13
Size, Location within Utility Network (N)	Trunkline/Interceptor Outfall Proximity	1-10	0.43

The scoring formula for a single asset is as follows:

$$CoF = (0.44*L) + (0.13*F) + (0.43*N)$$

The scoring is more straightforward as the location of all evaluated assets is known and the evaluating data (e.g. location of schools, downtown, etc.) covers the entire area of interest. As such there is no need to account for missing variables. The minimum CoF (where all variables are equal to 1) is 1 and the maximum CoF (where all variables are equal to 10) is 100.

5.1.3 Business Risk Score

The Business Risk Score of each asset is calculated using the following equation:

Business Risk = Likelihood of Failure Score (LoF) × Consequence of Failure Score (CoF)

This score ranges from the minimum LoF score (when a CoF is equal to 1) to a maximum of 100. The scores are then normalized across all storm water collection system assets (based on the minimum and maximum values of Business Risk for the entire set of assets) and assigned a Normalized Risk score, also on a scale of 1 to 100. The Business Risk or Normalized Risk score is an informative indicator for rehabilitation prioritization. The Business Risk and Normalized Risk scores are numerically close to each other, with the Normalized Risk score being slightly larger.

5.1.4 Risk Rating

The Risk Rating of each asset identifies its relative “criticality”, or level of attention needed for appropriate risk management. Risk Ratings range from *Negligible* to *Extreme Criticality* and are determined from a combination of assets’ likelihood to fail (i.e. LoF score) and potential consequences of failure (i.e. CoF score). Assets with high consequence and high likelihood of failure are vital to the storm sewer system operation and require some form of near-term renewal. Assets with high consequence, but low likelihood of failure, are vital to the storm water system operation and should be regularly monitored to mitigate potential failure. Assets with low consequence of failure and high likelihood of failure are likely to fail sooner but are less vital to the storm system operation. These assets should be preemptively replaced as the budget allows or as they fail. Assets with low consequence and low likelihood of failure are “run to failure” type assets which are not likely to fail soon.

Based on this rationale, the ranges each asset’s LoF and CoF scores fall into determine its Risk Rating. Conceptually, the relationship between LoF, CoF, and Risk Rating can be depicted by a 3x3 matrix, illustrated in Figure 14. As shown, each “box” of the matrix corresponds to a Risk Rating (color-coded to better identify significance), and each “box” is defined by a particular combination of LoF and CoF score ranges.

The Risk Rating of each asset determines the appropriate strategy for risk management, as listed in Table 11.

5.2 Business Risk Evaluation of Storm Water System

Using the strategy outlined above, a Business Risk Evaluation was performed on each asset for the planning area storm water system. A comprehensive map and list of the (Normalized) Business Risk Score and Risk Rating of each asset is included in Appendix D: Figure D-1 and Table D-1. Tables D-2 through D-6 present tables for each agency.

Figure 15 provides the Risk Rating for storm sewer pipes by number of pipe segments in the collection system. As shown, 40 pipe segments have an *Extreme* Risk Rating and are recommended to be replaced, upsized, fully lined, or point repaired in the next 1-2 years. In contrast, 1,931 segments have a *Negligible* Risk Rating.

Figure 16 provides the Risk Rating for storm pipes by total sewer length. As shown, most of the collection system has either low to negligible risk (approximately 82% of the linear feet), while 6% has high or extreme risk.

Consequence of Failure	Low	Medium	High
High	**Medium Risk**	**High Risk**	**Extreme Risk**
Medium	**Low Risk**	**Medium Risk**	**Extreme Risk**
Low	**Negligible Risk**	**Low Risk**	**High Risk**

Likelihood of Failure

Figure 14. Risk Rating Matrix (conceptual).

Table 11. Strategies for Asset Rehabilitation and Replacement.

Strategies for Asset Rehabilitation and Replacement	
Risk Rating	**Strategies for Asset Rehabilitation or Replacement**
Extreme	Inspect immediately and develop 1-2 year rehabilitation plan
High	Inspect immediately and develop short to medium term rehabilitation plan
Medium	Inspect immediately and develop long-term rehabilitation plan
Low	Develop short-term inspection strategy and develop long-term rehabilitation plan
Negligible	Develop long-term inspection strategy

Pipes

Consequence of Failure	Low	Medium	High
High	**330**	**30**	**16**
Medium	**740**	**56**	**24**
Low	**1,931**	**172**	**79**

Likelihood of Failure

Figure 15. Risk Rating Matrix for Planning Area Storm Sewer System by Number of Pipes

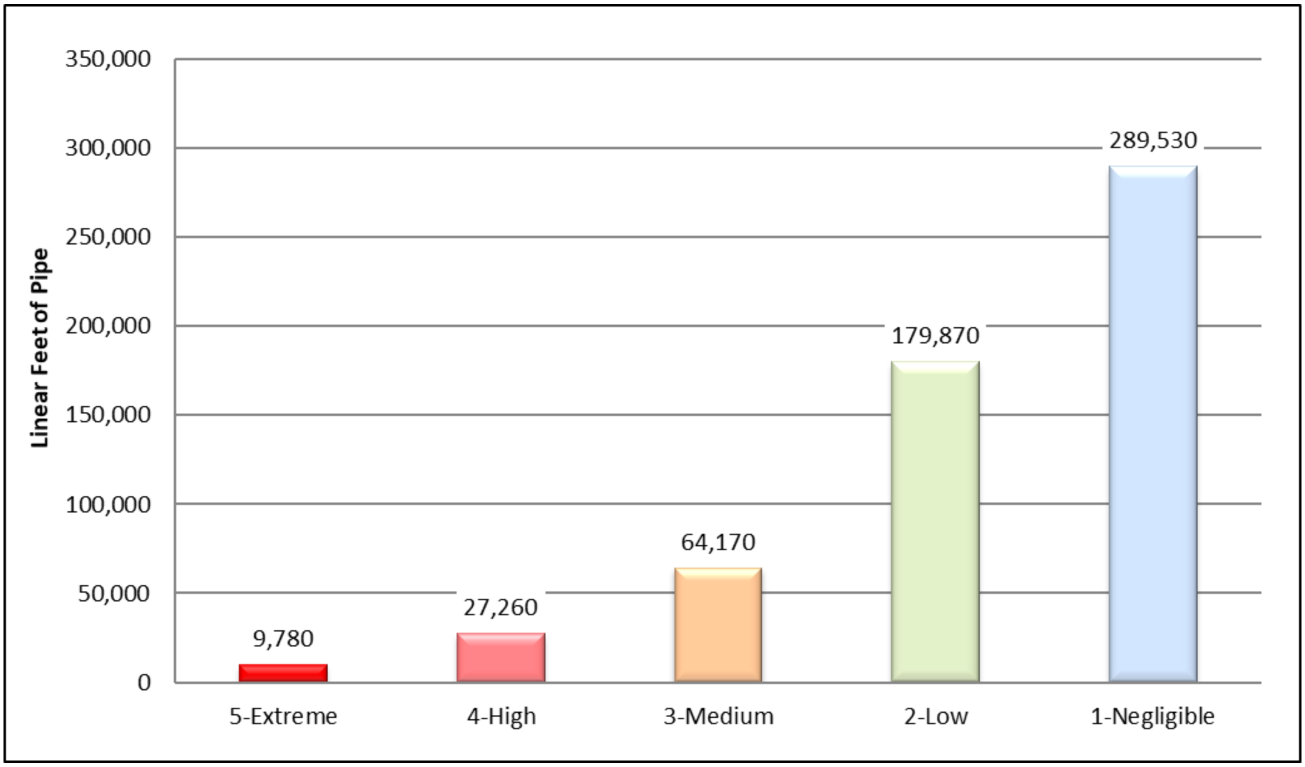

Figure 16. Risk Distribution by Length of Storm Sewer

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6.0 Capital Improvement Plans

Based on the Business Risk Evaluation, a Short-Term 1-5 Year and Long-Term 6-20 Year Capital Improvement Plan (CIP) was prepared to address the projected needs for each asset in the collection system.

6.1 Approach to Capital Improvement Planning

The development of the CIP incorporates the goals and objectives of the planning area stakeholders and individual agencies through a Level of Service (LOS) consideration. The LOS defines the way in which the planning area stakeholders want the utility to perform over the long term and includes any technical, managerial, or financial components the agencies consider while meeting all regulatory requirements. The LOS for the planning area storm water system is stated as follows:

To provide appropriate storm water collection, diversion, and conveyance at a minimum cost, consistent with applicable regulations. The LOS for the planning area storm water system includes the following directives:

- Provide adequate storm water collection system and conveyance capacity for all service areas
- Actively maintain storm water collection and conveyance system assets in reliable working condition
- Minimize flood damage caused by land use changes and infrastructure deficiencies
- Reduce storm water runoff rates / volumes from new developments and previously developed lands
- Preserve and enhance habitat and biological conditions of open channel conveyances
- Minimize non-point source pollutant discharges from land in the planning area and upgrade storm water infrastructure to minimize its transport to waters of the state

To create the CIP, each asset was assigned a strategy based on 1) the type and severity of defects identified in the condition assessment and 2) the HM&A results. IAP utilizes a “decision tree” rehabilitation model process to assign a rehabilitation strategy for each asset. Rehabilitation strategies include (see Figure 17):

- No Action;
- Pipe replacement (possibly with upsizing) either through direct-bury or trenchless construction; or
- Pipe rehabilitation (options include cleaning and CIPP lining, pipe bursting, or point repair).

Assets were grouped by strategy and assigned costs from a unit database. This database includes unit construction values in 2021 construction dollars based on a survey of recent projects in Michigan and includes engineering and administrative rates where applicable. The database is specific to asset size and material. Costs assume basic construction practices, including imported sand bedding and backfill, compaction, pavement removal, hauling, shoring, trench excavation and testing.

6.1.1 Limitation of CIP Approach and Real-World Considerations

It is important to understand that the asset management protocols used in assessing risk and assigning actions for the nearly 3400 evaluated pipes combine numerous disparate data sets and generate automated solutions for each pipe on an individual basis (as this is the only reasonable way to process this many data). In some cases, the proposed solutions may seem incomplete. For example, if a stretch of two 12-inch pipes is assessed by the model to be undersized, both will be recommended for upsizing. If the downstream pipe is a PVC pipe installed in 2012 and has no defects and the upstream pipe is a clay pipe from 1920 with documented structural deficiencies, the upstream pipe could end up being recommended for upsizing much sooner than the downstream pipe and if this were done as scheduled this location would have the odd reality of having a larger pipe flowing into a smaller pipe until the downstream pipe is replaced in the future.

The CIP as presented is not a completely prescriptive plan of action for every single asset but is a prioritization mechanism that requires implementing authorities to provide the finishing touches for various projects that considers alternatives, the effects of changes to pipes on flows in downstream pipes, external utility and road work schedules, budgeting realities, and other long-term planning considerations.

Where pipe upsizing is recommended, the planning cost estimates assume the new pipe is the next larger standard pipe size to provide a baseline. Appendix D: Table D-7 lists each pipe where capacity concerns exist for any modeled scenario and includes the recommended diameter for each modeled rainfall event / runoff scenario to adequately serve the modeled flows (to assist the various agencies in sizing according to their design standards. Additional estimated flows from sump pump disconnection programs are also presented. This information is also available in the storm sewer pipes / links database.

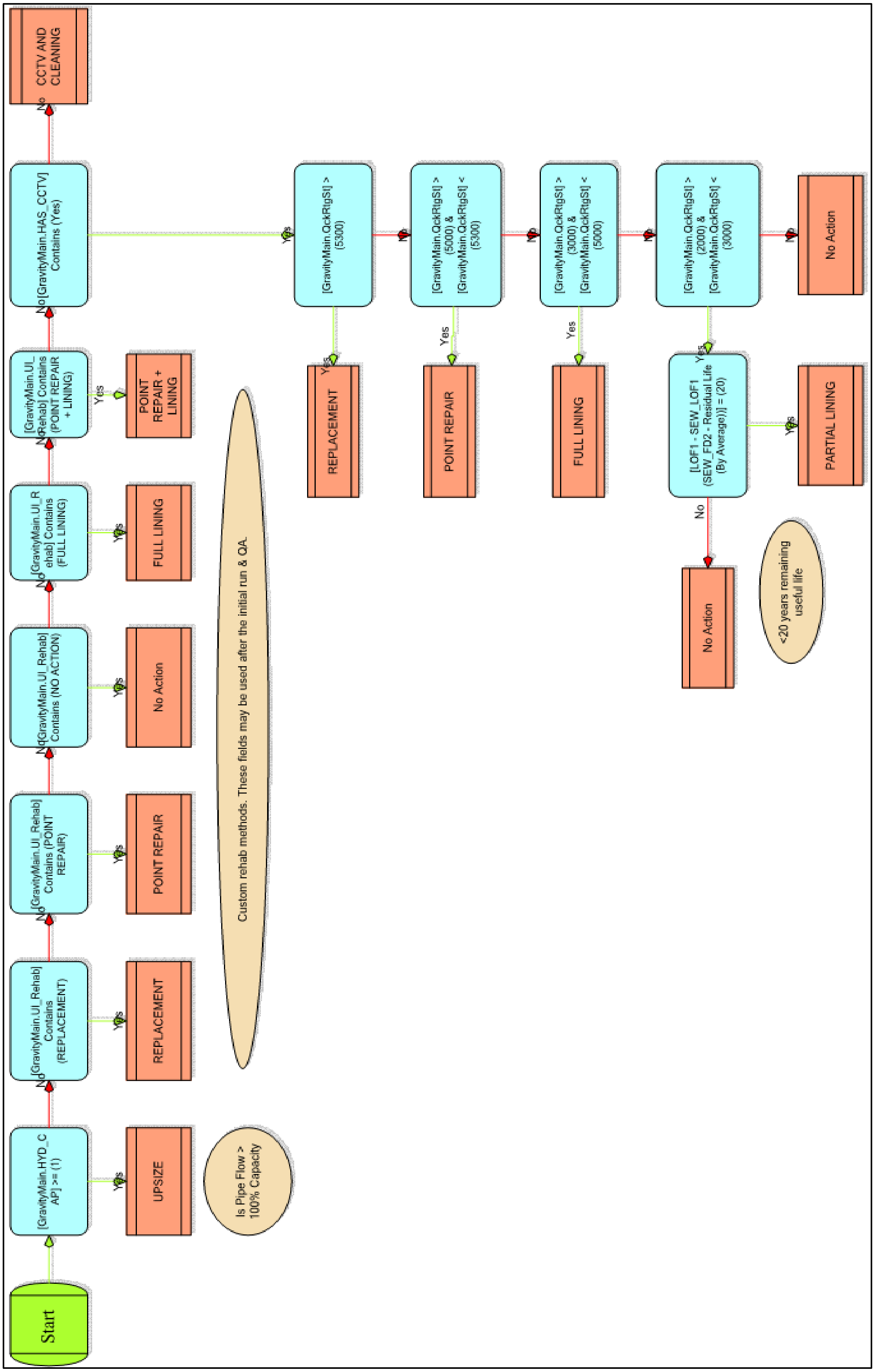


Figure 17. Rehabilitation decision-tree.

6.2 Recommendations for Addressing Assets Over Time

The development of CIP recommendations includes identifying and prioritizing asset rehabilitation strategies and grouping those assets into recommended rehabilitation projects. A table listing each asset targeted for rehabilitation (those with risk of 'Medium' or higher) is presented as Table E-1 of Appendix E and includes a proposed strategy and cost for each asset.

Individual CIP rehabilitation actions that may be impacted by regional projects (see Section 11.0) are denoted with the ID field presented as **red, bold, underlined** text. Those IDs flagged include pipes that are likely to be directly impacted and those downstream that may see changed flow rates. The cross-reference to specific projects can be found in the digital data.

6.2.1 Assets Recommended in the Short-Term 1-2 Year CIP

Assets in this category are those that are at extreme risk. These assets should be considered for immediate attention in the 1-2 Year CIP and include replacement, lining, or point repairs for pipes. The short term 1-2 Year CIP including the asset strategy and cost are identified in Table F-1 and in Figure F-1 of Appendix F.

6.2.2 Assets Recommended in the Short-Term 3-5 Year CIP

Assets in this category are those that are at extreme or high risk. These assets should be considered in the 3-5 Year CIP and include replacement, lining, or point repairs for pipes. The short term 3-5 Year CIP, including the asset strategy and cost are identified in Table F-2 and graphically in Figure F-2 of Appendix F.

6.2.3 Assets Recommended in the Long-Term 6-20 Year CIP

Assets in this category are at lower risk and are of a condition or age that will require attention in the future, but specific timelines cannot be accurately determined based on available information. Table F-3 of Appendix F presents a list of these assets, ranked by grading and risk score, that includes the recommended action strategy and cost based on 2021 prices. The long-term 6-20 Year CIP is shown graphically in Figure F-3.

6.3 Overall Storm Water System Capital Improvement Plan

The 1-5 Year CIP was prepared based on the Business Risk Evaluation and the planning area agencies' desired Level of Service. The evaluation of collection system assets also allows for identification of projects that will likely be needed in the extended 6-20 year timeframe.

6.3.1 Overall 1-5 Year Storm Water CIP

The 1-5 Year CIP was developed by assigning each project to a CIP year (1-5) based on several factors:

- Risk Rating;
- Hydraulic modeling and analysis results;
- Asset rehabilitation grouping (i.e. the type of repair/construction recommended);
- Logical construction project groupings based on geographic proximity; and,
- Coordination with other planned projects to achieve economies of scale or limiting disruption (an example is a street reconstruction project where identified utility recommendations can be included).

An asset-by-asset breakdown of the proposed rehabilitation component of the 1-5 Year CIP is included in Table F-4, located in Appendix F. A summary of this 1-5 Year CIP is included in Table 12. Note that all of the 1-5 Year CIP rehabilitation actions are assigned to City-owned assets by virtue of Risk Rating values.

Table 12. 1-5 Year Capital Improvement Plan: Rehabilitation.

5-Year Capital Improvement Cost: Rehabilitation						
Agency & Rehabilitation Action	Total Cost (2021 Dollars)	2021	2022	2023	2024	2025
City	***$ 7,178,360***	***$ 844,520***	***$ 859,060***	***$ 2,513,710***	***$ 1,764,580***	***$ 1,705,770***
Pipe Replacement	$ 2,370,320	$ 324,910	$ 441,600	$ 967,030	$ 712,740	$ 59,530
Pipe Upsize	$ 3,812,770	$ 323,710	$ 353,500	$ 1,376,210	$ 894,940	$ 1,158,880
Pipe Point Repair	$ 439,280	$ 88,140	$ 61,490	$ 89,260	$ 126,430	$ 103,100
Pipe Full Lining	$ 547,350	$ 107,760	$ 2,470	$ 81,210	$ 30,470	$ 374,530
Pipe Partial Lining	$ 8,640	$ -	$ -	$ -	$ -	$ 9,730
TOTAL	**$ 7,178,360**	**$ 844,520**	**$ 859,060**	**$ 2,513,710**	**$ 1,764,580**	**$ 1,705,770**

6.3.2 Overall 6-20 Year Storm Water CIP

Rehabilitation projects were assigned to the 6-20 Year CIP based on the same factors used to assign 1-5 Year CIP projects to a particular year. For the purposes of this plan, these projects were divided into 6-10 year, 11-15 year, and 16-20 year timeframes, based only on project cost, such that each timeframe has relatively even costs. This was done to aid the planning area agencies in developing a schedule to complete recommended 6-20 Year rehabilitation items.

6.3.3 CIP Caveats and Implementation Approach

It should be noted that a handful of projects for extreme and high-risk assets were included in the 6-20 Year CIP based on other factors than Risk Rating. Specifically, these projects are for pipes recommended for upsizing but predicted (in the HM&A) to receive peak flows reaching 75-100% hydraulic capacity during the 1-year storm. In contrast, pipes recommended for upsizing in the 1-5 Year CIP are predicted to receive peak flows *exceeding* hydraulic capacity and are therefore deemed higher priority.

Design of upgrades should include a detailed survey of the potential improvement areas, as the model does not necessarily extend upstream to the smaller upstream pipes and the CIP and model specifically exclude dedicated catch basin leads from analysis.

An assessment of the manholes in areas to be upgraded should also be conducted to determine if any additional structural improvements are needed to support any conveyance upgrades or to address structural deficiencies in the areas of planned upgrades (since data on the condition of manholes and other structures was not available for this project, nor were assessments of these structures part of the scope). Any planned work on the structures in these areas will need to be costed and this cost should be considered in addition to the costs estimated in this plan.

Where possible, storm system upgrades should be coordinated with roadway and utility improvements so that the work is done as efficiently and economically as possible.

6.4 Storm Water System Capital Improvement Plans by Agency

An agency-specific CIP has been developed for each agency that owns a significant number of assets in the planning area. These can be found in Appendix G and are as follows:

- City of Mt Pleasant: Table G-1
- Isabella County Road Commission: Table G-2
- Isabella County Drain Commissioner: Table G-3
- Michigan Department of Transportation: Table G-4
- Central Michigan University: [no rehabilitation work recommended in the 20-year planning period]*

*Additional considerations regarding CMU assets are discussed in Section 6.4.1.

6.4.1 CMU CIP Considerations

This master plan evaluation was done on a regional basis, recognizing that resources are finite; therefore, capital improvements must be prioritized based on the risk analysis described in Section 5. In general, assets owned by CMU, serving the CMU campus have a lower risk rating in the context of the overall planning area than many of the assets owned by other jurisdictions. Refer to Appendix D for the complete list of Asset Business Risk and recommended rehabilitation method / actions.

