STORMWATER MANAGEMENT PLAN

May 2017

City of Traverse City Engineering Department

City of Traverse City Guide for Water Quality

IN COLLABORATION WITH

The Watershed Center Grand Traverse Bay

OHM Advancing Communities®

GEI Consulting Engineers and Scientists

Prince-Lund Engineering, PLC

Stormwater Management Plan

CITY OF TRAVERSE CITY ENGINEERING DEPARTMENT

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EXECUTIVE SUMMARY

Stormwater runoff has been identified as one of the threats impacting water quality of the watershed of Grand Traverse Bay. The City of Traverse City was awarded funding from the MDEQ for the development of a Stormwater Management Plan to investigate existing infrastructure conditions and assess options to improve the quality of stormwater runoff. The objectives of the Report were to:

- Identify the baseline conditions
- Evaluation of open channels and shoreline
- Capacity analysis of open channels
- Determination of water quality considerations
- Creation of an updated Capital Improvement Plan

These five objectives are presented as their own sections in the report and are expanded upon in the appendices. These sections are explained as follows:

- **Identify Baseline Conditions**
  - Historical information such as previous reports, technical data, utility records, plans and mapping
  - Outcomes of public meetings
- **Asset Evaluation—Open Channels and Shoreline**
  - Identified key drainage courses
  - Kids Creek and tributaries streambank inventory
  - Channel cross section survey
  - Boardman Lake shoreline inspection
  - Stream data transferred to GIS
- **Capacity Analysis**
  - Capacity Level of Service
  - Hydrologic and hydraulic modeling of Kids Creek
- **Water Quality Considerations**
  - Identified key subwatersheds of concerns
  - Stakeholder meetings
  - Proposed capital improvements to address water quality problems
- **Capital Improvement Plan (CIP)**
  - Update to Grand Traverse Bay Watershed Protection Plan
  - Stormwater Management Plan
  - Coordination of the CIP with the Stormwater Asset Management Plan

STORMWATER MANAGEMENT PLAN

MINIMUM CONTROL MEASURES

- Public Education and Outreach
- Public Participation and Involvement
- Illicit Discharge Detection and Elimination
- Construction Site Runoff Control
- Post-Construction Runoff Control
- Pollution Prevention/Good Housekeeping

Plan Highlights

- Match resident flooding survey to the XP-SWMM modeling and confirm if the Kid's Creek and Cedar Street area as are the primary locations for folding concerns in the City
- City purchase of the XP-SWMM software for analysis of all drainage areas within the City Limits
- Calibration of the XP-SWMM model using actual storm events in order to confirm the model results are within 15% of actual stormwater runoff volumes and 20% of actual peak flow rates
- City to continue monitoring water quality
- Regular updating of the Stormwater Control Ordinance Guidelines to meet current best management practices and incorporation of the guidelines into the City's stormwater ordinance, including the regulation of open loop geothermal systems
- It is recommended that the stormwater guideline of 0.78 inches for the 90% design storm be incorporated into the City stormwater ordinance for water quality considerations
- Document locations where water quality devices have been installed and tabulate investments for various treatments
- Determine water quality treatments for remaining City storm sewers and estimate required investment
- Coordinate with the Stormwater Asset Management Plan for determining a system wide level of investment
- TWC applied to EPA Great Lakes Restoration Initiative for $500,000 for improving the outfall to the 14th Street drain
- TWC applied to National Fish and Wildlife Foundation Sustain Our Great Lakes for $537,000 to improve natural stream function and in stream habitat on Kids Creek between 7th Street and Silver Lake Road

- **Appendices**
  - Appendices A, B, C and D
    - The contributing drainage area map, hydraulic capacity of storm sewers and the field data sheet for the majority of the points of entry. Some of the points of entry did not have data for storm sewers available and/or could not be field located.
  - Appendix E
    - Runoff calculations for the contributing drainage areas for the points of entry. The calculations include drainage area in acres, surface type by land use, and determination of the potential runoff volume and discharge rates.
  - Appendix F
    - Current City ordinance and guidelines for stormwater runoff control. It also includes a copy of PA 507 of 2002 which enables local health officials to test, monitor and report beach area water quality.

- Appendix G
  - Maps showing Stormwater Treatment locations and details.
- Appendix H
  - Bibliography, resource documents, Flooding Survey, and referenced materials.
- Appendix I
  - Prince-Lund Engineering's "Drainage Analysis and Comparison: An Analysis and Comparison of Hydrologic Runoff Models" from April 2017.
- Appendix J
  - TWC's proposed updates to the Grand Traverse Bay Watershed Protection Plan specific to the City's SAW grant

SECTION 1: IDENTIFY BASELINE CONDITIONS

In order to determine a starting point for assessing the current and future conditions of the City's stormwater system, baseline conditions needed to be established. These baseline conditions were determined by reviewing historical documents, conducting a flooding survey, and holding a number of public meetings. The review of historical documents included the review and update of the 2007 Stormwater Management Report, the Grand Traverse Bay Watershed Protection Plan, and the Boardman Lake Watershed Study, to bring them up to current standards and to make them applicable in 2017.

1.1 Review of Historical Information

It is necessary to review the historic information and technical data that is available to begin the process of identifying points of stormwater entry into Grand Traverse Bay and its watershed within the city limits of Traverse City. The following reports and documents were reviewed and key information about existing stormwater systems compiled.

Report on Sewage Disposal (1931) - This identified the need to eliminate all the direct sewage discharges into the Boardman Lake, Boardman River and Tributaries and the Grand Traverse Bay. It recommended a centralized sewage treatment facility at the present site of the sewage treatment plant to comply with a court order. It also recommended the main intercepting sewer and retaining wall along the river ending at a Front Street Lift Station; an east side intercepting sewer heading east on Front Street; a south side intercepting sewer serving the area south and west of the Oak Street and connected to the new sewer at the Hospital; a Bay Street Sewer System with a pump station at Bay Street and Maple Street; An Oak Street Trunk Sewer; and a Cass Street Trunk Sewer.

Report on One Year Operation of Sewage Disposal System (1933) **-** This report focused on the success of the first year of operation of the City's sewage collection and treatment system including storm sewers.

Report on Sewerage and Drainage (1945) - This comprehensive report provided the basis of design and general plans for much of the City Storm and Sanitary Sewer system. This report references a 13 year frequency for the basis of design for stormwater infrastructure.

Report on Water Supply Improvements for City of Traverse City (1956) **-** This report provided the basis of design for the relocation of the City water supply from West Grand Traverse Bay to East Grand Traverse Bay due to water quality concerns in West Grand Traverse Bay. The new water treatment plant and intake was completed in November 1965 and put into service in 1966.

Engineering Report Storm Sewer Study Centre-Carver Area for City of Traverse City (1965) - This report provided the 5 year frequency for residential area and 10 year frequency for more dense areas as the basis of design for the storm sewer system in the Traverse Heights area of the City.

Water Quality Models for Total Coliform Bacteria in Grand Traverse Bay (1967) - This study provided significant water quality data for the West Grand Traverse Bay and references the transfer of the City water supply intake to East Grand Traverse Bay in 1966 as a result of water quality concerns which affected public health.

Report on Algal Nutrients in the Boardman River (1968) - This report provided significant water quality data for the Boardman River and discussed eutrophication of West Grand Traverse Bay.

Sanitary Sewerage and Water Supply Systems (1970) - This report focused on the regional sanitary sewer and water supply and states; "The problems of combined sewers are evident in Traverse City" and