It should be noted that although actions recommended for CMU they are in the long-term (20+ year horizon) on a regional context, based on overall risk scoring, CMU and other stakeholders should adjust the recommended schedules as appropriate to best handle local flooding issues and to coincide with other projects, as needed. Specifically, it should be noted that the hydraulic modeling analysis indicates that several pipe segments on campus are operating near or above capacity during the 1-year storm. These pipes are recommended for upsizing beyond the 20-year planning period; based on overall risk scoring. CMU may wish to address these issues sooner.

7.0 Operations and Maintenance

Regular O&M is essential in the management of a storm water collection system.

7.1 Approach to Operations and Maintenance

The collection system is subject to a variety of operational problems and can suffer from clogging, scour, corrosion, and collapse. These adverse effects can lead to deterioration and reduction of asset useful life.

7.1.1 Physical Inspection

Physical inspection of assets to help quantify problems is vital to an O&M program. Without it, a systematic maintenance program cannot be implemented. Elements of a physical inspection program include visual and equipment-based techniques that use established industry methods of asset evaluation. Physical inspections should be performed on a regularly scheduled basis as a part of a preventive maintenance program.

7.1.2 Cleaning

Stoppages in sewers usually are caused either by structural defects or by an accumulation of material in the pipe. Accumulated material can include sediment, garbage, or other materials. Certain structural defects, such as protruding taps, may catch debris, which then causes a further buildup of solids that will eventually block the sewer. Root intrusion through structural defects is a major contributor to blockages. Repair or elimination of any defects that contribute to a buildup of material in the pipe should be evaluated as part of a rehabilitation program since the defects will always be a maintenance problem. Good records and planned analysis of the record data will aid in the development of a cost-effective preventative maintenance program.

An O&M Plan with recommendations was prepared for the storm water assets based on the Business Risk Evaluation. As previously described, the IAP software utilizes a “decision tree” rehabilitation model where assets were further evaluated and prioritized for possible preventative maintenance, including cleaning and inspection. If no preventative maintenance was needed, the asset’s O&M Plan was classified as “No Action Needed.” The proposed O&M strategy and cost for each asset is presented in Table H-1 of Appendix H.

Assets in need of O&M were grouped by strategy and assigned costs from a unit database. This database includes unit construction values in 2021 construction dollars based on a survey of recent projects in Michigan and includes engineering and administrative rates where applicable. The database is specific to pipe and manhole, size, and material. Assets were categorized and prioritized by year, based on Risk Rating & Criticality Score, to develop the O&M Plan.

7.2 O&M Recommendations for Addressing Assets Over Time

The specific O&M recommendations are presented in this section.

7.2.1 Pipeline CCTV Recommended in the Short-Term 1-5 Year O&M Plan

A preventative maintenance program to systematically clean and CCTV-inspect pipelines to NASSCO-certified standards is critical for a sound storm water system. The process of cleaning and CCTV inspection of pipelines either with equipment owned by the community or contracted is a relatively inexpensive maintenance effort when compared to rehabilitation efforts. For this reason, it is recommended that at a minimum, all pipelines be cleaned and televised every five years, or that 20% of the system be cleaned and televised annually. Available budget will dictate the frequency or size of yearly projects.

By performing cleaning and CCTV inspection on all remaining pipeline assets not previously inspected, 100% of the collection system will be inspected in the next 5 years, thereby providing full “baseline” assessment data for the entire storm water collection system. Beyond the initial 5-year period, the planning area agencies encouraged to develop an ongoing preventative maintenance program for cleaning and CCTV inspection meeting NASSCO-certified standards. Pipelines should be cleaned and CCTV-inspected on a periodic basis to better ensure that proper operating conditions exist, and to plan proactive maintenance where needed.

Approximately 36 miles of the City storm water collection system was cleaned and CCTV-inspected in the years preceding the development of this master plan. It is recommended that the various agencies clean and CCTV-inspect an additional 51 miles over the next five years at an estimated cost of $1.1 million.

Detailed summary tables listing remaining pipelines that are recommended to be cleaned and CCTV-inspected in the short term are included in Table H-2 of Appendix H. The summary tables list each asset by Risk Rating to assist in determining a year-by-year preventative maintenance pipeline cleaning and CCTV inspection program and estimated inspection costs.

7.2.2 Structure Cleaning & Assessment Recommended in the 1-5 Year O&M Plan

It is recommended to conduct NASSCO MACP inspections of structures in concert with all future televising efforts so that both the conveyances and structures within a given area are on the same assessment schedule and that when upgrades are planned, the condition of both the conveyances and structures can be understood without the need for in-depth pre-planning assessments.

7.3 Storm Water System Operations and Maintenance Plan

Storm water assets are designed to serve for a specific period. O&M is necessary to optimize this 'useful life'.

7.3.1 5-Year Storm Water System O&M Plan

O&M recommendations (pipeline cleaning/CCTV inspection & manhole cleaning/inspection) have a relatively low cost and are therefore not included in the 5-year CIP. They are important elements for ongoing operation of the system. list of each asset identified for O&M action is provided in Table H-2 of Appendix H.

Table 13 summarizes the recommended preventative maintenance inspections to be considered in the short term (1-5 years) with associated costs over the 5-year period. Refer to Appendix I for details by agency.

Table 13. 5-year Capital Improvement Plan: Maintenance.

5-Year Capital Improvement Plan: Maintenance						
Agency & Maintenance Action	Total Cost (2021 Dollars)	2021	2022	2023	2024	2025
City	***$ 322,830***	***$ 75,020***	***$ 18,710***	***$ 100,760***	***$ 76,000***	***$ 73,300***
CCTV and Cleaning	$ 322,830	$ 75,020	$ 18,710	$ 100,760	$ 76,000	$ 73,300
CMU	***$ 276,660***	***$ 10,320***	***$ 18,770***	***$ 48,060***	***$ 81,360***	***$ 144,470***
CCTV and Cleaning	$ 276,660	$ 10,320	$ 18,770	$ 48,060	$ 81,360	$ 144,470
ICDC	***$ 292,360***	***$ 33,740***	***$ 129,160***	***$ 61,780***	***$ 60,010***	***$ 22,590***
CCTV and Cleaning	$ 292,360	$ 33,740	$ 129,160	$ 61,780	$ 60,010	$ 22,590
ICRC	***$ 113,940***	***$ 28,750***	***$ 52,750***	***$ 14,640***	***$ 15,870***	***$ 6,360***
CCTV and Cleaning	$ 113,940	$ 28,750	$ 52,750	$ 14,640	$ 15,870	$ 6,360
MDOT	***$ 93,340***	***$ 73,200***	***$ 8,690***	***$ 7,070***	***$ 5,510***	***$ -***
CCTV and Cleaning	$ 93,340	$ 73,200	$ 8,690	$ 7,070	$ 5,510	$ -
TOTAL - CCTV and Cleaning	***$ 1,099,130***	***$ 221,030***	***$ 228,080***	***$ 232,310***	***$ 238,750***	***$ 246,720***
TOTAL	**$ 1,099,130**	**$ 221,030**	**$ 228,080**	**$ 232,310**	**$ 238,750**	**$ 246,720**

The O&M plan should also include regular observations of storm water inlet and catch basin conditions, especially in areas that have been reported to have surface flooding. A plan of regular street-sweeping, inlet-raking, and catch basin sump emptying should be instituted to provide for the optimal storm water conveyance and minimize the discharge of pollutants through the system into receiving waters.

These actions will also help improve the assessment of the cause of street flooding when it is reported as if the inlets are properly maintained then the cause of surface flooding is much more likely to be an issue with conveyance capacity within the storm sewer system.

7.4 Operations and Maintenance Plans by Agency

An agency-specific O&M plans can be found in Appendix I and are as follows:

- City of Mt Pleasant: Table I-1
- Isabella County Road Commission: Table I-2
- Isabella County Drain Commissioner: Table I-3
- Michigan Department of Transportation: Table I-4
- Central Michigan University: Table I-5

8.0 ENVIRONMENTAL CONSIDERATIONS

While not the major thrust of this planning effort, considerations such as surface and ground-water quality, terrestrial and aquatic habitat conditions, and the health of biological populations are important to not only the agencies in the area but also to the people as these conditions have a direct impact on the quality of life for the residents of the area.

8.1 ENVIRONMENTAL STRESSORS

Stressors are natural or man-induced things or conditions that are the reason *why* something impacts the natural environment. Stressors generally fall into four major non-exclusive classes: chemical, physical, biological, and radiological. A list of the commonly evaluated stressors in these classes includes:

- Chemical: nutrients, inorganic compounds, heavy metals, organic compounds, oxygen-consuming substances, pH, and dissolved solids;
- Physical: suspended solids / sediment, trash / debris, temperature, hydrologic / hydraulic characteristics, and natural feature / habitat degradation;
- Biological: invasive species and pathogens; and,
- Radiological: radiation.

Stressors may be considered individually against established water quality standards (or other limits) or as an aggregate measure. An example of one such index was created and designed by the National Sanitation Foundation (NSF) in 1970 called the Water Quality Index (WQI). The purpose of the index is to measure water quality changes in a particular river reach over time and provide a means to compare results with different reaches of the same river or other rivers.

8.2 CURRENT CONDITIONS

In the planning area, monitoring and assessment activities by SCIT have held that as of 2015, in the planning area, the Chippewa River does not fully support the 'designated uses' of aquatic life, human health, and recreation and that the Onion Creek is similarly impaired, although assessed downstream of the planning area.

8.3 MONITORING AND DATA AGGREGATING PROGRAMS

There are a variety of environmental monitoring programs that can be leveraged for data to identify stressors impacting the natural environment and the extent to which the stressors are impacting and/or impairing environmental conditions. This list is not exhaustive and many other organizations ranging from local conservation groups to international institutes may have data that is useful to assessing environmental health.

8.3.1.1 The Central Michigan District Health Department (CMDHD)

The CMDHD operates an Environmental Health Services program that administers programs related to drinking water and wells, on-site sewage disposal (residential and commercial), land use and division, well sampling and testing, and swimming beach water quality monitoring, among other programs.

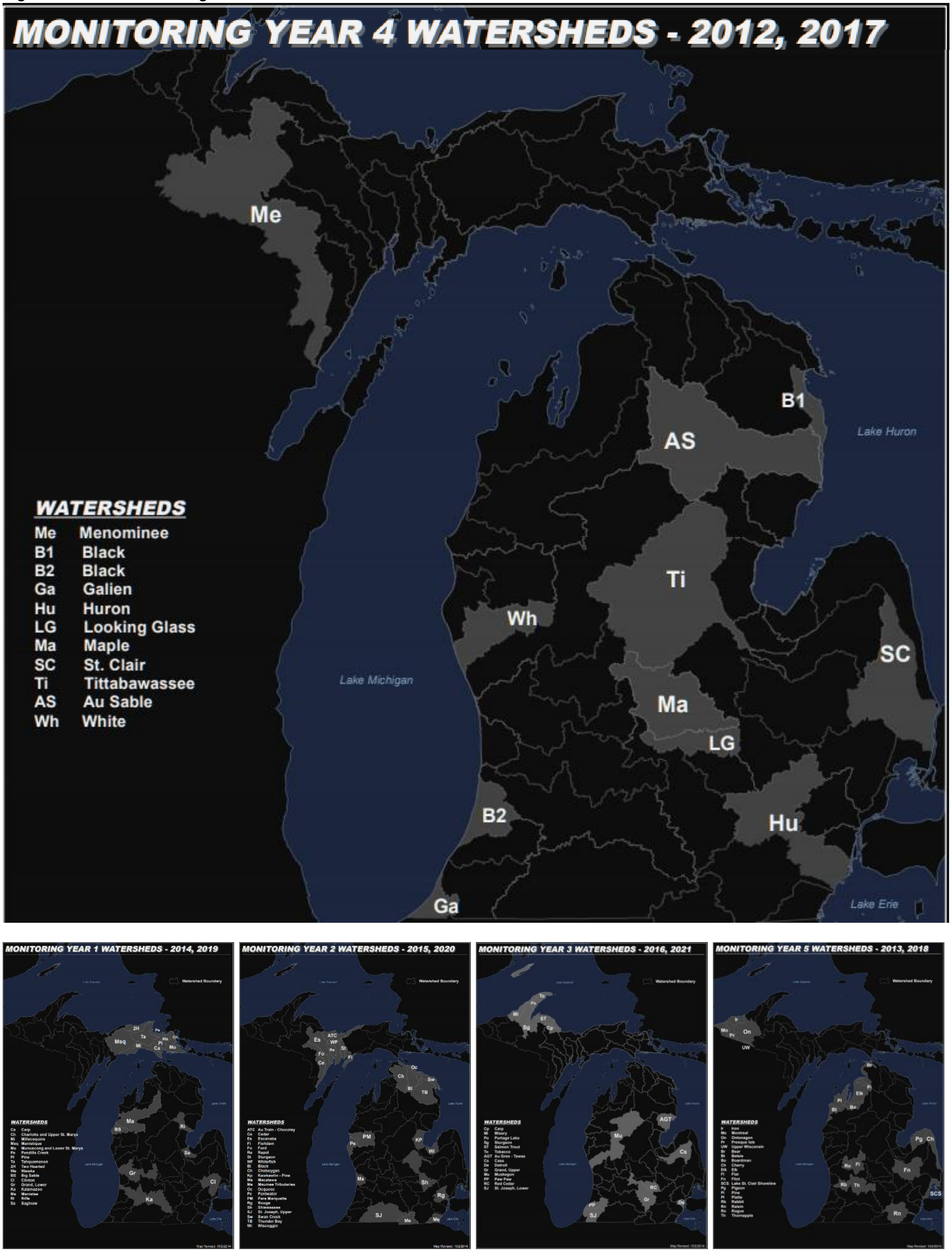
8.3.1.2 The Saginaw Bay Cooperative Invasive Species Management Area (CISMA)

The Saginaw Bay CISMA exists to create and support collaborative invasive species management among federal and state agencies, municipalities, tribes, nonprofits, community organizations and private landowners within 15 counties in the Saginaw Bay Watershed. The organization takes reports and maintains data on invasive species found within the entire Saginaw Bay Watershed.

8.3.1.3 Michigan Department of Environment, Great Lakes, and Energy (EGLE)

EGLE routinely collects data that include water quality, macroinvertebrate sampling, and fish studies. The environmental monitoring program incorporates four main goals, including assessment of current conditions of waters of the state, identifying whether water quality standards are being met, measuring water quality trends, evaluating water quality protection and prevention program effectiveness, and recognize emerging water quality problems. The data collection occurs on a watershed-based five-year cycle (see Figure 18).

Figure 18. EGLE Monitoring Watersheds.



The five-year rotating basin watershed monitoring activities include fish contamination studies, macroinvertebrate evaluations, water and sediment chemistry studies, and wildlife contamination studies. Information from the studies is summarized and available to the public.

8.3.1.4 Michigan Department of Natural Resources (MDNR)

The Michigan Department of Natural Resources (MDNR) routinely collects data similar to EGLE's but with a greater focus on macroinvertebrates and especially fish studies (including habitat, diversity of fish, abundance of fish, contaminants in fish tissue, and taste and odor tests). A wildlife action plan was generated for Michigan to identify and prioritize conservation needs of native species and habitats. The plan gives a greater emphasis on species of greatest conservation needs. Other monitoring and management programs include the fish consumption advisory study, fish identification programs, and amphibian (frog and toad) surveys.

8.3.1.5 United States Geological Survey (USGS)

The United States Geological Survey (USGS) is involved in obtaining stream-flow data and some water quality data. The USGS maintains the National Water Information System that houses and organizes this data for easy access.

8.3.1.6 Environmental Protection Agency (USEPA)

In some cases, the U.S. Environmental Protection Agency (EPA) may be involved in obtaining water quality, biological, and physical data. This data may be documented in specific reports and stored in the agency's STORET (STOrage and RETrieval) database. This database also contains data provided by other sources such as state environmental agencies, other federal agencies, universities, private citizens, and many others. The database may be accessed at http://epa.gov/storet/.

The purpose of the Clean Water Act Section 106 is to monitor water quality while preventing and reducing pollution. The Program has sponsored developments including water quality assessment, planning, monitoring, water protection, watershed-based planning, and data management.

8.3.1.7 Saginaw Chippewa Indian Tribe (SCIT) Water Program

The SCIT Water Program monitors and assesses the health of Tribal waters including rivers, streams and lakes. The Monitoring Team samples every summer and uses a rotational basin approach with fixed stations (which remain the same each year) and rotating stations (which change each year). Fixed stations are on the Chippewa River and its tributaries. The SCIT Water Program receives funding from the Environmental Protection Agency under Clean Water Act Section 106 to monitor Tribal waters.

The Program has sponsored developments including water quality assessment, planning, monitoring, water protection, watershed-based planning, and data management. The SCIT's Water Quality Program has been collecting data from reservation waters since 2004. The data is used to identify issues such as pathogens, excess nutrients, and changes in the water quality throughout Tribal Waters. Once issues are identified the Tribe and partnering agencies can work together to fix the problems identified.

8.4 Other Protocols

The protocols listed below are not currently implemented on a regular basis but should be considered as methods to obtain appropriate data for conducting assessments.

8.4.1.1 Road-Stream Crossing Surveys

The stream crossing watershed survey is an approach used to collect information about the quality of a stream. A standard data collection form is used to ensure uniformity throughout the watersheds. The physical habitat of the site including water characteristics, stream characteristics, plant life, foam and trash presence, substrate type, stream morphology, land use, and corridor description are recorded. Also potential sources of pollution upstream and downstream of the site are identified if apparent.

EGLE maintains a statewide database and standard protocol set that can easily be implemented.

8.4.1.2 Stream Assessment

During this effort the participants walk reaches of a stream looking for and recording issues potentially impacting the waterbody such as outfalls, bank erosion, buffer, channel modifications, trash and debris, and impacts from utilities. Issues such as substrate, water clarity, plant and wildlife, shade cover can also be noted. Some data collected during the assessments overlap with data collected using other methods. Stream corridor assessments may be conducted as part of a canoe trip on waterways large enough to support canoeing.

This method is similar to the Road-Stream Crossing Surveys but is conducted on entire stretches of stream as opposed to discrete sites where streams and roads cross. Example methodologies include that which is developed by the Center for Watershed Protection (CWP) and outlined in 'Unified Stream Assessments: A User's Manual' and the method developed by the U.S. EPA.

8.4.1.3 Unified Subwatershed and Site Reconnaissance

The Unified Subwatershed and Site Reconnaissance (USSR) survey, developed by the CWP (2005), involves conducting quick but thorough characterizations of upland areas. The goal of the USSR is to identify major source types and areas that potentially contribute pollutants to waterbodies. The four major components of this survey include: neighborhood source assessments, hotspot site investigations, pervious area assessments, and street and storm drains assessments.

8.4.1.4 Hot Spot Testing

Parts of the watershed encompass land once and currently used for industrial and commercial purposes. Prior to government regulation, many pollutants were released without realizing their potential impacts on public health and safety and water quality in aquatic environments. In addition to this historical pollution, various hot spots of pollution may exist due to accidental release or intentional, illegal releases. Any known or discovered hot spots may be monitored for the applicable pollutants.

8.4.1.5 BMP Monitoring

Monitoring may be done at sites where BMPs are installed both before and after implementation. This helps gauge the effectiveness of various attempts at environmental impact mitigation and provides a basis for pollution reduction estimates in the future.

8.4.1.6 Dry and Wet Weather Storm Water Discharge Sampling

To properly document discharges from storm sewer systems, sampling should be done be done during dry (during low and high groundwater seasons) and wet weather conditions. In addition to documenting the level of pollutants discharged in runoff, these efforts would help identify groundwater issues and illicit discharges.

8.4.1.7 Additional Methodologies

Additional methodologies may be required to properly assess the effectiveness of this plan. Possibilities for these include assessments of: the R-B flashiness index; the extent of channelization; the level of imperviousness; open space; development in the floodplain; flooding problems; the status of the designated and/or beneficial uses for waterbodies; and groundwater conditions

9.0 Master Plan Institutionalization

Institutionalization involves defining a mechanism to implement the actions contained within, including essential adaptive management measures such as provisions for updating and improving the plan. Defining the actual mechanism will involve researching the myriad alternatives that are available and evaluating how successful the implementation is under the current mechanism.

The purpose of this section is to first define these inner workings, provide options for the institutionalization mechanism, and then explore how these options and some additional programs can fund implementation of this master plan. Additionally, regardless of the mechanism that is chosen, the inner workings of a cooperative approach must be defined.

The information in this section is not exhaustive. The focus is on the enabling statutory provisions most likely to be used. In large part, this section is an updating and reorganization of the Southeast Michigan Council of Governments' (SEMCOGs) *Options for Local Government Funding of Water Quality Activities (2003)*.

9.1 Current Organization

The development of this master plan has occurred under the direction of a voluntary group of representatives from the various agencies / entities with land / infrastructure and/or storm water assets in the planning area. The City has funded the development of this plan with direct financial support from the ICDC and SCIT and input from and cooperation with all of the agencies / entities.

It is expected that this structure will guide the implementation of the master plan once it is finalized. During this time, the agencies / entities will evaluate how the current structure is able to implement the plan as it relates to achieving the objectives of

- Identifying (and addressing) shortcoming of the current storm water management systems; and,
- cooperatively addressing the identified shortcomings that cross jurisdictional boundaries

towards the goal of defining (and implementing) a **unified, collaborate approach to storm water management issues in the Mt. Pleasant, Michigan area**. Specifically, how voluntary participation with ad-hoc organization can implement and track the various actions and results and the ability to get the members to act in concert as opposed to isolated and independent actors.

9.2 Future Considerations

Some of the actions proposed or recommended in this SWMP may require focused attention of planning area agencies / entities to provide a coordinated approach. As such, it is important to consider organizational options as implementation of the plan moves forward. It is also necessary to provide an outline for guiding an on-going cooperative approach.

9.2.1 Organizing Mechanisms

Michigan has numerous options for the planning area agencies / entities to form into a legal entity. At least seven approaches are available under Michigan statutes to lead and assign funding responsibilities for SWMP implementation. These options include the following:

1) Drain Code – Public Act 40 (1956);
2) County Department and Board of Public Works – Public Act 185 (1957);
3) Inter-Municipal Committee Act – Public Act 200 (1957);
4) Municipal Sewerage and Water Systems - Public Act 233 (1955);
5) County Public Improvement Act – Public Act 342 (1939);
6) Watershed Alliance Act – Public Act 517 (2004); and
7) Voluntary Cooperation.

Table 14 presents some of the more popular options, including: a general description of the option, how each of these options can be used, examples throughout the State of Michigan (where available), and some advantages or disadvantages for using each option. Any of these options could be used independently or in combination to handle a specific portion of the SWMP.

Table 14. Organizational options for planning area agencies / entities.

Option	Description
The Drain Code	**PA 40(1956).** The watershed drainage district created under Chapter 20 could include an area within a single municipality or more than one municipality, depending upon the type of agreement to be used. A watershed drainage district established under the Drain Code petition process can be accompanied by a contract between the municipality and the Drainage Board through the execution of an agreement under section 471 or 491. These agreements would describe the services the Drainage Board would provide for each community in the drainage district, identify the process of assessing charges for those services, and establish a mechanism for identifying and approving needed projects. In the case of a section 471 agreement, a planning area committee would be established with a representative from each agency / entity in the drainage district. Before a proposed project could go to the Drainage Board for consideration, it would need the approval of the watershed committee. Each municipality in the watershed drainage district would be apportioned their share of the cost of the projects. Municipalities could cover their costs either through their general fund or levy those costs to the individual properties within the drainage district through ad valorem taxes, rates/fees, or special assessments.
Public Works Act	**PA 185(1957).** Gives county departments of public works broad authority to provide a range of services, including the collection and transport of storm water. These county departments may also contract with other units of government to provide specific facilities or services. Funding mechanisms for these services includes property taxes, special assessments, and user charges/rates.
Inter-Municipal Committee	**PA 200(1957).** Allows participating municipalities to adopt resolutions for the establishment of a study committee. Funding is provided by the participating agencies / organization. However, activities of the committee are limited to study and planning. Construction, operation, maintenance of facilities or implementation of projects beyond studies is not permitted under this legislation.
Municipal Sewerage & Water Systems	**PA 233(1955).** Municipalities can jointly create an Authority which then contracts with individual municipalities and other agencies / organizations to provide specific facilities or services. Once established, activities of the Authority are limited to those related to owning and operating a sewage disposal system, including storm sewers. Contracting municipalities use a variety of mechanisms to pay for the facilities or services they receive from the Authority, including property taxes, special assessments, and user charges/rates. PA 233 authorities can issue bonds for capital improvements.
County Public Improvement Act	**PA 342(1939). S**imilar to the Public Works Act as related to storm water issues, this act authorizes the County Board of Commissioners to designate a county agency to provide specific services, including the collection and transport of storm water. County agencies eligible to serve as the designated agency include the Board of Public Works, Road Commission, or Drain Commissioner. Rates, charges, or assessments are paid based on the facilities or services provided and the agency can contract with other agencies / entities for the cost of such facilities or services. Again, property taxes, special assessments, and user charges/rates can be used by the participating municipalities to pay for the facilities or services they receive.
Watershed Alliance Act	**PA 517(2004).** Two or more communities can form a watershed alliance if they adopt bylaws with the approval of the governing body. Through by-laws, Alliances establish boundaries, assessments to members, structure, and decision-making process. The law provides for authority to receive grant funding, manage its own money, contract its own staff and services, and implement plans and projects. Alliances *cannot* levy taxes or assess individuals, businesses, or property. They do not have the authority to regulate or issue permits. Membership is voluntary and can include municipalities, counties, school districts, colleges and universities, or other local or regional public agencies.
Voluntary Cooperation	It is possible to work voluntarily without any contracts or legal agreements. To accomplish this, involved government entities and other agencies / organizations must voluntarily agree to work together cooperatively. This requires trust and accountability. There are myriad ways to implement a cooperative agreement, with reliance upon committees being one of the dominant structures. Different structures can be considered prior to organizing a committee. Regardless of what structure is decided upon, leadership is a critical component. Some committees elect chairman, others have series of subcommittees. Many committees use Roberts Rules of Order to manage committee operations.

Table 14. Organizational options for planning area agencies / entities. (continued across from previous page)

Option	Advantages	Disadvantages	Example
The Drain Code	▪ Flexibility in paying apportioned share (property taxes, rates/fees, special assessments, or general fund); such property taxes may not be subject to the Headlee Amendment. ▪ Define the scope of the work to be performed, responsibilities, active participation by local governments and various agencies involved; allows for use of in-kind services in lieu of cash payments.	▪ Petition needs to be carefully drafted to include implementation activities. ▪ Agreements with multiple municipalities can be difficult and time consuming. ▪ May limit the role of local government in decision making.	Isabella County Drain Commissioner
Public Works Act	▪ Allows use of various funding mechanisms.	▪ Absent companion agreements, may limit the role of local government in decision making.	Isabella County – various
Inter-Municipal Committee	▪ Simple to start. ▪ Municipal support can be funds or in-kind services, equipment, etc.	▪ For study purposes only.	Greater Lansing Regional Committee
Municipal Sewerage & Water Systems	▪ Allows use of various funding mechanisms. ▪ Can provide services to non-member municipalities at same or greater fee.	▪ Creates a separate authority. ▪ Primarily intended for water and waste-water services but can include storm water. ▪ Contracts between county and municipality(ies) are subject to a right of referendum.	Saginaw Area Storm Water Authority
County Public Improvement Act	▪ Allows use of various funding mechanisms.	▪ Absent companion agreements, this approach may limit the role of local government in decision making. ▪ Contracts between the county and participating municipality(ies) are subject to a right of referendum.	Lower Flint River
Watershed Alliance Act	▪ Specifically written to allow communities to undertake water quality activities. ▪ Allows for the planning/design and implementation of multi-jurisdictional projects. ▪ Can receive and administer external funding. ▪ Equitable membership. ▪ Auditing of finances required by State.	▪ All participating entities / organizations are still independent within the planning area. ▪ Does not address funding issues directly.	The Alliance of Rouge Communities
Voluntary Cooperation	▪ Raising revenue is each agencies' / entities' responsibility which allows for flexible approaches. ▪ Direct relationship between cost and benefit to each participant.	▪ Requires trust and individual accountability. ▪ Absence of leadership can limit implementation. ▪ Not necessarily a reliable stream of long-term funding for planned actions.	Battle Creek Area Clean Water Partners

9.2.2 Cooperative Approach

These concepts and suggestions in this sub-section consist of those that are meant to foster a cooperative planning and decision-making approach in both the short and long term between all levels of government, participating agencies and organizations, and other local stakeholders.

9.2.2.1 Organizing Structure

Some recommendations for the committees that may be utilized under any organizational structure to oversee and implement the actions of the SWMP include:

- Implementation and Evaluation Committee – overseeing plan implementation progress, integrating data to evaluate the achievement of goals and objectives, marking plan and organizational change recommendations;
- Ordinance and Standards Committee – assessing the language of ordinances, standards, and programs and recommending changes;
- Technical Guidance Committee – providing consistent technical guidance for the planning and implementation of plan actions or other storm water related proposed actions not addressed by the plan;
- Public Education Committee – developing and implementing a unified approach to educating the public on the cooperative work of agencies / organizations in the planning area and organizing participation and feedback opportunities to improve public understanding and support;
- Budget and Funding Committee – providing funding guidance for individual agencies / entities, developing funding plans for joint projects and handling requests, and exploring funding options in general; and,
- Conservation / Recreation Committee – developing approaches for integrating conservation efforts and funding in storm water actions and expanding buy-in to storm water projects through representing recreation stakeholders (e.g. trails organizations).

9.2.2.2 Information Sharing and Access

Maintaining a cooperative approach requires deliberate structures for sharing of information and progress. This includes reporting issues throughout the planning area, updating relevant agencies / organizations of work being done, understanding how that work impacts neighboring jurisdictions, operating on a shared understanding of the problems, and sharing a vision for addressing the problems, as well as assessing the success or failure of doing so. These things require procedures to share, disseminate, and access up-to-date information, including construction plans and the collective asset database and model. Establishing a method to maintain the procedures and tools established in support of, or in furtherance of, this SWMP is essential and necessitates a clearinghouse for information and maintenance of the tools with provisions for funding such efforts.

9.2.2.3 Tracking and Evaluating Progress

Maintaing a cooperative approach may include regular e-mail communication with the member entities about the mission and purpose of the SWMP, current news, status of activities, a schedule for upcoming activities, and benefits of active participation and may include communication with other interested entities third parties. Other considerations include formal means of communication such as a newsletter and attendance at relevant meetings.

Those implementing the SWMP should establish measurable guidelines to evaluate progress not only towards implementation but also towards the goals and objectives of the plan. These guidelines will provide the context for measuring action completion and a decrease in the impacts of storm water management on the natural environment and the people within the planning area. The guidelines may recommend such things as:

- Monitoring protocols (locations, data, parameters, etc.) that can leverage existing information
- Achievement levels to help gauge success;
- Data reporting/submittal requirements;
- Indices to initiate revision of the SWMP; and,
- The steps to take to improve the SWMP through these revisions.

9.2.2.4 Diverse Stakeholder Representation

When feasible and appropriate the agencies / entities in the planning area should attempt to coordinate efforts with neighboring jurisdictions and utilize third party organizations that maintain a presence throughout these broader areas. Including upstream and downstream stakeholders helps to foster a unified vision and enhance buy-in on a larger scale. It also helps streamline the implementation of actions for agencies whose jurisdiction extends beyond the planning area.

9.2.2.5 Consistent Planning and Metrics

When feasible and appropriate, the agencies / organizations should utilize common data and tools and collectively decide what should comprise this common toolbox. The geospatial database can be shared online and accessed through standard Geographic Information Systems (GIS) programs or web-based interfaces. The model should be accessible for any agency to explore storm water alternatives. Numerous other analysis tools exist and each agency / entity currently utilizes its own internal guidelines and tools to accomplish storm water calculations, design, and planning. Establishing consistent approaches to be used by SWMP participants will streamline cross-jurisdictional projects.

9.2.2.6 Funding Transparency and Coordination

Funding levels, mechanisms, and sources for various projects implementing actions discussed in this plan and/or related to storm water in the planning area should be routinely shared among the various agencies / organizations. Coordinated efforts should be made to maintain appropriate levels of cost-sharing and to cooperatively seek and allocated funds for multi-jurisdictional efforts. Sources of outside funding from various levels of government and third parties should be maintained with up-to-date information on program dates, eligibility requirements, funding levels, advantages and disadvantages, and steps to take to procure funding.

9.2.2.7 Consistent Communication

Agencies / organization in the planning area should maintain regular and consistent communications regarding work and initiatives related to storm water within the planning area. Preparing and disseminating an annual report that documents the decisions, actions, and results performed as part of storm water management during the previous year can be a standardized way to disseminate such information to other agencies / organizations and stakeholders in general.

Legal communications related to storm water issues should also be coordinated so that all impacted agencies / organizations can raise issues for discussion and that the impacts of other agency / organization decisions are understood.

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10.0 FUNDING AND SUPPORT CONSIDERATIONS

Each agency / entity has its own funding mechanisms that allots funds to applied towards storm water infrastructure construction and maintenance. As such, the CIP recommended actions may not align with existing storm water budgets. Thus it may be necessary to, at a minimum, complete recommended 1-5 year CIP items over a longer period and in conjunction with improvements to other utilities (e.g. roads, water mains), which would provide for more efficient spending of funds. Before implementing a CIP plan that is larger than previously planned, it is recommended to consult with a municipal / institutional financial expert.

Given the interconnected nature of many areas of storm water system, it will be necessary to apportion costs appropriately and previous apportionments may need to be revisited if system changes result in increased or decreased storm water generation, discharge, and/or routing. A common method for funding allocations is to use a formula that is a function of estimated storm water discharge using a common methodology, typically considering land area, land use, and impervious cover. Other factors may be considered as appropriate, including: population, number of parcels, diversity of development, opportunity for new development, and community resources. Furthermore, not every situation requires using the same formula. Independent of which allocation approach is selected is the issue of raising the funds to pay for the activity.

10.1 CAPITAL EXPENDITURE REVENUE MECHANISMS FOR LOCAL GOVERNMENTS

Capital projects are paid through some combination of either a pay-as-you-go basis as revenues are available or from the proceeds of indebtedness (bonds), with revenues dedicated to debt retirement. In either case, the revenues supporting the CIP may include some or all of tax revenues, user rates and charges, special assessments, connection fees, and capital reserve funds. Capital improvement projects generally require a significant investment over a short period of time with a repayment schedule that can extend several years beyond the actual construction schedule. Local governments have three basic means of raising revenues – special assessments, taxes, and fees.

10.1.1 Special Assessments

Special assessments are assessments imposed on real property which benefits especially from a government expenditure or service. Special assessments are limited in amount to no more than the increase in value which the real property gains because of the expenditure. Local street and sewer projects are often paid for by special assessments on the real property served by the street or sewer.

10.1.2 Taxes

Local governments' power to tax is limited to those taxes expressly authorized by constitution or statute. Local government taxing authority is primarily limited to ad valorem taxes on real and personal property and to personal income tax. The rate of these taxes is also limited by statute. In general, local governments do not have the authority to tax on any other basis and cannot impose a sales tax or a tax on consumption like state and federal taxes on gasoline. Thus, a local government does not have the authority to impose a tax on sewer or water use in order to pay for providing those services. Taxes may be imposed to raise revenues for general governmental purposes or for specific projects or objects.

Michigan's Headlee Amendment requires a local vote of approval for any tax not authorized by law at the time the amendment was enacted. In addition, some authorizing statutes also require a local vote before a tax is imposed under certain circumstances.

In the *Bolt* decision, the court established a three-part test for distinguishing a valid user fee from a tax:

- The fee must serve a *regulatory purpose* rather than a revenue raising purpose;
- A user fee must be *proportionate* to the necessary costs of the service; and
- A user fee must be *voluntary* – users must be able to refuse or limit their use of the commodity or service.

These criteria are being used to distinguish whether a government-imposed charge is a fee or a tax. As noted above, this distinction is important because there are constitutional and statutory limitations on a government's authority to impose taxes. A charge which is determined to be a tax is subject to those limitations. The *Bolt* decision and subsequent court decisions have far reaching implications for both state and local governments. While the *Bolt* case dealt with a fee imposed by a local government for a sewer project, the fee versus tax test laid out by the *Bolt* court has been applied in many cases beyond water and sewer fees at both the state and local level. The result of the *Bolt* decision has been a lack of necessary certainty and predictability with respect to using fees as a mechanism to fund the provision of essential governmental services.

A SEMCOG study (*Land Use Change in Southeast Michigan: Causes and Consequen*ces, March 2003) has shown that because Proposal A limits taxable value increases for properties remaining in the same ownership to five percent or the rate of inflation, whichever is less, communities without much land available for development are severely limited in taxable value growth. Without new construction to bring more State Equalized Valuation (SEV) and its full taxable value, municipal revenues from ad valorem taxes often do not keep pace with increases in SEV.

10.1.3 Fees

Fees are charges for services offered or carried out pursuant to a local government's "police" power, meaning government's authority to undertake or regulate actions to promote public health, safety, and welfare. Building inspection fees paid for city building inspection services conducted as a part of the city's program to maintain safe housing are one example of a fee. The *Bolt* decision, together with many other court decisions, puts bounds on the circumstances under which a local government can impose a valid fee. Because fees are the most common method in Michigan for financing the provision of safe drinking water and sewerage services, any changes in the law which affect how a local government can impose a fee are of great import to both a local government and its residents.

A stormwater utility bill that would outline requirements for stormwater user fees in Michigan (that would comply with the *Bolt vs. City of Lansing* decision) has been introduced in the Michigan House of Representatives during the last two legislative sessions; but never went to a vote. It is anticipated that the previously proposed bill will be reintroduced during the 2021-2022 Legislative session.

While most communities, for example, the City of Royal Oak, are waiting to implement their planned stormwater utility fees until the Stormwater Utility bill is passed[36], some large, urban communities (City of Ann Arbor[37], City of Oak Park[38], and City of Detroit[39]) have implemented stormwater user fees in recent years without waiting for the Michigan Legislature to adopt the stormwater utility bill. It should be noted that the City of Detroit is currently in a lawsuit regarding their stormwater "drainage fee".

10.2 Other Expenditures

With the recognition that land use activities directly impact storm water runoff volumes and rates and the quality and physical (e.g. habitat) conditions of receiving water bodies, managing storm water impacts requires implementing a broad range of policies and active measures to preserve healthy conditions in the natural environment. The development and maintenance of plans and the implementation of non-capital programs (e.g. public education programs and ordinance development and enforcement) are on-going in nature, and, for the most part, do not require the outlay of large financial resources. Nonetheless, they do require a commitment to long-term, stable sources of funding.

Many of the actions that planning area agencies / organizations may be seek to implement to address storm water issues may go beyond their technical and financial resources. Additionally, there are significant cost efficiencies that may be realized by developing programs that meet the needs of numerous planning area agencies / organizations instead of a collection of independent programs. Therefore, the planning area agencies / organizations may opt to contract with other agencies or third parties for specific planning and program implementation activities.

[36] Royal Oak website: https://www.romi.gov/1438/Stormwater-Utility
[37] Ann Arbor website: https://www.a2gov.org/departments/systems-planning/planning-areas/water-resources/Pages/Stormwater-Rates-and-Credits.aspx
[38] Oak Park website: https://www.oakparkmi.gov/stormwater.php
[39] Detroit website: https://detroitmi.gov/departments/water-and-sewerage-department/dwsd-customer-care/drainage-charge

10.3 Summary of Funding Mechanisms

This subsection discusses in more detail the possible taxes, special assessments, and fees that can be used to generate funding. Also included are appropriate grant programs. The mechanisms include:

1) Storm Water Utility (fee based)
2) Special Assessment;
3) Natural Resources and Environmental Protection Act;
4) Revised Municipal Finance Act (RMFA);
5) Other State grant and loan programs, which may validly be used for the contracted purpose.

The individual mechanisms are presented in Table 15.

10.3.1 New and Upcoming Funding Programs

The COVID-19 pandemic highlighted the importance of public infrastructure, such as drinking water and wastewater service. The economic impacts of the pandemic have also spurred economic recovery and “stimulus” bills, many which include public infrastructure funding, including stormwater funding.

The American Rescue Plan Act of 2021 (ARP) included direct payments to municipalities, which can be used to fund infrastructure improvements, including the recommended near-term stormwater system improvements. In addition, a portion of the ARP funds allocated to the State of Michigan will likely be utilized to fund public infrastructure projects. At the time of this writing, the Michigan House has proposed $250 million in grants to fund sewer replacement projects identified in Asset Management Plans. The ARP bill also included additional funding for the US Economic Development Administration (EDA), which can be used to fund eligible infrastructure projects in economically stressed areas.

The Biden Administration recently unveiled the American Jobs Plan, which includes a proposed $2.25 trillion infrastructure bill. While this bill is currently being negotiated with Congress, it is anticipated that some version of the bill will pass by the end of 2021, offering substantial funding for public infrastructure improvements projects.

In addition to COVID related stimulus bills, additional funding mechanisms have recently been announced. The Michigan Economic Development Corporation (MEDC) announced grant funding up to $2.0 million for eligible water related infrastructure projects, including stormwater projects. The City of Mt Pleasant is listed on the MEDC low-to-moderate income list; therefore, the City is eligible to apply for the grant. Applications for this round of funding are due May 31, 2021. It is our understanding that MEDC intends to offer similar grant programs on a periodic (annual) basis for the next several years.

10.3.2 Tribal / EPA Funding

In 2013, the Clean Water Act (CWA), Section 319 grants program was made available to tribal entities. The program is used to address the issues identified in Tribal Waters through the CWA Section 106 Program. The US EPA provides funding for the Tribe to work with partnering agencies on water quality improvement projects such as stream bank restoration, erosion reduction, filter strips, and more to reduce the pollution in Tribal Waters.

Table 15. Summary of funding mechanisms.

Option	Description	Advantages	Disadvantages
Storm water Utility	Like other utilities, storm water utilities are established to charge a fee for providing a service, and typically are accounted for as an enterprise fund. This fund is used to cover the operation and maintenance of the storm water system and, in some cases, finance capital improvements. Fees are paid periodically, often quarterly, and included on the water and sewer billing. Fee structures often include a flat rate charge and a land area charge, generally with a minimum per parcel fee. The land area charge may vary, based on such factors as the parcel's total impervious area, ratio of impervious to pervious surface area, the ratio of retention to impervious surface, or the installation of approved storm water management best management practices (BMPs).	• Fee based on runoff; assessed against all properties. • Is equitable; directly related to benefit received. • Not based on property value. • Consistent funding stream. • Use existing billing system; reduces costs. • Fee can be reduced through implementation of BMPs. • Can contract with other governmental units.	• Must be set up to withstand challenges under *Bolt* - this may add complexity to the utility and increase costs. • Determining ratio of impervious surface area for parcels may be difficult / costly. • Risk of financial liability for refunds in the event a user fee is determined later to be a tax.
Special Assessment	Special assessments are levied against individual properties benefiting from the program/project through the establishment of a special assessment district (SAD) to cover the cost of specific activities/improvements. While the authority to establish special assessment districts varies by the type of governmental unit, special assessments must always be directly related and proportional to the benefit received from the improvement and funds can only be used to pay for the cost of the improvement.	• Direct relationship between benefit and assessment. • No property tax limitations. • Assessments are against all properties (certain tax-exempt entities are also exempted by the General Property Tax Act from paying special assessments).	• Municipality may incur additional administrative costs. • Difficult to achieve consensus for the allocation of benefits.
Natural Resources & Environmental Protection Act	**PA 451 (1994)**. Part 43 of the Natural Resources and Environmental Protection Act authorizes cities, villages and townships to borrow to pay the cost of improvements to waterworks systems or sewage systems in those instances in which EGLE, State Department of Public Health or a court of competent jurisdiction has ordered the installation, construction and/or improvement of such systems or EGLE has issued a permit for the installation, construction, alteration, improvement or operation of such a system and the plans for such improvements or system have been prepared and approved by the State department or agency having the authority to grant such approval.	• Municipality can borrow in response to court or regulatory order with respect to water quality.	• Borrowing is subject to a right of referendum. • Borrowing is limited to the purposed set forth in the order.
RMFA	**PA 34 (2001)**. Section 517 of the Revised Municipal Finance Act authorizes counties, cities, villages and townships to borrow for capital improvement items that will improve or protect water quality.	• Use more than one funding mechanism to pay debt. • No need to have EGLE or court order to borrow.	• Borrowing is subject to a right of referendum. • Borrowing is limited to 5% of municipality's State Equalized Value (SEV).
Other Grant & Loan Programs	EGLE administers a range of grant and loan programs aimed at assisting local governments develop and implement pollution abatement programs. Information on EGLE grant and loan programs can be obtained from EGLE Assistance and Support Services. Additionally, there are numerous other local, state, federal, and international entities that operate myriad grant programs providing funds to implement actions to improve storm water management, protect waterbodies and aquatic habitats, reduce or eliminate sources of water quality impairments, and generally protect the natural environment.	• Many programs are grants. • Many programs require inter-governmental cooperation. • Municipality does not have to draw on general fund for program/initiative.	• Programs tend to be focused. • Limited funds available. • Many programs are competitive. • Local match funding is usually required. • Many programs require inter-governmental cooperation.

11.0 Future Efforts, Target Areas, and BMPs

This section highlights the possible large-scale storm water infrastructure projects discussed in Section 4.0 and identifies important options and considerations for these areas. The second part of this section details common best management practices that can be used in these and other smaller projects to improve storm water management.

11.1 Sanitary Sewer Sump Pump Disconnections

The City has a program to disconnect sump pumps from the sanitary sewer and connect them to the storm sewer system. In areas with significant capacity concerns, especially for the 1-year storm, and areas that flood damage has been reported such efforts should be coupled with appropriate sewer upgrades. It is also advisable to conduct a pilot study in an area with significant existing capacity to better quantify the levels of flow that can be expected through such a program as it moves forward.

11.2 Regional Storm Water Infrastructure Upgrade Targets

The major potential system upgrades discussed in Section 4.0 are presented in Table 16. These conceptual projects can be seen in Exhibit 2 in Appendix J. These projects can potentially be implemented in lieu of local / specific improvements to sewers based on capacity concerns and / or conditions as these projects are primarily intended to alleviate numerous conveyance concerns. These projects should be scheduled as appropriate in the context of the overall asset-condition based rehabilitation and replacement schedule.

Individual CIP rehabilitation actions that may be impacted by these regional projects are denoted in Table E-1 (Appendix E) with the ID field presented as **red, bold, underlined** text. Those IDs flagged include pipes that are likely to be directly impacted and those downstream that may see changed flow rates. The cross-reference to specific projects can be found in the digital data.

11.3 Green Infrastructure and Best Management Practices

Storm water nonpoint source (NPS) pollution is the primary source of stressors that diminish water quality in the U.S. To reduce the impact, it is important that actions related to storm water include best management practices (BMPs) used to reduce the amount of pollution entering receiving water bodies. Since development also causes hydrological changes in a watershed, BMPs must also be chosen to mitigate this effect.

Storm water related BMPs fall into five basic categories: impervious surface mitigation, infiltration techniques, filtration techniques, vegetative buffers and natural conveyances, and storm water detention and retention.

Additional resources for specific storm water BMPs and details about performance and design include:

- The Stormwater Manager's Resource Center's *BMP Fact Sheets* (www.stormwatercenter.net).
- *Stormwater Management Guidebook*. Menerey, B.E., et al. (1999). EGLE Land and Water Management Division;
- *Guidebook of Best Management Practices for Michigan Watersheds*. Peterson, A., et al. (1998). EGLE Surface Water Quality Division; and
- EPA's *National Menu of BMPs* at cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm

The implementation of storm water BMPs will typically not fully eliminate sewer capacity issues, but they can reduce costs associated with upgrades and significantly help alleviate surface flooding. Additionally, BMPs typically result in water quality improvements in addition to controlling storm water runoff volumes and rates.

Good soil erosion and sediment control (SESC) is also a critical tool that protects surface waters from the effects of sedimentation, flooding, and other property damage. The construction related SESC permitting agency covering the planning area (i.e. the County Enforcing Agent) is the Isabella County Community Development Department. MDOT is an authorized public agency that is not required to obtain a CEA permit.

Non-construction SESC includes any activity that is not undertaken in relation to an active construction site. These actions consist of those specifically targeted to prevent soil erosion, control NPS and point source sediment, and correct known soil erosion problems, and can be implemented on public land and are generally enforced on private lands through ordinances, zoning, and development standards.

Table 16. Regional Infrastructure Upgrade Targets.

Map Number	Project	Location / Benefits
1	Grewes Drain Expansion & Quarterline Drain Reconstruction Option: East Side Storm Sewer Relief Option: Hance Drain Relief	Improve Quarterline Drain and relieve MDOT Pickard Street Flows north through Grewes Drain; provide relief for north areas of ESSS; provide relief for upstream areas of Hance Drain
2	Hance Improvement Drain No 2 Storage Williams Street / Broadway Street Storage	Provide storage for areas in the upstream portion of the Hance Drain in the Township and the City
3	East Side Storm Sewer Relief to Onion Creek along Preston Road	Provide upstream relief of the ESSS to expand capacity in downstream areas; construction here requires disruption of less intensely developed areas and has adjacent undeveloped or public parcels to provide storage or natural management considerations; this area also helps alleviate adjacent flooding issues
4	Oxford Row and Onion Creek Headwaters Flood Mitigation	Related to the above project; replaces or provides additional drainage route through and upstream of the Oxford Row area to alleviate local flooding concerns
5	Bellows Street Storm Sewer Relief to Lincoln Street Sub-Basin along Kinney Avenue	Relieves downstream Bellows Street sewer capacity issues and those in the ESSS and Onion Creek area sewers
6	Michigan Street and Cemetery Storm Sewer Upgrades	Provide relief drainage path for numerous over capacity northwest area sewers and connect to the upstream end of the Bradley Street Storm Sewer (at the Beltnick Drain) to alleviate current capacity concerns and re-direct future development flows from the west side of the planning area
7	Cross-Campus 54-inch Relief, Preston Road Storm Sewer Replacements, and Upton Drain Relief	Provide relief flow path to eliminate capacity concerns in main pipe; eliminate connections to the ESSS; reduce capacity issues in on-campus sewers and potentially intercept Bellows Street flow from the ESSS; eliminates capacity issues in downstream enclosed sections of the Upton Drain
8	Theirs Drain Upgrade / Abandonment	Provide upgraded drainage for area, including Airport and River Road; consider vacating portions best served by ICRC sewers
9	Pickard Road / Bamber Road Relief	Potential to re-route flow north along Bamber Road into the Mission Creek Sub-Basin to reduce capacity concerns and alleviate flooding issues in northwest City service area
10	Industrial Drive Reroute (disconnect from ESSS)	Reroute flow north to natural area; free up storm surge pond for more ESSS equalization
11	Potter-Brodie Drain Expansion & Upton Drain Relief	Expand service area / diversion percentage from Upton Drain to Potter Brodie Drain to utilize natural low-lying area for storage and to reduce flows through the more developed Upton corridor

Table 16. Regional Infrastructure Upgrade Targets. (rows continue across from previous page)

Map Number	**Agencies and Estimated Conceptual Costs** (if calculated) * denotes that additional road drainage costs may apply depending on project specifics	**Total Estimated Conceptual Costs and Pipe Details**
1	Drainage: City, Township, ICDC, ICRC, MDOT Assets: City ($1,200,000)*, ICDC ($3,150,000), ICRC*, MDOT ($2,150,000)* Downstream Conveyance: MDOT / Private (Grewes Drain) – *additional work may be necessary to accommodate new flows*	<u>$6,500,000</u> 3,200 ft of 84-inch pipe 1,400 ft of 72-inch pipe 2,600 ft of 54-inch pipe 2,000 ft of 36-inch pipe
2	Drainage: City Assets: City Downstream Conveyance: ICRC sewers to ICDC (Hance Drain)	N/A – project dependent on additional modeling to alleviate capacity concerns in adjacent City areas and in downstream portions of Hance Drain
3	Drainage: City Assets: City ($3,300,000)* Downstream Conveyance: ICDC (Onion Creek) – *additional work may be necessary to accommodate new flows*	<u>$3,300,000</u> 2,700 ft of 108-inch pipe 1,350 ft of 66-inch pipe
4	Drainage: City Assets: City ($2,100,000)* Downstream Conveyance: City sewer to ICDC (Onion Creek) – *additional work may be necessary to accommodate new flows*	<u>$2,100,000</u> 1,400 ft of 66-inch pipe 1,050 ft of 54-inch pipe 650 ft of 36-inch pipe
5	Drainage: City Assets: City ($1,500,000)* Downstream Conveyance: City sewer to Chippewa River	<u>$1,500,000</u> 2,300 ft of 42-inch pipe
6	Upstream Drainage: ICRC, ICDC, Township Drainage: City Assets: City ($,3,600,000)* Downstream Conveyance: Chippewa River	<u>$3,600,000</u> 1,250 ft of 66-inch pipe 1,450 ft of 60-inch pipe 850 ft of 54-inch pipe 1,650 ft of 48-inch pipe
7	Drainage: City, CMU Assets: City ($2,100,000)*, CMU ($1,100,000) Downstream Conveyance: ICDC (Upton Drain)	<u>$3,200,000</u> 950 ft of 78-inch pipe 1,100 ft of 72-inch pipe 1,750 ft of 42-inch pipe 950 ft of 36-inch pipe
8	Drainage: Township, ICRC, ICDC Assets: ICRC ($350,000)*, ICDC ($850,000) Downstream Conveyance: ICDC (Thiers Drain) to Chippewa River – *additional work may be necessary to accommodate new flows*	<u>$1,200,000</u> 1,700 ft of 24-inch pipe 800 ft of 18-inch pipe
9	Upstream Drainage: Township, ICRC Drainage: City, ICRC Assets: City ($1,000,000)*, ICRC ($400,000)* Downstream Conveyance: ICRC sewer to Mission Creek – *additional work may be necessary to accommodate new flows*	<u>$1,400,000</u> 650 ft of 54-inch pipe 200 ft of 42-inch pipe 1,400 ft of 36-inch pipe
10	Drainage: City Assets: City ($400,000) Downstream Conveyance: ICRC to MDOT channel to Chippewa River – *additional work may be necessary to accommodate new flows*	<u>$400,000</u> 600 ft of 48-inch pipe
11	Upstream Drainage: City, CMU, ICDC (Cole Drain) Drainage: City, CMU, ICDC (Cole Drain) Assets: City, CMU, ICDC Downstream Conveyance: through Mission Street culvert (ICRC) to Potter Brodie Drain (ICDC) passing through SCIT parcel	N/A – project dependent on additional modeling to alleviate Upton Drain capacity concerns and flooding issues adjacent to Upton Drain open channel

<u>Note</u>: costs given reflect jurisdictional location of assets and ultimate costs to jurisdictions may differ based on details of cost assessment mechanisms (which may pass costs to private land owners and other jurisdictions based on drainage areas and expected flows in downstream pipes)

Categories of these actions include:

- Repairing bare soil such as occurs on poorly maintained yards or eroding hillsides;
- Repairing and stabilizing stream banks that are eroding;
- Repairing roads and associated transportation structure that are eroding or causing nearby erosion;
- Excluding sensitive uses from occurring near waterbodies, especially within the riparian corridor;
- Insuring sediment generating sites install proper controls to prevent sediment from leaving the property;
- Providing controls in sensitive areas to ensure that sediment is not transported by wind;
- Installing structural controls at inlets to, or inside of, the storm sewer system to ensure sediment does not travel to receiving waterbodies; and
- Encouraging the implementation of agricultural runoff BMPs that prevent soil particles from traveling to nearby waterbodies.

Many other techniques, such as street sweeping, may be considered non-construction SESC. A number of BMP types are discussed in the following subsections.

11.3.1 Infiltration Techniques

In general terms, infiltration systems can be described as natural or constructed depressions located in permeable soils that capture, store, and infiltrate storm water runoff. These depressions can be located at the surface of the ground or they can be designed as underground facilities. Common infiltration practices include:

- Rain gardens – small depressions typically planted with native vegetation, no structural infrastructure;
- Tree boxes – ground-level or raised vegetation-filled boxes with open bottoms connected to soils;
- Bioretention facilities – large depressed areas with engineered soils and native planting, typically with supporting infrastructure such as overflows to the storm drain system;
- Infiltration basins – natural or constructed impoundment;
- Infiltration trenches – shallow excavated trenches, 3 to 12 feet deep, backfilled with coarse stone aggregate;
- Porous pipe – underground pipes made of porous substance or with weep holes that allow infiltration as water flows;
- Dry wells – smaller variation of infiltration trench;
- Underground systems – typically pre-manufactured structures that are buried in space-limited locations; and
- Water spreading / irrigation – involves the reuse of stored runoff water for land-based functions such as crop irrigation.

Benefits of infiltration systems include:

- Reduced runoff volume;
- Increased groundwater recharge;
- Improved surface water quality;
- Thermal protection; and
- Simulation of pre-development hydrology.

Limitations of infiltration systems include:

- Unusual construction considerations;
- Potential for groundwater contamination;
- May lose effectiveness over time if not maintained;
- Not recommended in areas with steep slopes; and
- May require landscaping for drought/inundation conditions.

Infiltration systems require semi-annual inspections (clogging, vegetation health, structural elements), regular removal of accumulated trash and vegetation maintenance (mowing, pipe auguring for roots), and extensive rehabilitation upon failure.

Infiltration Systems Scorecard

Infiltration practices provide wide-ranging water quality and water quantity benefits. The information presented below is for comparative purposes only. Values to be used for design purposes or to calculate pollutant load reductions should be determined through additional research.

WATER QUALTIY CATEGORY	REMOVAL EFFICIENCY*
TSS	95%
Phosphorus	65%
Metals (Cd, Cu, Pb, Zn)	95%
Nitrogen	50%
Pathogens	n/a
Toxins	n/a

* *Efficiency = % removal of influent concentration (median)*
Source: Winer, 2000.

WATER QUANTITY CATEGORY	APPLIC.**
Channel Protection	M
Overbank Flood Protection	M/L
Extreme Flood Protection	L
Recharge Volume	H

** *Applicability = suitability of practice for given purpose; H=High, M=Medium, L=Low*
Source: Minnesota, 2005.

11.3.2 Mitigate Existing Impervious Surfaces

Impervious surface mitigation is a broad category comprised of practices designed to directly reduce impervious surface and/or treat the runoff from impervious areas. Some of these practices have the characteristics of the practices discussed in the following subsections ('Infiltration Practices', etc.) This category focuses on retro-fit implementation, but the practices herein can be implemented on new development and/or incorporated into ordinances, zoning, or development standards (discussed under 'Other Considerations'). Common mitigation practices include:

- Vegetated Parking Lot Islands – vegetated depressions receiving runoff from parking lots and other impervious surfaces for infiltration into ground and filtration before discharging to storm sewer system or waterbody;
- Vegetated Road Medians and Side Ditches – vegetated channels in the median or along the side of a road, functioning similar to parking lot islands except they also convey runoff;
- Green Roofs – building roofs that are covered with vegetation and soil planted over a waterproof membrane to retain and evaporate rainfall and slow its runoff;
- Pervious Pavement and Asphalt / Paving Bricks – alternative paving types that allow for the percolation of water into subgrade soils or an engineered sub-base that facilitates infiltration and/or slow discharge to the storm sewer system;
- Rain Barrels and Cisterns – storing of rooftop runoff for later use as irrigation or other non-potable applications, these only provide benefits if water is used or drained between rainfall events;
- Bridge Scupper Drain Treatment – install piping on bridge scupper drains to ensure runoff does not directly drop into waterbody, but instead is treated through natural and/or structural means; and
- Impervious Surface Disconnection – altering drainage systems such that adjacent pervious areas are not hydraulically connected (i.e. routing rooftop downspouts to discharge onto grass instead of onto a driveway).

Benefits of impervious surface mitigation include:

- Reduced storm water runoff volume;
- Increased groundwater recharge;
- Improved runoff water quality; and
- Simulation of pre-development hydrology.

Limitations of impervious surface mitigation include:

- May fail if not properly maintained; and
- May consume land or surfaces available for other uses.

Due the wide array of possible actions that fall in this category, cost and maintenance requirements range from low cost / low maintenance, such as impervious surface disconnection, to high cost / high maintenance, such as intensive green roof systems.

Impervious Surface Mitigation Scorecard

Impervious surface mitigation practices provide wide-ranging water quality and water quantity benefits. The information presented below is for comparative purposes only. Values to be used for design purposes or to calculate pollutant load reductions should be determined through additional research.

WATER QUALTIY CATEGORY	REMOVAL EFFICIENCY*
TSS	60%
Phosphorus	45%
Metals (Cd, Cu, Pb, Zn)	55%
Nitrogen	50%
Pathogens	50%
Toxins	50%

* *Efficiency = % removal of influent concentration (median)*
Source: Winer, 2000.

WATER QUANTITY CATEGORY	APPLIC.**
Channel Protection	H/M/L
Overbank Flood Protection	M/L
Extreme Flood Protection	L
Recharge Volume	M/L

** *Applicability = suitability of practice for given purpose; H=High, M=Medium, L=Low*
Source: Minnesota, 2005.

11.3.3 Filtration Techniques

In general, filtration systems are structural controls that capture, temporarily store, and route storm water runoff though a filter bed to improve water quality. Filtration systems can be off-line systems or designed as pre-treatment before discharging to other storm water features. Common filtration practices include:

- Sand Filters – systems designed to route runoff through sand to remove pollutants, variations include: surface, pocket, underground, and perimeter;
- Organic Filters – generally a surface or pocket variant of sand filter that utilizes an organic media either alone or mixed with sand to increase filtration efficiency; and
- Re-circulating Variant – involves add-on structural components such as a holding tank and pump to store runoff greater than filter capacity for later treatment and to recirculate treated runoff for greater removal efficiency.

Benefits of filtration systems include:

- Good for highly impervious areas with low sediment/high pollutant load (e.g. urban land use and retrofit scenarios);
- High pollutant removal rates;
- May be used in a variety of soil types; and
- Good for the treatment of hotspots because it can be isolated from ground water if contamination concerns exist.

Limitations of filtration systems include:

- Some applications may require indoor location (e.g. dedicated heated building) to ensure proper functioning in Michigan's cold-weather climate;
- Higher maintenance requirements (facility should be kept dry before it freezes in late fall);
- Some installations (media filters) have higher construction costs;
- Potential to cause odor problems;
- Minimal treatment of soluble nutrients; and
- Potential for nitrification in media filters where aerobic conditions exist.

Filtration systems require monthly inspections to ensure that tributaries areas are stabilized and that the structural components are free of debris. Annual maintenance involves inspecting for clogging and sediment filling, checking the concrete walls, looking for signs of bypassing flow, and correcting these problems, if documented.

Filtration Systems Scorecard

Filtration practices provide wide-ranging water quality and water quantity benefits. The information presented below is for comparative purposes only. Values to be used for design purposes or to calculate pollutant load reductions should be determined through additional research.

WATER QUALTIY CATEGORY	REMOVAL EFFICIENCY*
TSS	85%
Phosphorus	50%
Metals (Cd, Cu, Pb, Zn)	50%
Nitrogen	35%
Pathogens	35%
Toxins	80%

* *Efficiency = % removal of influent concentration (median)*
Source: Winer, 2000.

WATER QUANTITY CATEGORY	APPLIC.**
Channel Protection	M
Overbank Flood Protection	L
Extreme Flood Protection	L
Recharge Volume	M/L

** *Applicability = suitability of practice for given purpose; H=High, M=Medium, L=Low*
Source: Minnesota, 2005.

11.3.4 Vegetative Buffers & Natural Conveyance

In general, vegetated buffers and natural conveyance predominantly use vegetation and natural drainage to control storm water runoff. Depending on the circumstances, some practices may require a minimal amount of structural features. These practices provide runoff reduction and water quality benefits in similar fashion to the infiltration and filtration practices, but do so as they provide water transport, as opposed to storage. Common practices include:

- Filter Strips - vegetated surfaces designed to treat sheet flow from adjacent surfaces, function by slowing runoff velocities and filtering out sediment and other pollutants, and by providing some infiltration into underlying soils;
- Buffers – areas of natural vegetation (grass, native vegetation, and forest) that filter storm water as it drains overland, especially useful for treating runoff before it enters sensitive environmental areas such as groundwater recharge areas or streams, wetlands, and lakes;
- Grassed Channels – simple drainage ditches with flat bottoms and shallow slopes, a main alternative to curb and gutter in residential areas; and
- Swales – drainage ditches with enhanced natural vegetation types, compost, and/or rip-rap to enhance pollutant removal, two types include:
  - Dry Swales – incorporate engineered underdrains that route percolated runoff, which is treated, to the storm sewer system; and
  - Wet Swales – eventually intersect the ground water table.

The benefits of vegetated buffers/natural conveyance systems include:

- Reduced storm water runoff volume;
- Increased groundwater recharge;
- Improved runoff water quality; and
- Simulation of pre-development hydrology.

The limitations of vegetated buffers/natural conveyance systems include:

- Pollutant removal may be limited;
- Space requirements;
- If not properly designed, they can change the natural flow of surface water and adversely affect downstream waters;
- If the design capacity is exceeded by a large storm event, the vegetation might not be adequate to prevent erosion and the channel might be destroyed. Clogging with sediment and debris reduces the effectiveness of for storm water conveyance; and
- Ponding can allow mosquitos to breed.

The maintenance requirements of vegetated buffers/natural conveyance systems include:

- Mowing
- Litter and sediment removal
- Spot vegetation repair

Vegetated Buffers / Natural Conveyance Scorecard

Vegetated buffers and natural conveyance practices provide wide-ranging water quality and water quantity benefits. The information presented below is for comparative purposes only. Values to be used for design purposes or to calculate pollutant load reductions should be determined through additional research.

WATER QUALTIY CATEGORY	REMOVAL EFFICIENCY*
TSS	55%
Phosphorus	50%
Metals (Cd, Cu, Pb, Zn)	50%
Nitrogen	50%
Pathogens	50%
Toxins	50%

* *Efficiency = % removal of influent concentration (median)*
Source: Winer, 2000.

WATER QUANTITY CATEGORY	APPLIC.**
Channel Protection	M
Overbank Flood Protection	M
Extreme Flood Protection	L
Recharge Volume	M

** *Applicability = suitability of practice for given purpose; H=High, M=Medium, L=Low*
Source: Minnesota, 2005.

11.3.5 Retention and Detention

Retention and detention is generally accomplished through the use of storm water ponds and/or storm water wetlands. Both provide similar

Retention / Detention Scorecard

Retention / detention practices provide wide-ranging water quality and water quantity benefits. The information presented below is for comparative purposes only.

water quality benefits, but ponds generally provide more effective water quantity control. These practices are discussed below:

- Storm water ponds – constructed basins that: 1) receive and hold runoff to improve water quality through settling and biological uptake; and 2) prevent downstream channel degradation or flood damage through peak flow reduction (detention) and total runoff reduction (retention); variation include:
  - Dry Detention – primarily designed for flood control; generally grass-lined so pollutant removal by settling only;
  - Wet – include a permanent pool of water which supports vegetation to enhance biological pollutant removal;
  - Wet Detention – a combination of a wet pond for water quality treatment and detention above the permanent pool for extreme runoff events;
  - Evaporation Basin – similar to a wet pond, but generally shallower to facilitate evaporation; and
  - Reuse – pond which acts as a source for water, primarily irrigation; and
- Storm water wetlands – constructed shallow marshes that: 1) receive and hold runoff to improve water quality through settling and biological uptake; 2) provide detention and retention benefits similar to, but less effective than, storm water ponds; and 3) provide additional benefits such as aesthetics and wildlife habitat; variation include:
  - Wetland/Marsh – provide shallow wetland areas and deep marsh areas for different biological treatment types;
  - Extended Detention – similar to the wetland/marsh but with extended storage above the normal water surface;
  - Wetland/Pond – the wet pond situated near the inlet allows pollutants to settle out prior to entering the more environmentally sensitive shallow wetland area; and
  - Submerged Gravel – more like a filtering system in which runoff is treated as it flows through a submerged bed of gravel that incorporates wetland vegetation.

Benefits of retention/detention systems include:

- Able to effectively reduce pollutant loads and control runoff;
- Relatively straightforward pond design procedure; and
- Potential wildlife habitat, aesthetic or recreational enhancement.

Limitations of storm water ponds include:

- Relatively large space requirement;
- Increase water temperature / cause downstream thermal impact;
- Potential nuisance for insects or odor;
- Poor in areas of low slope, high water table, and shallow bedrock;
- More complicated wetland design procedure; and
- Water quality behavior can change seasonally.

Maintenance includes annual vegetation and sediment accumulation inspections, monthly debris removal, and 5-year to 20-year sediment removal.

11.3.6 Bare Soil Repair

Areas of bare soil have the potential to erode and load sediment into waterbodies. The most problematic bare soil areas are those near waterbodies or those near impervious surfaces. Bare soil repair steps include:

- Repairing soil problem areas on public land and contact private landowners to encourage repair;

- Researching the possibility for instituting corrective action on private lands through various enforcement mechanisms; and
- Implementing enforcement mechanism if possible, and correct bare soil problems on private lands.

Efforts to repair bare soil include grass or native vegetation planting and sod placement or the use of containing structures, retaining walls, or terracing. Steep slopes which contribute to the problem may be mitigated with stabilization structures, including vegetation, and grade breaks.

11.3.7 Streambank / Shoreline Stabilization

Streambank and outfall erosion are of critical concern because the eroded soil directly enters a waterbody. Stabilization steps include:

- Repair eroding streambanks in accessible locations;
- Seek access to problematic locations through interactions with appropriate stakeholders and repair streambanks when access issues are resolved; and,
- Document that stream hydraulics for new or retrofitted channels will not cause the problem to return.

11.3.8 Road and Ditch Stabilization

Road and ditch erosion is of critical concern because the eroded soil may directly enter the storm sewer system or a nearby waterbody (through runoff or by wind action) and may also cause a public safety concern. Road and ditch stabilization steps include:

- Repairing failing paved roads, paving or stabilizing dirt roads, and stabilizing ditches and embankments on public land and contact private landowners to encourage repair;
- Researching the possibility for instituting corrective action on private lands through various enforcement mechanisms; and
- Implementing an enforcement mechanism and correcting eroding roads and ditches on private lands.

11.3.9 Streambank Use Exclusion

Certain activities in the riparian corridor may exacerbate soil erosion problems. These may include ad hoc walking trails too near a waterbody (as opposed to planned and properly constructed trails) or livestock with access to a stream. Streambank use exclusion steps include:

- Identifying local problematic uses;
- Installing physical barriers to restrict access where appropriate and feasible;
- Installing educational / informational signage; and
- Engaging in cooperative efforts with riparian landowners to restrict harmful uses.

11.3.10 Specific Site Control

Certain sites (e.g. landscaping supply companies), have the potential to generate large amounts of sediment that may unintentionally enter the storm water drainage system either on-site or by being transported off-site and deposited on impervious surfaces. Steps for site-specific controls include:

- Identifying specific sites;
- Developing appropriate procedures or structural modifications to implement at these sites and working with the sites to realize the improvements (i.e. on-site vehicle washing for vehicles dealing with sediment generating substances); and
- Installing appropriate structures in the public right-of-way (i.e. rock entrances designed to dislodge sediment from vehicle tires).

11.3.11 Structural Controls

Where point sources cannot be controlled with sensitive site actions or non-point sources are a problem, structural controls may be added that intercept sediment either before it enters or before it is discharged from the storm sewer system. This practice involves Installing controls (e.g. catch basin inserts, grit chambers) in strategic locations. The implementation of structural controls should be coordinated with road or utility work to reduce installation costs.

11.3.12 Agricultural BMPs

Runoff and wind-borne pollutants from agricultural areas have the potential to introduce excessive loadings of pollutants into waterbodies. Minimizing pollution from agricultural locations involves:

- Identifying agricultural sources;
- Encouraging agricultural land operators to implement appropriate actions and encouraging them to work with appropriate agencies and funding programs;
- Contacting appropriate agencies to begin dialogue with operators and seek implementation of actions; and
- Implementing mechanisms in the public right-of-way in problematic locations where operator cooperation has not been obtained.

It should be noted that the NRCS provides a service to farm owners experiencing storm water-related problems in which a conservationist performs a site visit, free of charge, and recommends specific BMPs for the owner. The NRCS also provides significant grant funding to owners to implement these BMPs. Based on these findings, it is recommended for the planning area to work with the owner of this field to explore the possibility of utilizing this service.

The Michigan Right to Farm Act, P.A. 93, 1981, provides farmers with protection from nuisance lawsuits and authorizes the development and adoption of Generally Accepted Agricultural and Management Practices for farms in Michigan to promote sound environmental stewardship and help maintain a farmer's right to farm." The various GAAMPs that have been developed can be accessed from the MDA's website by selecting 'Farming' → 'Environment' → 'GAAMPs' in the link list on the left-hand side of the page.

12.0 OTHER CONSIDERATIONS

Additional considerations not addressed elsewhere in the plan are discussed in this section.

12.1 CONSIDERATIONS BY AGENCY / ENTITY

The following sub-sections list recommendations for each agency undertake to make the long-term management of storm water in the planning area more effective, transparent, and cooperative.

12.1.1 City of Mt Pleasant

The City should evaluate model flows against contracted flow arrangements to ensure flow capacity is being utilized equitably. Ownership / maintenance arrangements should also be evaluated (e.g. the large pipe through the CMU campus used by MDOT, the City, and CMU)[40].

Areas highlighted in the database with unresolved asset issues or missing plans should be investigated to get a full picture of assets and their connections.

12.1.2 Union Township

Union Township should adopt the City / County storm water regulation language (or cooperatively develop new language for the existing regulations) so that all three entities have matching standards.

12.1.3 ICDC

A number of issues in drain districts throughout the planning area should be addressed to clarify asset ownership and responsibility. The ICDC should also seek to digitize records and improve access to information for planning area agencies / organizations.

12.1.3.1 Lea Drain and District

The City currently utilizes the originally constructed Lea Drain outfall just south of Pickard Road east of the railroad tracks. Other upstream areas also interconnect and intercept flow from segments of the original Lea Drain. These assets have been assigned to the City as owner / operator in the database but no documentation has been located indicating that the drain / district has been vacated.

It is recommended that the ICDC provide this documentation to the City if the drain / district has been vacated or officially vacate the drain / district if this has not already been done. The portion of 6-inch pipe along Pickard Road west of the City limits would be in under ICRC jurisdiction if vacated but it does not appear to connect to any ICRC structures.

12.1.3.2 West Side Drain and District

The City currently utilizes the originally constructed West Side Drain outfall on the south side of Broadway Street about 700 feet west of the river. Other upstream areas also interconnect and intercept flow from segments of the original West Side Drain. These assets have been assigned to the City as owner / operator in the database but no documentation has been located indicating that the drain / district has been vacated.

It is recommended that the ICDC provide this documentation to the City if the drain / district has been vacated or officially vacate the drain / district if this has not already been done.

12.1.3.3 Beltnick Drain

The original Beltnick Drain connected to the West Side Drain just east of the current City limits south of the Broadway Street alignment. Much of the old drain appears to have been abandoned / removed with the installation of the new Beltnick Drain (which connects to the City's Bradley Street Storm Sewer) and nearby development in the Township.

[40] Note that there appears to be no City easement in place for this sewer and it is not located in a public ROW.

The old West Side Drain tile is still served through a 15-inch storm sewer in an easement west of Bradley Road along the Fessenden Avenue alignment. A portion of the old Beltnick Drain may still be connected and served along these conveyances. If this is the case, the easement along the old pipe (within the City limits) and ownership of the remaining in-ground assets should be officially transferred to the City. If this has already been done, appropriate documentation should be provided.

12.1.3.4 Upton Drain and District (including upstream drains)

It would be beneficial to clarify the legal status of the Log Cabin Drain and small upstream reaches of the Upton Drain (which if any reaches have been vacated) and to clarify the ownership of assets and what currently constitutes the Upton Drain in the vicinity of the CMU ponds. Additionally, the Cole Drain north of Deerfield Road only serves CMU campus. It may be worthwhile to vacate this portion of the drain to avoid issues of overlapping jurisdiction and asset ownership.

12.1.3.5 Hance Drain and District (including upstream drains)

Notes indicate that the Turney Drain was vacated in 1977 but the original drain pipe connects to the City sewer in Broadway Street (upstream of the end of the Hance Drain) and routes flow from a catch basin adjacent to a church driveway. If the drain has been vacated, documentation should be provided to the City.

The Hance Improvement Drain Branch No 2 and its district (serving Smalley Drive, Greenfield Drive, Michigan Street, and Williams Street) currently exists wholly within the City. It may be prudent to vacate the drain and transfer ownership of the assets in this area to the City, if this is not already been done.

12.1.3.6 Onion Creek Drain and District (including upstream drains)

Numerous notations have been observed pertaining to vacated and/or abandoned portions of the Onion Creek Drain. The following steps should be taken to clarify asset ownership / jurisdictional issues:

- Provide documentation of vacating of the drain through the Oxford Row area and for any other portions of the drain currently within City limits.
- If Branch No. 1 has not been vacated, it may make sense to officially vacate that portion within the City limits.
- If the Neff Extension Drain west of Isabella Road has not been vacated, it may make sense to officially vacate that portion and transfer the assets to the ICRC.
- If plans are available for Sterling Drain work done before it was vacated please provide those to the City as numerous assets from the drain still interconnect to the City storm sewers.
- No active inlets to the Sponseller Drain can be identified and the only structure identified in the field (in Mission Road) is largely filled with sediment. Since the City is legally responsible for the drain outlet, it is appropriate to vacate the drain.

12.1.3.7 Quarterline Drain / Quarterline Extension Drain and District

Notes indicate that portions of the Quarterline Drain (particularly within City limits, west of Packard Road) were previously abandoned. The City maintains an interconnection with an pond and related assets along the drain. If possible, documentation should be provided to the City related to the vacated portions of the drain.

Additionally, the drain now exists in two distinct drainage areas with different outfalls (bisected by US-127). It may be appropriate to establish separate districts for each or to vacate the drain portion along Airport Road to the ICRC.

12.1.4 ICRC

The ICRC should also seek to digitize records and improve access to information for planning area agencies / organizations. The road design standards and storm water connection standards should also be easily accessible for the public and planning area agencies / organizations.

12.1.5 CMU

CMU should seek to formalize a cost-sharing arrangement with the ICDC / ICRC for inter-jurisdictional storm water drainage / service and upgrades required for these assets.

12.1.6 MDOT

MDOT should also seek to digitize records and improve access to information for planning area agencies / organizations. MDOT should also obtain an easement for the Grewes Drain (or should encourage the ICDC to establish a legal county drain) as the drainage path for a large portion of its runoff from the northern portions of US-127 and US-127 BR.

12.1.7 SCIT

The Tribe should officially adopt the development standards that have been adopted by the co-located jurisdictions of the City, Township, and ICDC.

The SCIT water quality program is an extremely valuable source of water quality data for all stakeholders in the area and should be continued. The past and future data will be extremely valuable in tracking long-term changes in water quality in the area due to continued growth in the area and to assess the impacts of improved storm water management.

12.2 Future Planning and Actions

When determining the specific actions to implement, each entity represented by the plan can reference "Opportunities for Water Resource Protection in Local Plans, Ordinances, and Programs" (SEMCOG, 2002) to help determine deficiencies and suggested improvements in the following categories:

- Stormwater Management Standards, including;
  - Limiting pollutant levels in runoff
  - Limiting peak runoff rates and discharge volumes
  - Prescribing engineered BMPs such as infiltration, retention, and detention
  - Mandating impervious surface requirements
  - Requiring preservation of natural drainage (e.g. natural topography, sheet flow, open channels)
- Engineered Best Management Practices;
- Infiltration Practices;
- Impervious Surface Reduction, including:
  - Parking Lots and Streets; and
  - Lot Setbacks, Widths, and Coverage;
- Land Conservation and Development Techniques, including:
  - Open Space and Parks Acquisition;
  - Conservation Easements and Similar Tools;
  - Urbanized Community Activities;
  - Rural Community Activities; and
  - Clustering and Open Space Development;
- Soil Erosion and Sediment Control;
- Sanitary Sewer Planning and Infrastructure, including:
  - Septic Systems; and
  - Illicit Discharge Elimination;
- Groundwater Protection;
- Green Infrastructure;
- Natural Area Preservation and Restoration, including:
  - Habitat;
  - Native Plant Species;
  - Wetland Protection;
  - Woodlands Preservation; and
  - Stream Corridors and Floodplains;
- Capital Improvement Plan;
- Watershed-based Activities;
- Public Education;
- Pollution Prevention / Good Housekeeping; and
- Development Review Process.

The document "Filling the Gaps: Environmental Protection Options for Local Governments" helps local governments sift through the approaches of protecting the environment from a top-down approach: applicable federal laws, applicable state laws, how these apply to various environmental features, and options for local governments authorized by federal and state law to protect the various environmental features.

An important first step in long-term storm water management / planning is to develop a comprehensive assessment of the environmental conditions in the planning area and the stressors impacting them so that long-term solutions can be implemented strategically and cost-effectively. Emerging stressors should be evaluated in this context to ensure long-term efforts do not exacerbate the impacts of such stressors and actively minimize their impacts, where possible.

This conditions and stressors assessment should be regularly updated to account for changing conditions and to incorporate new information and public perceptions. Approaches for maintaining such this assessment include conducting: stakeholder surveys, additional field assessments, and reports from field crews (for which reporting protocols may be developed and adopted). Focus should also be placed on distinguishing wet weather and dry weather stressor sources and their relative contributions.

When a lake or stream does not meet Water Quality Standards (WQS), a study is led by EGLE to determine the amount of a pollutant that can be put in a waterbody from point sources and nonpoint sources and still meet WQS. The result of this study is termed a 'Total Maximum Daily Load' (TMDL) and describes how much of a pollutant a lake or stream can assimilate.

There are two statewide TMDLs that intersect the planning area: one for PCBs and one for E. coli (includes all of the planning area except the Onion Creek drainage basin). Based on the most recent data from the EPA, certain waterbodies in the Chippewa River / Mission Creek drainage basin will be subject to a future TMDL for fish consumption due to compounds like DDT and dioxin.

12.3 Uniform Standards / Consolidated Guideline Reference

Effectively managing storm water requires employing a broad range of environmental protection planning and regulatory options at the local and county government level and through permitting, regulation, and guidelines for other asset-owning entities (e.g. government agencies for the State of Michigan). The techniques, designed to minimize negative impacts of land use decisions, can be used separately or in most cases together, to establish the amount of protection and effort a community or planning group is comfortable with. These efforts can range from simply targeting peak flow reduction of storm water runoff into waterbodies to attempting to meet ambitious water quality targets. The techniques that are selected need to be crafted with professional planning and legal assistance to fit each stakeholder and its available resources.

The remainder of this section presents three levels of planning that need to be considered in storm water management: 'Coordinated Planning', 'Zoning', and 'Advanced Regulation'. Coordinated Planning and Zoning are the most familiar options, but Advanced Regulation tends to provide the most powerful protection authority. These three levels are discussed in the following subsections, along with some additional considerations.

There are many objectives to such efforts and those with noted stormwater considerations include:

- encouraging infill and redevelopment (i.e. relaxing frontage and setback requirements);
- encouraging open space in development and redevelopment projects;
- limiting future infrastructure expansion (i.e. sewer and water service boundaries);
- restricting the construction of private roads;
- developing urban growth boundaries;
- restricting development in the 100-year floodplain;
- setting large minimum lot sizes for development;
- requiring cluster development;
- implementing forest districts; and
- implementing farming districts to preserve farmland.

The information presented in this section is intended to be informational in nature and does not evaluate the current standards utilized by the various stakeholder agencies. Some information about existing zoning, regulation, standards, and planning/permitting procedures are presented for comparative purposes.

12.3.1 Coordinated Planning

The first step for a local government to manage storm water is to prepare a future land use plan in cooperation with neighboring jurisdictions. Future land use plans (also known as Comprehensive Plans or Master Plans) should be based on a comprehensive inventory of natural resources and environmental features. Because the environment knows no jurisdictional boundaries, the most effective plans are developed when communities work together, as this prevents competing or incompatible actions. If one community along a river approves development in a floodplain, downstream communities are likely to be flooded. If one community on a lake adopts keyhole development regulations, but other communities abutting the same lake do not, then achieving the objective of preventing overuse of the surface of the lake is not likely to be achieved. If one community establishes a buffer zone around sensitive environmental areas, but abutting jurisdictions do not, then the benefits of the buffer zone will be limited. These examples demonstrate the importance of communities working cooperatively in the development of plans and the implementation of programs to protect our natural resources.

A future land use plan sets forth the desired pattern of land uses in the community for the next 20 to 30 years. It shows where agricultural and forest land should be retained and where new residences, commercial and industrial areas should be constructed. It creates the basis for planning for new roads, sewers and water infrastructure to meet the needs of the land uses displayed on the map. Future land use can work with nature, or against it. Communities can plan to keep development out of floodplains and population density low along waterbodies. Communities can plan to preserve greenbelts for wildlife and vegetation along waterbodies to help filter storm water runoff and provide space for trees to shade streams, keeping temperatures lower and improving habitat. By planning with nature, they can preserve the characteristics of nature that immeasurably add to our quality of life. Following is a list of key strategies that communities can follow in the development of local future land use plans to help protect the environment and natural resources for use and enjoyment by both present and future generations:

- Prepare local future land use plans based on a comprehensive inventory of natural resources;
- Keep density and intensity of land use low near and along watercourses;
- Avoid developing in sensitive areas like floodplains, wetlands, environmental areas, sand dunes and high risk erosion areas;
- Plan for greenbelts and buffers along watercourses;
- Provide for links between natural areas so wildlife have safe corridors to move within;
- Protect renewable natural resources like farm and forest land in large blocks; and
- Set forth the specific zoning and other land use regulations that should be adopted to promote wise natural resource management and environmental protection.

The future land use plan provides the legal foundation for local land use regulations. If the community wishes to protect natural resources and the environment through local land use regulations, then it must have a basis for these regulations in the future land use plan and then adopt zoning and related regulations consistent with the plan. However, to realize the maximum benefit, communities must coordinate the future land use plan with the planning efforts of adjoining communities and other entities that own stormwater assets in a given planning area.

12.3.2 Zoning

Zoning is the principal local tool for guiding land use change in a community. Zoning classifies land uses into zones or districts generally on the basis of land use intensity ranging from “high” (e.g. industrial) to “low” (e.g. nature preserve) intensity. The range of intensity is based largely on environmental impacts and infrastructure needs of the land use. A zoning map illustrates the location of various zones or districts within a given jurisdiction. Within each zone, a range of land uses are permitted by right, or after some special review and approval process. The zoning ordinance establishes development standards for each mapped district. This includes the uses permitted, building height, bulk, lot size, setback, minimum yard and related standards. If the zoning ordinance has appropriate standards to protect our waterways and minimize harm to them as new development occurs, then not only the present generation, but also future generations will benefit.

An enforceable zoning ordinance requires that it be based on some type of plan for a given community, such as a land use master plan. Zoning options include:

- Form-based Zoning (also called Character-based Zoning) – this type of zoning is intended to facilitate predictable, contextually-based planning and development of walkable, mixed use, human-scaled places of character, accomplished by establishing a range of standards for Use and other elements of development that define a place.[41]

- Watershed-based Zoning – this is a zoning methodology designed to consider information presented in the context of a plan developed for a particular drainage / runoff area.
- Prescriptive Zoning – characterized by segregation of land uses into districts; includes very explicit standards and use exclusions.
- Mixed-Use Zoning – exemplified by the juxtaposition of different uses to reduce automobile dependence, preserve green space, and promote a sense of community.
- Incentive Zoning – a reward-based system to encourage development that meets established development goals.
- Performance Zoning – uses goal-oriented criteria to establish review parameters for proposed development projects in any area of a municipality.

The City of Mt. Pleasant adopted a Form-based Zoning ordinance, that established four Character Districts plus five Special Districts; and took effect on February 21, 2018. A copy of the current zoning map can be found in Appendix K.

The four Character Districts include CD-3L (Sub-Urban Large Lot), CD-3 (Sub-Urban), CD-4 (General Urban), and CD-5 (Urban Center). The five Special Districts include SD-H (Hospital, for a small hospital campus), SD-I (Industrial, for light manufacturing), SD-RC (Research Center, for a business park focusing on scientific, business, and industrial research, testing and production), SD-A (Agricultural), and SD-U (University use). The Zoning Ordinance defines the use, building type(s), density, and characteristics (lot size and setback requirements, block size, building standards, and thoroughfare elements, including sidewalks, curbs, landscaping, and other elements) for the Character and Special Districts. Stormwater management must be accomplished in the context of the City's Zoning Ordinance requirements and standards.

12.3.3 Advanced Regulation

There are many regulatory options communities may consider for improving storm water management. This section describes three regulatory tactics that are available to communities to better protect their local natural environment and water resources. These tactics are not mutually exclusive nor are they interdependent. Because of this flexibility and the potential complexity, it is important that properly trained planners and attorneys be involved in developing ordinance language in the context of a community's planning and regulatory structure. The options are discussed below:

- The first tactic is ordinance language that specifically addresses storm water management. These models could be adopted as overlay zones in the zoning ordinance, or as a separate ordinance that applies to development in particular locations, in addition to zoning;
- The second tactic is a series of brief ordinance provisions that address common natural resource and environmental protection concerns associated with storm water management. These provisions are commonly found in zoning ordinances across the state; and
- The third tactic focuses on coordinating land use permit review and approval procedures between EGLE and local zoning authorities. This approach is based on refining the local site plan review procedure

Other asset-owning stakeholders (i.e. non-municipal) may develop internal rules and guidelines that serve similar purposes but apply specifically to the entities operations and to those that utilize the assets.

12.3.3.1 Adopt Ordinance Language Targeted at Storm Water and Other Natural Resources

Separate statutory authority exists for local units of government to adopt regulations to protect the following natural resources:

- Environmental areas (e.g. sand dunes, submerged lands, forests);
- Wetlands;
- Soil erosion and sedimentation control;
- Inland lakes and streams;
- Natural rivers;
- Floodplains;
- High risk erosion areas; and
- Landmark trees.

[41] Mt Pleasant, Michigan Chapter 154 Zoning Ordinance, Town Planning & Urban Design Collaborative LLC

Mt Pleasant Stormwater Ordinance

The City adopted its current Storm Water Management ordinance (No. 992 of the City Code) in 2015. The ordinance was prepared in collaboration with the Isabella County Drain Commissioner's office, the Charter Township of Union, Chippewa Township, and the City of Mt. Pleasant. The City Storm Water Management Ordinance provides both general compliance requirements, and specific retention and detention standards for stormwater management practices, and establishes an approval process for stormwater management for new developments and redevelopment to accomplish the following objectives:

- Reduce artificially induced flood damage;
- Minimize increased storm water runoff rates and volumes from identified new land development;
- Minimize the deterioration of existing watercourses, culverts and bridges, and other structures;
- Encourage water recharged into the ground water where geologically favorable conditions exist;
- Reduce non-point source pollution;
- Maintain the integrity of stream channels for their biological function, drainage and other purposes;
- Minimize the impact of development upon stream bank and streambed stability;
- Reduce erosion from development or construction projects;
- Preserve and protect water supply facilities and water resources by means of controlling increased flood discharges, stream erosion, and runoff pollution;
- Reduce storm water runoff rates and volumes, soil erosion, and non-point source pollution, wherever practicable, from lands that were developed without storm water management controls meeting the purposes and standards of the ordinance; and
- Reduce the adverse impact of changing land use on water bodies and, to that end, the Storm Water Ordinance establishes minimum standards to protect water bodies from degradation resulting from changing land use where there are insufficient storm water management controls.

As such, stormwater management is highly regulated for new developments and re-developed areas in the City of Mt. Pleasant.

Isabella County Stormwater Ordinance

Isabella County has adopted the same set of storm water regulations as presented above. The regulations assign the ICDC to be the backstop organization having site plan approval unless an incorporated portion of the County (e.g. city, charter township, or village) asserts its authority to be the entity that reviews and approves them.

The ordinance also highlights the numerous situations that involve the permitting of other agencies when work that impacts storm water is being planned and implemented. This information is presented in the 'Coordinated Permit Review and Approval Procedures' sub-section below.

Union Charter Township Stormwater Ordinance

While Union Township participated in the process drafting the shared ordinance that was adopted by City and the County, the Township has yet to officially adopt the ordinance and still enforces an ordinance that was originally drafted in 1991.

This ordinance states that: '*The purpose of this ordinance is to reduce or eliminate the hazards to the public health and safety caused by excessive stormwater runoff; to reduce the economic losses to individuals and the community at large; to enhance broader social and economic objectives; and to protect, conserve, and promote the orderly development of land and water resources*'. The ordinance is similar in a general sense to the City/County shared ordinance but differs in aspects of language, procedures, and some development standards.

Central Michigan University

CMU is subject to the shared City/County storm water ordinance but maintains its own internal 'Storm Water Management Design and Performance Standards' to ensure it is in compliance with the shared ordinance and that its development efforts further minimize the potential for flooding on campus and that discharged storm water meets minimum quality standards.

12.3.3.2 Zoning Ordinance Provisions that Cover a Wide Range of Environmental Issues

Many local units of government are unwilling to take on the significant administrative responsibilities and potential liability associated with implementation of some or all of the model ordinance language described in the first option above. Many simple approaches to environmental and/or natural resource protection are available and include:

- Require applicants to submit an environmental assessment which details the impact of the proposed development on natural resources.
- Buffer strip or greenbelt provisions that address the application of fertilizers or weed killers in near shore and stream bank areas, the trimming of shoreline vegetation for views, prohibitions on removal or replacement of natural shoreline vegetation with grass or ornamental landscaping, or requiring restoration of damaged natural vegetation on stream banks.
- Developing and implementing groundwater protection standards as a part of the local site plan review process.
- Listing a set of sensitive areas or natural features in the community and requiring that all new structures or intensive use areas of the proposed development be set back at least a certain distance from the identified natural feature.
- Encouraging planned unit developments (PUDs) and cluster developments that are designed around a sensitive natural feature like a small pond or wetland or generalized open and shared space. Good design with a large natural vegetation buffer area around the sensitive resource can result in its protection as an asset to the PUD.
- Incorporating better site design options into the site plan review process, including:
  - Decreased number of parking lots;
  - Providing compact car parking spaces and minimizing stall dimensions;
  - Encouraging shared parking;
  - Minimizing required street pavement width based on need to support travel lanes, street parking, and emergency, maintenance, service vehicle access;
  - Optimizing street layout to minimize total roadway length;
  - Minimizing required street right-of-way widths to accommodate travel-way, sidewalk, and vegetated open channels;
  - Minimizing the number of street cul-de-sacs and reducing cul-de-sac radius to accommodate emergency and maintenance vehicles;
  - Considering alternative turnarounds, including the use of mountable curbing and grass shoulders for occasional access by fire trucks and other large commercial trucks;
  - Promoting flexible design standards for residential subdivision sidewalks such as locating sidewalks on only one side of the street and providing common walkways linking pedestrian areas; and
  - Relaxing side yard setbacks and allowing narrower frontages to reduce total road and driveway lengths within the community.

A detailed analysis of the advanced zoning ordinance provisions of the stakeholders in the planning area is beyond the scope of this report. It is the purpose of this discussion to illuminate the kind of options that are available to municipal entities like the City, Township, and County. CMU has the ability to go above and beyond requirements of the City and County in managing its land and infrastructure. Its unique status as a state-funded university does place certain limits on it and creates some complex inter-agency issues (e.g. the ICDC cannot legally assess campus land). MDOT and the ICRC have the ability to improve road design standards, maintenance and management practices, and enforce practices on adjacent landowners who desire to connect stormwater drainage systems to sewers owned by these entities.

12.3.3.3 Coordinated Permit Review and Approval Procedures

An effective way to combine the strength of local zoning with the weight of state environmental permitting and enforcement is for local governments to coordinate zoning decisions with EGLE and MDNR when sensitive natural features are involved. When local governments have appropriate, but limited environmental protection standards in the zoning ordinance, they can condition final development approval on receipt of necessary permits from the state government. This type of coordinated review and approval process helps ensure key environmental and natural resources are protected as new development occurs.

The multi-jurisdictional nature of storm water management in the area makes a coordinated approach necessary. As the shared ordinance language indicates:

- EGLE has jurisdiction over work done in the 100-year floodplain, near inland lakes and streams, and in wetland areas
- MDOT has permit requirements that must be met to discharge to drainage that serves its managed ROWs including major highways, state roads, and railroads
- ICRC has permit requirements that must be met to discharge to drainage that serves its managed ROWs including major county roads and minor roads outside of incorporated areas
- The ICDCD has permit requirements to manage Soil Erosion and Sediment Control (SESC) activities
- The ICDC has jurisdiction for site plan review for all developments in the county unless another incorporated jurisdiction is exercising its authority under the shared ordinance provisions

Through the 'Joint Permit Application' with the USACE, EGLE implicitly engages in collaboration with that federal agency. EGLE also has implementation authority for the Environmental Protection Agency's (EPA's) National Pollutant Discharge Elimination System (NPDES) program that may be expanded to include portions of the planning area in the future.

12.3.4 Additional Measures to Consider

Some other common zoning techniques that have significance as regards to certain decisions affecting natural resource and environmental protection are presented below.

12.3.4.1 Nonconforming Uses

Uses of land that pre-date the zoning ordinance or an ordinance amendment that no longer comply with zoning regulations are called nonconforming uses. Essentially, these uses are protected from changes created by new zoning regulations. Local governments are permitted to restrict or prohibit expansion or structure additions of nonconforming land uses or structures, with the long-term goal of eventually phasing them out.

12.3.4.2 Rezoning

The process of changing from one zoning district classification to another is called rezoning. The most fundamental question which must be asked regarding a rezoning request is whether the area proposed to be rezoned is an appropriate area for the permitted uses in the proposed zone. Typically, rezoning requests are made for the purpose of increasing the intensity of the use of a parcel. In riparian areas, where there are significant, fragile natural features such as critical habitats and wetlands, rezoning from a low-intensity use classification to a high-intensity use classification could have significant ecological impacts.

12.3.4.3 Special Land Uses

Special land uses, also called conditional uses or special exception uses, are uses of land that are allowable within a particular zone only when the proposed activity meets a defined set of standards that are particular to that use and are included in the zoning ordinance. Site-specific issues can be addressed using these designations as opposed to the more general considerations typical of a zoning district.

12.3.4.4 Variances

A variance is a legally granted action to waive a requirement in a zoning ordinance. If a community grants a variance, it permits one property owner to do something that is otherwise not permitted in the zoning ordinance. As a result of the zoning enabling acts, most zoning ordinances and court cases have a very narrow set of circumstances that must exist before a variance can be lawfully granted. In most cases, if a property owner can use the land for the desired use, or place a structure or addition elsewhere on the land without a variance, then the variance is not appropriate. As is apparent, the improper granting of a variance can quickly undermine the integrity of the zoning ordinance. This is even more consequential when the variance has the effect of undermining the integrity of natural resources. In general, if communities adopt zoning measures to protect natural resources and prevent pollution, impairment or destruction of the watershed, they should consider variance requests very carefully and only grant them when not doing so would preclude the land owner from otherwise exercising a lawful property right. Even then, the community should consult with environmental professionals and attorneys familiar with zoning and environmental law.

12.3.4.5 Land Division and Subdivision Ordinances

Two of the local regulatory tools with the greatest potential to minimize harm in sensitive environmental areas are regulations that apply to land divisions and subdivisions. These are usually two separate ordinances that are linked to the zoning ordinance, but because the authority for them derives from a statute different from the zoning enabling acts, they are adopted as separate ordinances. The first is usually known as a land division ordinance. The second is usually called a subdivision or plat ordinance.

The primary environmental issues associated with land divisions and plats relate to lot width, depth, area, access and "buildability". Proper review and approval of land divisions and plats can dramatically reduce future problems associated with use of the lots. The process is similar to site plan review described earlier, except that in the case of plats, there are many statutorily required reviews by different entities, including the local government, the county road commission, drain commissioner, Michigan Department of Transportation (MDOT), and EGLE, depending on the location and characteristics of the parcel being platted. For example, deep narrow frontage lots along shorelines will often result in long driveways and many structures close to the water. This often translates into considerable impervious surface and water runoff which can carry pollutants, nutrients and warm water into the lake, river, stream or pond. Shallow lots also often have considerable impervious surface and leave little room to site a structure farther from the shoreline. This may be critical in the case of a high risk erosion area, wetland, or floodplain.

The best proactive measures a community can take to prevent the creation of lots that do not undermine the integrity of the environment and are "buildable", are listed below:

- Adopt and consistently administer land division regulations and subdivision regulations;
- Try to persuade landowners who propose to create "unbuildable" lots not to do so. If unsuccessful, file a notice with the County Register of Deeds that runs with "unbuildable" parcels that informs purchasers of the unique status of such lots; and
- Put overlay provisions in the zoning ordinance which:
    - Require wide and deep lots with shared access; or
    - Ensure lots are clustered with all the common open space along the shoreline, sensitive environmental areas are avoided and all access is shared.

12.3.4.6 Public Spending and Capital Improvement Programs

Another important way to protect sensitive natural features is to watch how, where and when the public spends money on public facilities. Where new public facilities are constructed and where they are not can have profound effects on natural resources. The extension of sewer and water lines into a sensitive environmental area or the construction of a new road along a large wetland will have significant long term impacts–many of which could be negative. At the same time, the construction of a sewer line around an inland lake being contaminated by leaking septic tanks can help restore water quality in the lake. Communities that work with nature avoid creating the conditions which promote intensive development in areas with a large area of sensitive natural features.

12.4 Good Housekeeping and Pollution Prevention Efforts

The purpose of good housekeeping and pollution prevention is to reduce the generation of pollutants and prevent those that have been generated from reaching environmentally sensitive areas, including waterbodies.

Various efforts that fall in this category include:

- selecting and implementing pollution prevention activities for current and potential future sources of sediment contamination and identifying remedial actions for contaminated areas that are cost effective and non-threatening to the environment (in terms of contaminant re-suspension);
- defining and implementing procedures to ensure that documentation, inspection, maintenance, and cleaning of the storm sewer systems are done in such a manner that pollutant discharges from the systems are minimized;
- managing / operating other utilities (e.g. sanitary sewers) to minimize pollutant discharges, such as:
    - prioritizing the connection areas of septic service, particularly those areas near natural features or causing documented problems;
    - ensuring proper operations and maintenance efforts and upgrades to maintain system capacities;

    - replacing failing system components;
    - constructing facilities or implementing programs to prevent the occurrence of CSOs, SSOs, and basement backups (e.g. infiltration and inflow programs including downspout disconnection);
    - improving municipal and industrial pretreatment programs (e.g. reduced pollutant concentrations, reduced flows – provides offset capacity for service expansion);
    - defining of future service areas or to guide development and preserve natural areas; and
- defining and implementing procedures to ensure that the discharges of pollutants from streets, roads, highways, and parking lots are minimized, such as
    - the proper design, construction, maintenance, and reconstruction of roads, utilities, and their waterbody crossings (including proper materials handling/disposal);
    - an optimized street and parking lot sweeping schedule;
    - an optimized street and parking lot sweeping protocol (e.g. wet instead of dry to minimize wind transport);
    - an optimized pavement de-icing protocol;
    - an optimized fire hydrant flushing protocol; and
    - consideration of structural BMPs, as necessary;
- defining and implementing procedures to ensure that the discharge of pollutants from maintenance garages and other infrastructure-supporting facilities is minimized (e.g. fleet management and materials storage);
- defining and implementing procedures to ensure that the discharge of pollutants such as pesticides, herbicides, and fertilizers from turf areas is minimized, such as
    - restrictions on the types / amounts of fertilizers, pesticides, and herbicides that can be used;
    - proper training and certification for pesticide applicators;
    - optimum watering protocols;
    - optimum mowing protocols; and,
    - standards and incentives to accelerate the planting of trees on both public and private lands;
- applying appropriate environmental considerations into solid-waste management plans such as household hazardous waste management, dumpster management and maintenance, and yard-waste collection;
- defining and implementing wild, farm-related, and domestic animal waste control measures (to reduce pathogen and nutrient loads to waterbodies);
- assessing the impacts of flood management projects on water quality and examining water quantity structures for incorporation of additional water quality protection devices or practices, such as:
    - making recommendations to other entities engaging in flood control management to report the impacts on water quality; and
    - instituting a program to examine water quantity structures under the permittee's jurisdiction, developing a prioritized program to retrofit these structures, and implementing the program;
- activities for identifying and correcting illicit connections, such as:
    - dry weather screening of outfalls into waters of the state;
    - dye testing municipal facilities, including swimming pools;
    - provisions for determining the source and responsibility of the discharge, and ownership and maintenance of the sewer system and drains;
    - an integration of outfall inspections and reporting during routine field operations;
    - a 24-hour hotline that provides the public an immediate mechanism to report any water quality issues; and
    - updates to outfall location maps, when appropriate;
- minimizing pollutant discharges from On-site Sewage Disposal Systems (OSDS) through:
    - technical assistance (clustering systems, maintenance education, maintenance districts, leaching chambers, siting, etc.);
    - inspections (point-of-sale, licensing, performance level, identification of failing systems, etc.);
    - enforcement (correction of problems, maintenance checks, etc.);
    - recommendations for alternative technologies in areas where septic systems and sewers are not highly feasible sewage disposal methods; and,
    - incentives for septage transfer stations and convenient disposal facilities;
- developing and implementing a program to identify sites that have excessive trash and debris and to prioritize addressing these sites by including procedures for removing the trash and debris;

- developing a spill prevention, notification, and response program which may include assistance with investigation of major spills to waterways, fish kills and other emergency water quality issues;
- developing a program to prevent the pollution of groundwater and ensure that levels are maintained by ensuring proper recharge and restricting overuse, including:
    - a groundwater inventory to identify areas of groundwater recharge and vulnerable areas, as well as their proximity to potentially polluting activities or land uses;
    - delineation of wellhead protection areas and the development of wellhead protection plans;
    - a program to location, inspect, and close abandoned wells;
- adopting ordinances targeted to specific sources of pollution, including requirements for:
    - the maintenance and disposal of wastes from private stormwater infrastructure;
    - private pavement (e.g. roads, lots) cleaning methods, schedules, and the disposal of wastes;
    - the restriction of phosphorus in fertilizers and the proper use of pesticides, herbicides, and fertilizers, including proper disposal of excess product;
    - waste management at vehicle service stations;
    - materials storage, spill prevention, and cleanup;
    - the use and maintenance of dumpsters;
    - proper solid waste management, including prohibitions against illegal dumping;
    - proper yard waste disposal; and
    - septic systems, including: site standards (e.g. exclusion areas, lot size requirements, setbacks), performance standards, point-of-sale inspections, and annual licensing based on proof of inspection.

12.5 Public Education and Involvement

Storm water management will be most effective when the public understands the environmental challenges and is invested in rectifying them. This understanding and investment ultimately comes through education and participation in meaningful activities. Many programs are available to consider when selecting a method to promote watershed stewardship. The main targets for education and participation include: businesses, municipal employees, and the general public. Some agencies and programs that can provide assistance in this area are discussed below.

In general, the planning area agencies / organizations can utilize the materials and messages of existing educational programs, such as local watershed groups or the state, to educate and engage the public.

A successful public education and involvement initiative involves the following considerations:

- Developing a plan that defines the goals and objectives and responsibilities for public education
- Developing or selecting, and utilizing, materials for target audiences and important messages:
    - Community Education – consisting of watershed stewardship, storm water system knowledge, personal actions impacting water quality, waste management / dumping, and riparian land management, habitat conservation and restoration, native and invasive wildlife management, dissemination of planning and water quality information, registered watercraft owner information, recreation education, and a rain garden awareness program;
    - Youth Education – consisting of the community education components repackaged for students, other programs, experiments and activities, and lesson plans / info for teachers.
    - Business Education – including how facilities and operations affect storm water, pollution prevention activities to minimize this potential, environmentally-friendly construction, new ordinance details, and environmental audit assistance;
    - Agricultural Education – such as how traditional agricultural practices affect soil erosion and receiving waters, encouraging the use of state-agency approved Generally Accepted Agricultural Management Practices (GAAMPS)[42];
- Training municipal employees to be aware of how their actions affect storm water. While many different departments affect storm water in some way, a key department is the maintenance department. Maintenance staff maintain fleet vehicles, store chemicals, sweep streets, clean catch basins, conduct lawn care, maintain dumpsters, dispose of solid waste, and de-ice the roads.

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[42] Agricultural education activities will require the involvement of appropriate agencies including the Natural Resources Conservation Service (NRCS), Farm Service Agency (FSA), the Michigan Department of Agriculture (MDA), soil conservation districts and/or Michigan State University Extension (MSUE)

- Supporting and spreading awareness of demonstration projects for storm water management at new developments or redevelopments will help the community, including municipal officials, developers, planners, residents, and businesses, understand how storm water management techniques can be incorporated into the community.
- Utilizing strategically located educational signage to educating the public about specific issues: storm water basin and watershed boundaries; wellhead protection areas; negative impacts of common polluting behaviors; recreational area closure reasons; water quality, vegetation, and wildlife protection tips at recreational areas / boat launches.
- Supporting volunteer-based watershed programs that help increase the public involvement in addressing and awareness of storm water issues.
- Holding community forums and workshops related to storm water issues and the steps being taken to address them.
- Involving and educating municipal officials (mayors, city/village councils, township trustees, department heads, zoning boards, planning commissions, etc.) on the existence, reason for, a storm water master plan is essential to successful implementation of many of the actions.

12.6 Natural Features and Resources Management

These actions target the identification, protection, and restoration of natural features within the planning area. Natural features include animal habitat, land preserves, water resources, geology, and wildlife. The benefit of these actions is to our natural resources that provide economic and social benefits as well as vital habitat for wildlife and aquatic animals.

Major actions include:

- Identifying natural features in the planning area to target for protection and restoration actions (e.g. preserving biological populations), status of impacted lands, required actions, and cost estimates;
- Actively protecting land through obtaining titles, development rights, and conservation easements, and establishing land trusts, leases, deed restrictions, covenants, and no-net-loss policies;
- Incentivizing land protection through mechanisms such as tax credits;
- Implementing protection measures on public and private lands (to reduce alternation of these areas), such as:
    - Establishing headwater zones, riparian corridors, various habitat conservations areas (e.g. forest land), and groundwater recharge areas that require special development protocols
    - Limiting soils disturbing activities in these areas
    - Ensuring appropriate boundaries around natural areas and waterbodies are established to exclude incompatible land uses and other problem activities (e.g. limiting impervious surfaces in adjacent areas, mitigating existing impervious areas)
    - Ensuring wetlands and floodplains are hydraulically available for water retention purposes
    - Encouraging the use of open-channel flow routing and natural flow characteristics in open channel flow conveyances (e.g. using natural bank stabilizations)
    - Considering terrestrial and aquatic habitat is the design of open channel conveyances
    - Constructing, retrofitting, and managing dams, culverts, and other obstructions to minimize biological impacts and protect natural water cycles (e.g. wetland protection, minimum flow rates, flow temperatures)
- Restoring natural features on public and private lands, such as:
    - Daylighting streams;
    - Utilizing/encouraging native plantings & management techniques;
    - Engaging in or encouraging reforestation and the planting of trees;
    - Protecting endangered and threatened species;
    - Eradicating invasive and exotic species;
    - Advocating the use of backyard conservation programs by private citizens to add valuable habitat in developed areas;
    - Supporting the stocking of native fish in streams;
    - Restoring and managing areas to provide habitat and act as corridors between natural areas (such as utility corridors and roads);
    - Incentives for private landowners to allow the reestablishment of vegetated buffers around already impacted waterbodies; &
    - A wetland mitigation/expansion program.

Some vegetation management actions to consider include:

- Maintaining or introducing native landscaping;
- Critical area plantings;
- Municipal buffer zones;
- Prescribed burnings;
- Reforestation;
- Urban forestry, tree plantings and protection ordinances;
- No mow zones;
- Protecting threatened and endangered species; and
- Eradicating exotic/invasive species.

12.7 Recreation Promotion and Enhancement

These actions relate to increasing recreational opportunities in the planning area and providing education within the recreation areas related to habitat, natural features, and the relationship of storm water management to these conditions. These actions connect the public and their recreation interests to natural resources and help foster a stewardship ethic.

Recreation features to develop, promote, and to target for educational opportunities include:

- Waterbody access points (e.g. watercraft launches and landings, portage locations)
- Fishing locations
- Trails
- Wildlife and natural feature observation areas
- Protected lands
- Conserved natural riparian corridors

Such actions should be coordinated with local recreation plans and recreation-focused organizations.

12.8 Potential Partner Organizations, Programs, and Resources

There are a considerable number of agencies, organizations, and programs that can be leveraged for resources and/or partnerships in implementing actions that relate to storm water management or broader environmental quality goals. Organizations, programs, and resources that may prove useful in the context of storm water master plan efforts include:

- United States (US) Department of Agriculture (USDA)
  - Rural Development (RD) program
  - Natural Resources Conservation Service (NRCS)
  - Conservation Reserve Enhancement Program (CREP)
  - Educational Resources
- US Environmental Protection Agency (EPA)
  - Office of Water
  - Office of Wetlands, Oceans, and Watersheds e.g. (Adopt Your Watershed program)
- US Department of the Interior (DOI)
  - US Forest Service (USFS)
  - US Fish and Wildlife Service (USFWS)
  - US Geological Survey (USGS) (e.g. Water Resources Outreach Program)
- US Public Health Service (PHS)
- Michigan Department of Energy, Great Lakes, and Environment (EGLE)
  - Environmental Education
  - Surface Water
  - Nonpoint Source Program
  - Enforcement
  - NPDES Permits
  - Water Quality Trading Program
  - Septage
  - CSO/SSO
  - Biosolids
  - Industrial Pretreatment Program
  - Drinking Water / Wellhead Protection Program
  - Emergency Response
  - Groundwater Discharge Program
  - Groundwater Modeling Program
  - Inland Lakes and Streams / Joint Permit Application

    - Water Management
    - Michigan Water Quality Monitoring
    - Land Development
    - Waste and Hazardous Materials Division
- Michigan Department of Natural Resources (MDNR)
- Michigan Department of Transportation (MDOT)
    - Educational Materials
    - Drainage Manual
- Michigan Department of Community Health
- Michigan Department of Agriculture
    - Right to Farm
    - Michigan Biosolids Program
    - MA Environmental Assurance Program
    - Organic Farming
    - Groundwater Stewardship Program
    - Home*A*Syst, Farm*A*Syst, Crop*A*Syst
    - Abandoned Well Closures
- Michigan State University (MSU)
    - MSU Extension (MSUE)
    - institute of Water Research
- Michigan Conservation Districts
- Michigan Sea Grant (MSU, University of Michigan, and National Oceanic and Atmospheric Administration – NOAA)
- Michigan Turfgrass Environmental Stewardship Program (MTESP)
- North American Association for Environmental Education
- The Center for Improved Engineering and Science Education
- Freshwater Wetlands Teaching Guide
- Clean Lakes Alliance / Yahara Watershed Academy
- Enviroscapes®
- Izaak Walton League – American Wetlands Campaign and Save Our Stream Curriculum\
- Center for Global Environmental Education
- Earthforce Global Rivers Environmental Education Network
- World Wildlife Fund (WWF)
- Wildlife Habitat Council (WHC)
- The Conservation Fund (TCF)
- National Wildlife Federation (NWF)
- The Groundwater Foundation
- Michigan Agriculture Environmental Assurance Program (MAEAP)
- Michigan Audubon Society
- Michigan Environmental Council
- Michigan Nature Centers (e.g. Chippewa Nature Center)
- Great Lakes Clean Water Organization
- Great Lakes Stewardship Network
- Great Lakes Restoration Initiative (GLRI)
- Great Lakes Watershed Management System (GLWMS
- Citizens for Alternatives to Chemical Contamination
- Little Forks Conservancy
- Partnership for Saginaw Bay Watershed
- Saginaw Bay Cooperative Invasive Species Management Area (CISMA)
- Saginaw Bay Watershed Initiative Network
- Saginaw Bay Land Conservancy
- Saginaw Bay Resource and Conservation Development
- Saginaw Bay Water Trails
- Saginaw Bay Watershed Conservation Partnership

Note that the list above is not an exhaustive detailing or organizations, programs, and resources.

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13.0 DATABASE & ELECTRONIC INFORMATION DETAILS

This section details the components of the database and the data fields within each layer of data. Linear features are referred to as links while point features are referred to as nodes.

13.1 LINKS

The links layer of the database contains linear features such as pipes, culverts, and open channels.

Table 17. Links layer field details.

Field	Definition	Field Format / Values	Comments
fetID	Feature identification number	[################]	Unique numerical identifier
ParentLink	Feature identification number for a parent feature	[alphanumeric values] – 40 characters *maps to fetID field*	If a link was sectioned into multiple features (e.g. to accommodate additional nodes) this indicates the original link number for the purposes of maintaining consistency with legacy data sets
AltParLink	Feature identification number for a secondary parent feature	[numerical value] [maps to fetID field]	If two line segments from original link database were merged, this will list the one that was eliminated (for the purposes of maintaining consistency with legacy data sets)
NEW_ID	Feature identification tag for linking to model	[alphanumeric values] – 30 characters	This field is for linking features to their corresponding SSA model representations
Link_Type	Descriptor of the asset type for the feature	[alphanumeric values] Connector Open Channel Orifice Outlet Pipe Pump Spillway Weir	25-character field Non-structural link used to indicate connectivity / flow routing between nodes Open channel flow link Flow opening / restriction – connects upstream and downstream flow nodes Non-structural link used to indicate connectivity / flow routing from storage nodes Sewers and culverts Pump and force main Surface flow spillway Flow control feature – connects upstream and downstream flow nodes
UpperfetID	Identifies upstream node for the link	[##############] *maps to NODES fetID field*	14-character numerical value
LowerfetID	Identifies downstream node for the link	[##############] *maps to NODES fetID field*	14-character numerical value
Connection	Type of downstream connection	[XXX] Wye Tee	3-charcter alphanumeric value
Comment	Provides additional general information	[alphanumeric values] – 100 characters	Typically indicates assumptions about a link, plans referenced, and/or other identifying information
LocatedWit	Indicates the primary source of link information	[alphanumeric values] *the '&' character is used to separate entries* CMU CAD Field Obs. HAGPS Imagery Measurement Other Doc. Plans Sketch Survey TV	20-character field – use alphabetical order when using multiple values Asset information imported from the CMU CAD data Asset information from field observation without GPS-level locating Asset information from high accuracy GPS and pipe observations before the master plan project Asset information taken from available aerial and street-level imagery Asset information from direct measurement (relative to other assets) Asset information taken from other available sources Asset information taken from available plans Asset information taken from sketched layout Asset information from high accuracy GPS and pipe observations before the master plan project Asset information from televising
PlanNum	A reference to a plan that provides asset information	[XXXXXXXXXX]	10-character alphanumeric value
FileLink	Link to plans or other information	[alphanumeric values] – 250 characters	Path to plans or other files and/or additional asset documentation

Field	Definition	Field Format / Values	Comments
DateLocate	The date an asset was observed in the field or with imagery	[yyyy-mm-dd]	10-characeter date field
Confidence	Relative confidence in asset location / data	0, 1, 2, 3, 4	0 = poor to 4 = full confidence
Resposibl	The primary owner / operator of an asset	[alphanumeric values] City CMU ICDC ICRC MDOT Private State of Michigan	20-character field This is used for open channels in the planning area that are 'waters of the state'
SubRespons	Used to identify a department or specific owner	[alphanumeric values] – 20 characters	Additional ownership and/or management information – e.g. City sewers serving parks; private assets belonging to a school district; MDOT assets along the railroad
ParcelID	Use to locate an asset relative to parcels	[##########]	10-character field to note location relative to parcels
YearInstal	The year the asset was installed	[##########]	10-character field to store installation date information
Future	Future asset flag	[#] 1 = Yes	Used to identify assets that have been planned but have not yet been installed
ToBeAbando	Asset to be abandoned	[#] 1 = Yes	Used to identify assets that are planned to be abandoned or removed
Abandoned	Abandoned flag	[#] 1 = Yes	Used to identify assets that have been abandoned (and may or may not have been removed)
Removed	Removed asset flag	[#] 1 = Yes	Used to identify assets that have been removed
Manufactur	Asset manufacturer	[alphanumeric values]	
OriginalMa	Asset material – detailed	[alphanumeric values]	Originally entered material information
Material	Asset material – simplified	[alphanumeric values]	Updated and consolidated material information
Rehab	Rehabilitation status	[#] 0 = No; 1 = Yes; 9 = Future	Defines the rehabilitation status for an asset
Rehab_Year	Rehabilitation year	[####]	Year of past or planned pipe rehabilitation [yyyy]
Rehab_Mat	Rehabilitation material	[alphanumeric values]	40-character text field for describing pipe rehabilitation and materials
Mann_Rough	Manning's Roughness Coefficient - Channel	[#.###]	Estimated manning's roughness coefficient for flow calculations assigned based on material
Mann_Obank	Manning's Roughness Coefficient	[#.###]	Estimated manning's roughness coefficient for flow calculations assigned based on material – overbank area
minor_loss	Minor losses in conveyance	[alphanumeric values]	Text field used to describe pipe bends and other complex configurations that can contribute to head losses
Shape_Type	Conveyance shape	[alphanumeric values] Arch Broad Crested Weir Circular Elliptical Rectangular Trapezoidal	Defines the shape of conveyance depending on the Link_Type field
Diam_Bot	Conveyance diameter or bottom-width in inches	[########.#]	Diameter of circular pipe or bottom width for non-circular geometries
Width_Top	Conveyance top-width in inches	[########.#]	Top width of pipe for non-circular geometries
Height_Tot	Conveyance height / depth in inches	[########.#]	Height of pipe for non-circular geometries
YearTelevi	Most recent televising year for asset	[####]	
CleaningSt	Cleaning Stage	[##########]	Field used for organizing cleaning program in moving from upstream to downstream
Length	Original length or provided from plans (in feet)	[##########]	

Field	Definition	Field Format / Values	Comments
Cal_Length	Length calculated from spatial GIS layout	[##########]	
Invert_Upp	Upstream invert of conveyance	[###.##]	Using NAD83 datum
Invert_Low	Downstream invert of conveyance	[###.##]	Using NAD83 datum
inv_update	Indication of invert confidence	[alphanumeric values] Low No Up Yes	Update invert of low end of conveyance Inverts for conveyance are acceptable Update invert of upper end of conveyance Update both inverts of conveyance
Plan_Slope	Asset slope provided from plans	[###.#######]	Slope from sewer plans
Calc_Slope	Calculated asset slope	[###.#######]	(Invert_Upp – Invert_Low) / Cal_Length
Tile_Pipe	Tile pipe flag	[#] 1 = Yes	Flagged if plans or inspections indicate a tile pipe configuration
Perf_Pipe	Perforated pipe flag	[#] 1 = Yes	Flagged if plans or inspections indicate a perforated pipe
CB_Pipe	Catch basin pipe flag	[#] 1 = Yes	Flagged if pipe serves one or two inlet structures or catch basins, is shorter than 60 feet in length, and has no more than 1 flagged catch basin pipe upstream
Bldg_Lead	Building roof lead flag	[#] 1 = Yes	Flagged if a pipe is dedicated to routing roof drains from a building
SumpDrain	Sump drain flag	[#] 1 = Yes	Flagged if a pipe is a sump pump lead from a building or a public main dedicated to serving only sump pump leads
UnderDrain	Underdrain flag	[#] 1 = Yes	Flagged if a pipe provides drainage for the subsurface of a road or other utility / infrastructure
Model_On	Model flag	[#] 1 = Yes	Flagged if a pipe was hydraulically modeled
Under	Location of pipe with respect to structures & easements	1 to 11	1 Open ROW or Easement | 2 Paved Easement 3 Paved ROW Sidewalk | 4 Paved ROW Local 5 Paved ROW Major | 6 No Easement 7 Structure – No Easement | 8 Gravel ROW or Easement 9 Structure with Easement | 10 Paved ROW Alley 11 Outside Easement
Branch	Branch of system that pipe is part of	[alphanumeric values]	10 character field
CatchmentI	The outfall area that the pipe belongs to	[numeric values]	10 character field; legacy field
ExportArea	The outfall area the pipe belongs to	[alphanumeric values]	40 character field
QckRtgSt	Alphanumeric NASSCO rating code	[alphanumeric values]	
QRS_number	Numeric NASSCO rating code	[#####]	Equivalent to QckRtgSt except numerically formatted for GIS legend formatting
TV_DATA	Indicates	[alphanumeric values] No Yes	Indicates if TV data is available for the asset
Cap_CFS	Conveyance capacity in cubic feet per second	[######.##]	As determined by the hydraulic model
CIPcomment	CIP comments	[alphanumeric values]	Info related to capital improvement planning
CIPactive	CIP inclusion flag	[#] 0 = No 1 = Yes 2 = Yes (alternative) 9 = Yes (assumed)	Exclude from CIP calculations Include in CIP calculations Options other than pipe upsizing may be appropriate Need to assess for inclusion / exclusion
D_Change	Pipe diameter change for design modeling	[#]	Values of 0 are held constant in the design model runs
1yr_CFS_c	1-year storm flow	[######.##]	Units are CFS
1yr_CFS_f	1-year storm flow with future buildout	[######.##]	Units are CFS
1yr_CFS_x	1-year storm flow with future buildout but no ordinance restrictions	[######.##]	Units are CFS
1yr_CFS_s	1-year storm flow with future buildout & sump	[######.##]	Units are CFS

Field	Definition	Field Format / Values	Comments
1yr_c_Qrat	1-year storm flow / capacity	[####.#]	
1yr_f_Qrat	1-year future storm flow / capacity	[####.#]	
1yr_x_Qrat	1-year future no ordinance storm flow / capacity	[####.#]	
1yr_s_Qrat	1-year future storm flow & sump / capacity	[####.#]	
10yr_CFS_c	10-year storm flow	[######.##]	Units are CFS
10yr_CFS_f	10-year storm flow with future buildout	[######.##]	Units are CFS
10yr_CFS_x	10-year storm flow with future buildout but no ordinance restrictions	[######.##]	Units are CFS
10y_c_Qrat	10-year storm flow / capacity	[####.#]	
10y_f_Qrat	10-year future storm flow / capacity	[####.#]	
10y_x_Qrat	10-year future no ordinance storm flow / capacity	[####.#]	
10y_dCFS_c	10-year storm flow – unrestricted conditions	[######.##]	Units are CFS
10y_dCFS_f	10-year storm flow with future buildout – unrestricted conditions	[######.##]	Units are CFS
10ydc_Qrat	10-year storm flow / capacity – unrestricted conditions	[####.#]	
10ydf_Qrat	10-year future storm flow / capacity – unrestricted conditions	[####.#]	
25yr_CFS_c	25-year storm flow	[######.##]	Units are CFS
25yr_CFS_f	25-year storm flow with future buildout	[######.##]	Units are CFS
25yr_CFS_x	25-year storm flow with future buildout but no ordinance restrictions	[######.##]	Units are CFS
25y_c_Qrat	25-year storm flow / capacity	[####.#]	
25y_f_Qrat	25-year future storm flow / capacity	[####.#]	
25y_x_Qrat	25-year future no ordinance storm flow / capacity	[####.#]	
25y_dCFS_c	25-year storm flow – unrestricted conditions	[######.##]	Units are CFS
25y_dCFS_f	25-year storm flow with future buildout – unrestricted conditions	[######.##]	Units are CFS
25ydc_Qrat	25-year storm flow / capacity – unrestricted conditions	[####.#]	
25ydf_Qrat	25-year future storm flow / capacity – unrestricted conditions	[####.#]	
100y_CFS_c	100-year storm flow	[######.##]	Units are CFS
100y_CFS_f	100-year storm flow with future buildout	[######.##]	Units are CFS
100y_cQrat	100-year storm flow / capacity	[####.#]	
100y_fQrat	100-year future storm flow / capacity	[####.#]	
SumpPumpQ	Sump pump flow	[######.##]	Units are CFS

Field	Definition	Field Format / Values	Comments
1yr_c_D	1-year storm flow necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
1yr_f_D	1-year storm flow with future buildout necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
1yr_x_D	1-year storm flow with future buildout but no ordinance restrictions necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
1yr_s_D	1-year storm flow with future buildout & sump necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
10y_c_D	10-year storm flow necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
10y_f_D	10-year storm flow with future buildout necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
10y_x_D	10-year storm flow with future buildout but no ordinance restrictions necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
10y_dc_D	10-year storm flow – unrestricted conditions necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
10y_df_D	10-year storm flow with future buildout – unrestricted conditions necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
25y_c_D	25-year storm flow necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
25y_f_D	25-year storm flow with future buildout necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
25y_x_D	25-year storm flow with future buildout but no ordinance restrictions necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
25y_dc_D	25-year storm flow – unrestricted conditions necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
25y_df_D	25-year storm flow with future buildout – unrestricted conditions necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
100y_c_D	100-year storm flow necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
100y_f_D	100-year storm flow with future buildout necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
1yr_D	All 1-year events max. necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
10y_D	All 10-year non-design events maximum necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
25y_D	All 25-year non-design events maximum necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
100y_D	All 100-year events max. necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
10y_dD	All 10-year design events maximum. necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
25y_dD	All 25-year design events maximum. necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
10y_allD	All 10-year events max. necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts

Field	Definition	Field Format / Values	Comments
25y_allD	All 25-year events max. necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
allD	All modeled events max. necessary diameter	[###]	Inches of diameter; negative values denote additional width for existing rectangular culverts
RegProjs	Regional project cross reference	[alphanumeric values]	

13.2 Nodes

The nodes layer of the database contains point features such as manholes, catch basins, outfalls, and storm water inlets.

Table 18. Nodes layer field details.

Field	Definition	Values	Comments
fetID	Feature identification number	[unique numerical value]	
ParentNode	Feature identification number for a parent feature	[numerical value] [maps to fetID field]	If a node is partitioned into multiple nodes to represent flow network features appropriately (e.g. a weir internal to a manhole would require two nodes to represent)
AltParNode	Feature identification number for a secondary parent feature	[numerical value] [maps to fetID field]	If a node was absorbed into a single node it will be listed here
NEW_ID	Name of node in model	[alphanumeric values]	80 character field
CMU_ID	Name of node in CMU documentation	[alphanumeric values]	30 character field
IDNum	Legacy ID number	[##########]	10 character field; from storm manhole layer
StructType	Type of structure / asset	[alphanumeric values]	20 character field
Function	Function of structure / asset	[alphanumeric values]	20 character field
Comment	Provides additional general information	[alphanumeric values] – 100 characters	Typically indicates assumptions about a link, plans referenced, and/or other identifying information
LocatedWit	LocatedWit	Indicates the primary source of link information	[alphanumeric values] – 20 characters *the '&' character is used to separate entries* CMU CAD Field Obs. HAGPS Imagery Measurement Other Doc. Plans Sketch Survey TV
Plan	A reference to a plan that provides asset information	[XXXXXXXXXX]	10-character alphanumeric value
FileLink	Link to plans or other information	[alphanumeric values] – 250 characters	Path to plans or other files and/or additional asset documentation
DateLocate	The date an asset was observed in the field or with imagery	[yyyy-mm-dd]	10-characeter date field
Confidence	Relative confidence in asset location / data	0, 1, 2, 3, 4	0 = poor to 4 = full confidence
Responsibl	The primary owner / operator of an asset	[alphanumeric values] City CMU ICDC ICRC MDOT Private State of Michigan	20-character field This is used for open channels in the planning area that are 'waters of the state'
SubRespons	Used to identify a department or specific owner	[alphanumeric values] – 20 characters	Additional ownership and/or management information – e.g. City sewers serving parks; private assets belonging to a school district; MDOT assets along the railroad

Field	Definition	Values	Comments
ParcelID	Use to locate an asset relative to parcels	[##########]	10-character field to note location relative to parcels
YearInstal	The year the asset was installed	[########]	8-character field to store installation date information
Future	Future asset flag	[#] 1 = Yes	Used to identify assets that have been planned but have not yet been installed
ToBeAbando	Asset to be abandoned	[#] 1 = Yes	Used to identify assets that are planned to be abandoned or removed
Abandoned	Abandoned flag	[#] 1 = Yes	Used to identify assets that have been abandoned (and may or may not have been removed)
Removed	Removed asset flag	[#] 1 = Yes	Used to identify assets that have been removed
Manufactur	Asset manufacturer	[alphanumeric values]	
OriginalMa	Asset material – detailed	[alphanumeric values]	Originally entered material information
Rehab	Rehabilitation status	[#] 0 = No; 1 = Yes; 9 = Future	Defines the rehabilitation status for an asset
Rehab_Year	Rehabilitation year	[####]	Year of past or planned pipe rehabilitation [yyyy]
Rehab_Mat	Rehabilitation material	[alphanumeric values]	40-character text field for describing pipe rehabilitation and materials
Material	Asset material – simplified	[alphanumeric values]	Updated and consolidated material information
minor_loss	Minor losses in conveyance	[alphanumeric values]	Text field used to describe pipe bends and other complex configurations that can contribute to head losses
Shape_Type	Asset shape	[alphanumeric values]	20 character field
Diameter	Asset diameter if circular	[########.#]	Can store primary dimension for non-circular geometries (inches)
Shape_Dim2	Second dimension	[####.##]	For non-circular geometries (inches)
YearInspe	Most recent inspection year for asset	[####]	
LastCleane	Most recent cleaning information	[alphanumeric values]	20 character field
Buried	Buried asset flag	[#] 1 = Yes	Used to identify assets that are buried
GroundSurf	Ground surface type at asset	[alphanumeric values]	10 character field
Cover_Type	Type of asset cover	[alphanumeric values]	20 character field
SW_Inlet	Stormwater inlet flag	[##] 1 = Yes	
SW_In_Type	Type of stormwater inlet	[alphanumeric values]	80 character field
LidDiamete	Diameter of lid if circular	[#######]	inches
LidWidth	Width of lid if rectangular	[##.#]	Inches
LidLength	Length of lid if rectangular	[##.#]	inches
screw_lock	Cover lock flag	[#] 1 = Yes	
RIMELEV	Elevation of structure rim	[#####.##]	International feet
UpdateRim	Update Rim condition	X = estimated Y = estimated N = from survey D = from survey	
CastingMod	Casting model number	[alphanumeric values]	20 character field
DistOfAdj	Distance (depth) of adjustment materials	[#######]	inches
NumberofRi	Number of spacing rings used	[##########]	
ConeDepth	Depth of cone	[####.##]	Feet
Depth	Total depth of structure	[###########]	Feet

Field	Definition	Values	Comments
Inv_bottom	Elevation of structure bottom	[####.##]	International feet
SumpDepth	Portion of total depth that is below outlet invert	[####.##]	Feet
MultiOut	Multiple outlet flag	[#] 1 = Yes	Flagged yes if structure has multiple outlet flow paths
Outfall_P	Physical outfall flag	[#] 1 = Yes	
OutfallNum	Outfall number	[####]	
OutGrate	Outfall grate flag	[#] 1 = Yes	
Flap_Gate	Outfall flap gate flag	[#] 1 = Yes	
Outfall_J	Jurisdictional outfall flag	[#] 1 = Yes	
up_jrsdctn	Upstream jurisdiction	[alphanumeric values]	80 characters
dn_jrsdctn	Downstream jurisdiction	[alphanumeric values]	80 characters
CONDITION	Condition information	[alphanumeric values]	20 characters
Model_On	Model on flag	[#] 1 = Yes	
NODE_TYPE	Model node type	[alphanumeric values]	20 characters
MODEL_OUT	Model outfall flag	[#] 1 = Yes	
ModelInput	Model flow input flag	[#] 1 = Yes	
STOR_FLAG	Model storage flag	[#] 1 = Yes	
S_DEPTH	Model storage depth	[####.##]	Feet
STOR_AREA	Model storage area	[###########.#]	Square Feet
LeachBasin	Leach basin flag	[#] 1 = Yes	
EXFIL_FLAG	Exfiltration flag	[#] 1 = Yes	
Sexfil_max	Exfiltration maximum rate	[######.####]	Inches / hour
Sexfil_min	Exfiltration minimum rate	[######.####]	Inches / hour
S_decay	Exfiltration decay constant	[####.####]	
ExportArea	The outfall area the asset flows to	[alphanumeric values]	40 character field
Restricted	Legacy information	[##########]	From catch basin layer
1yr_c_dmax	Maximum flow depth (ft)	[####.##]	1-year existing conditions model
1yr_c_Vtot	Flooding volume (acre-inches)	[#######.##]	1-year existing conditions model
1yr_c_ttot	Flooding time (minutes)	[##########.##]	1-year existing conditions model
1yr_c_Sin	Storage node peak inflow rate (cfs)	[#####.##]	1-year existing conditions model
1yr_c_Sout	Storage node peak outflow rate (cfs)	[#####.##]	1-year existing conditions model
1yr_c_Sexf	Storage node exfiltration volume (cfs * 1000)	[#######.###]	1-year existing conditions model
1yr_f_dmax	Maximum flow depth (ft)	[####.##]	1-year future conditions model with detention
1yr_f_Vtot	Flooding volume (acre-inches)	[#######.##]	1-year future conditions model with detention
1yr_f_ttot	Flooding time (minutes)	[##########.##]	1-year future conditions model with detention

Field	Definition	Values	Comments
1yr_f_Sin	Storage node peak inflow rate (cfs)	[#####.##]	1-year future conditions model with detention
1yr_f_Sout	Storage node peak outflow rate (cfs)	[#####.##]	1-year future conditions model with detention
1yr_f_Sexf	Storage node exfiltration volume (cfs * 1000)	[#######.###]	1-year future conditions model with detention
1yr_s_dmax	Maximum flow depth (ft)	[####.##]	1-year future conditions model with detention and sump pumps
1yr_s_Vtot	Flooding volume (acre-inches)	[#######.##]	1-year future conditions model with detention and sump pumps
1yr_s_ttot	Flooding time (minutes)	[##########.##]	1-year future conditions model with detention and sump pumps
1yr_s_Sin	Storage node peak inflow rate (cfs)	[#####.##]	1-year future conditions model with detention and sump pumps
1yr_s_Sout	Storage node peak outflow rate (cfs)	[#####.##]	1-year future conditions model with detention and sump pumps
1yr_s_Sexf	Storage node exfiltration volume (cfs * 1000)	[#######.###]	1-year future conditions model with detention and sump pumps
1yr_x_dmax	Maximum flow depth (ft)	[####.##]	1-year future conditions model without detention
1yr_x_Vtot	Flooding volume (acre-inches)	[#######.##]	1-year future conditions model without detention
1yr_x_ttot	Flooding time (minutes)	[##########.##]	1-year future conditions model without detention
1yr_x_Sin	Storage node peak inflow rate (cfs)	[#####.##]	1-year future conditions model without detention
1yr_x_Sout	Storage node peak outflow rate (cfs)	[#####.##]	1-year future conditions model without detention
1yr_x_Sexf	Storage node exfiltration volume (cfs * 1000)	[#######.###]	1-year future conditions model without detention
10y_c_dmax	Maximum flow depth (ft)	[####.##]	10-year existing conditions model
10y_c_Vtot	Flooding volume (acre-inches)	[#######.##]	10-year existing conditions model
10y_c_ttot	Flooding time (minutes)	[##########.##]	10-year existing conditions model
10y_c_Sin	Storage node peak inflow rate (cfs)	[#####.##]	10-year existing conditions model
10y_c_Sout	Storage node peak outflow rate (cfs)	[#####.##]	10-year existing conditions model
10y_c_Sexf	Storage node exfiltration volume (cfs * 1000)	[#######.###]	10-year existing conditions model
10y_f_dmax	Maximum flow depth (ft)	[####.##]	10-year future conditions model with detention
10y_f_Vtot	Flooding volume (acre-inches)	[#######.##]	10-year future conditions model with detention
10y_f_ttot	Flooding time (minutes)	[##########.##]	10-year future conditions model with detention
10y_f_Sin	Storage node peak inflow rate (cfs)	[#####.##]	10-year future conditions model with detention
10y_f_Sout	Storage node peak outflow rate (cfs)	[#####.##]	10-year future conditions model with detention
10y_f_Sexf	Storage node exfiltration volume (cfs * 1000)	[#######.###]	10-year future conditions model with detention
10y_x_dmax	Maximum flow depth (ft)	[####.##]	10-year future conditions model without detention
10y_x_Vtot	Flooding volume (acre-inches)	[#######.##]	10-year future conditions model without detention
10y_x_ttot	Flooding time (minutes)	[##########.##]	10-year future conditions model without detention
10y_x_Sin	Storage node peak inflow rate (cfs)	[#####.##]	10-year future conditions model without detention
10y_x_Sout	Storage node peak outflow rate (cfs)	[#####.##]	10-year future conditions model without detention

Field	Definition	Values	Comments
10y_x_Sexf	Storage node exfiltration volume (cfs * 1000)	[#######.###]	10-year future conditions model without detention
10ydc_dmax	Maximum flow depth (ft)	[####.##]	10-year existing conditions model with unrestricted pipe network
10ydc_Vtot	Flooding volume (acre-inches)	[#######.##]	10-year existing conditions model with unrestricted pipe network
10ydc_ttot	Flooding time (minutes)	[##########.##]	10-year existing conditions model with unrestricted pipe network
10ydc_Sin	Storage node peak inflow rate (cfs)	[#####.##]	10-year existing conditions model with unrestricted pipe network
10ydc_Sout	Storage node peak outflow rate (cfs)	[#####.##]	10-year existing conditions model with unrestricted pipe network
10ydc_Sexf	Storage node exfiltration volume (cfs * 1000)	[#######.###]	10-year existing conditions model with unrestricted pipe network
10ydf_dmax	Maximum flow depth (ft)	[####.##]	10-year future conditions model with detention and unrestricted pipe network
10ydf_Vtot	Flooding volume (acre-inches)	[#######.##]	10-year future conditions model with detention and unrestricted pipe network
10ydf_ttot	Flooding time (minutes)	[##########.##]	10-year future conditions model with detention and unrestricted pipe network
10ydf_Sin	Storage node peak inflow rate (cfs)	[#####.##]	10-year future conditions model with detention and unrestricted pipe network
10ydf_Sout	Storage node peak outflow rate (cfs)	[#####.##]	10-year future conditions model with detention and unrestricted pipe network
10ydf_Sexf	Storage node exfiltration volume (cfs * 1000)	[#######.###]	10-year future conditions model with detention and unrestricted pipe network
25y_c_dmax	Maximum flow depth (ft)	[####.##]	25-year existing conditions model
25y_c_Vtot	Flooding volume (acre-inches)	[#######.##]	25-year existing conditions model
25y_c_ttot	Flooding time (minutes)	[##########.##]	25-year existing conditions model
25y_c_Sin	Storage node peak inflow rate (cfs)	[#####.##]	25-year existing conditions model
25y_c_Sout	Storage node peak outflow rate (cfs)	[#####.##]	25-year existing conditions model
25y_c_Sexf	Storage node exfiltration volume (cfs * 1000)	[#######.###]	25-year existing conditions model
25y_f_dmax	Maximum flow depth (ft)	[####.##]	25-year future conditions model with detention
25y_f_Vtot	Flooding volume (acre-inches)	[#######.##]	25-year future conditions model with detention
25y_f_ttot	Flooding time (minutes)	[##########.##]	25-year future conditions model with detention
25y_f_Sin	Storage node peak inflow rate (cfs)	[#####.##]	25-year future conditions model with detention
25y_f_Sout	Storage node peak outflow rate (cfs)	[#####.##]	25-year future conditions model with detention
25y_f_Sexf	Storage node exfiltration volume (cfs * 1000)	[#######.###]	25-year future conditions model with detention
25y_x_dmax	Maximum flow depth (ft)	[####.##]	25-year future conditions model without detention
25y_x_Vtot	Flooding volume (acre-inches)	[#######.##]	25-year future conditions model without detention
25y_x_ttot	Flooding time (minutes)	[##########.##]	25-year future conditions model without detention
25y_x_Sin	Storage node peak inflow rate (cfs)	[#####.##]	25-year future conditions model without detention
25y_x_Sout	Storage node peak outflow rate (cfs)	[#####.##]	25-year future conditions model without detention
25y_x_Sexf	Storage node exfiltration volume (cfs * 1000)	[#######.###]	25-year future conditions model without detention

Field	Definition	Values	Comments
25ydc_dmax	Maximum flow depth (ft)	[####.##]	25-year existing conditions model with unrestricted pipe network
25ydc_Vtot	Flooding volume (acre-inches)	[#######.##]	25-year existing conditions model with unrestricted pipe network
25ydc_ttot	Flooding time (minutes)	[##########.##]	25-year existing conditions model with unrestricted pipe network
25ydc_Sin	Storage node peak inflow rate (cfs)	[#####.##]	25-year existing conditions model with unrestricted pipe network
25ydc_Sout	Storage node peak outflow rate (cfs)	[#####.##]	25-year existing conditions model with unrestricted pipe network
25ydc_Sexf	Storage node exfiltration volume (cfs * 1000)	[#######.###]	25-year existing conditions model with unrestricted pipe network
25ydf_dmax	Maximum flow depth (ft)	[####.##]	25-year future conditions model with detention and unrestricted pipe network
25ydf_Vtot	Flooding volume (acre-inches)	[#######.##]	25-year future conditions model with detention and unrestricted pipe network
25ydf_ttot	Flooding time (minutes)	[##########.##]	25-year future conditions model with detention and unrestricted pipe network
25ydf_Sin	Storage node peak inflow rate (cfs)	[#####.##]	25-year future conditions model with detention and unrestricted pipe network
25ydf_Sout	Storage node peak outflow rate (cfs)	[#####.##]	25-year future conditions model with detention and unrestricted pipe network
25ydf_Sexf	Storage node exfiltration volume (cfs * 1000)	[#######.###]	25-year future conditions model with detention and unrestricted pipe network
100_c_dmax	Maximum flow depth (ft)	[####.##]	100-year existing conditions model
100_c_Vtot	Flooding volume (acre-inches)	[#######.##]	100-year existing conditions model
100_c_ttot	Flooding time (minutes)	[##########.##]	100-year existing conditions model
100_c_Sin	Storage node peak inflow rate (cfs)	[#####.##]	100-year existing conditions model
100_c_Sout	Storage node peak outflow rate (cfs)	[#####.##]	100-year existing conditions model
100_c_Sexf	Storage node exfiltration volume (cfs * 1000)	[#######.###]	100-year existing conditions model
100_f_dmax	Maximum flow depth (ft)	[####.##]	100-year future conditions model with detention
100_f_Vtot	Flooding volume (acre-inches)	[#######.##]	100-year future conditions model with detention
100_f_ttot	Flooding time (minutes)	[##########.##]	100-year future conditions model with detention
100_f_Sin	Storage node peak inflow rate (cfs)	[#####.##]	100-year future conditions model with detention
100_f_Sout	Storage node peak outflow rate (cfs)	[#####.##]	100-year future conditions model with detention
100_f_Sexf	Storage node exfiltration volume (cfs * 1000)	[#######.###]	100-year future conditions model with detention

13.3 Catchments

The catchments layer of the database contains polygon features that correspond to runoff areas.

Table 19. Catchment layer field details.

Field	Definition	Values	Comments
id	Feature identification number	[##########]	Unique basin identified
Name_ID	Name of runoff basin	[alphanumeric values]	80 character field
CatchGroup	Catchment group of runoff basins	[alphanumeric values]	80 character field
Drain	Drain or major sewer serving runoff basin	[alphanumeric values]	80 character field
MajorBasin	Outfall ultimately serving runoff basin	[alphanumeric values]	80 character field
Descriptio	Additional information about runoff basin	[alphanumeric values]	80 character field
MODEL_ON	Model on flag	[#] 1 = Yes	
Area_acres	Area	[###########.#]	Acres
Mod_acres	Area served by existing detention	[###########.#]	Acres
Rdev_acres	Future development / redevelopment area	[###########.#]	Acres
Structure	Runoff node for area	[alphanumeric values]	20 character field
SF_land	Surface flow land cover type	[alphanumeric values]	20 character field
SFsegments	Number of surface flow segments	[#]	
SFlength	Length of SF segment	[###########.#]	Feet
SFmannings	Manning's coefficient of SF segment	[#.###]	
SFtravtime	SF travel time	[###########.#]	Minutes
SCF_land	Shallow concentrated flow land cover type	[alphanumeric values]	20 character field
SCFsegment	Number of SCF segments	[#]	
SCFlength	Length of SCF segment	[###########.#]	Feet
SCFcoeff	SCF flow coefficient	[#####.#####]	
SCFveloc	SCF flow velocity	[######.##]	Feet / second
SCFtrvtime	SCF travel time	[###########.#]	Minutes
CF_land	Concentrated flow land cover type	[alphanumeric values]	20 character field
CFsegments	Number of CF segments	[#]	
CFlength	Length of CF segment	[###########.#]	Feet
CFcoeff	CF flow coefficient	[#####.#####]	
CFveloc	CF flow velocity	[######.##]	Feet / second
CFtravtime	CF travel time	[###########.#]	Minutes
TOCmethod	Time of concentration calculation method	[alphanumeric values]	20 character field
trav_time	Calculated travel time	[######.##]	Minutes
TOCmodel	Model utilized travel time	[######.##]	Minutes
ImpSurface	Impervious surface coverage	[###.#]	Percentage
HighElev	Catchment highest elevation to nearest foot	[###.#]	International feet
LowElev	Catchment lowest elevation to nearest foot	[###.#]	International feet

Field	Definition	Values	Comments
Est_Slope	Slope of catchment	[####.######]	
CNweighted	Weighted curve number	[###.##]	
PondMajor	Number of modeled stormwater ponds	[#]	
PondMinor	Number of unmodeled stormwater ponds	[#]	
PondNat	Number of natural ponds	[#]	
UnderStor	Number of underground storage facilities	[#]	
HydSoilGrp	Dominant hydrologic soil group in catchment	[alphanumeric values]	10 character field
Sump_Pumps	Future sump pump connections	[#####]	Estimated number of sump pumps to be connected to storm sewers
SumpPumpQ	Future peak sump pump flow	[#######.###]	cfs

13.4 Additional Data Layers

Additional geolocated data sets that were delivered as a part of the development of this plan include:

- Additional / continuing investigation recommendations:
  - Low priority / non-essential asset documentation
  - Low priority / connectivity survey
  - High priority / connectivity survey
  - High priority / asset survey
- Missing plans locations
- Survey points
- Water storage assets:
  - Natural waterbodies,
  - Modeled ponds (generally larger public ponds),
  - Non-modeled ponds (generally smaller private ponds), and
  - Underground storage
- Modified HUC boundaries
- Boundaries related to planning area and excluded areas
- Modified roads to show newer county roads
- Potential storm water storage / wetland restoration areas
- Other flow channels and flow paths

13.5 Electronic Document Files

In addition to the electronic report document files and the geospatial data layers, the final project deliverable also includes a file set that contains all the plans referenced during the project organized into folders based on discharge outfall and major sewer branches. Field survey notes are also included to provide context to the provided project field survey layers.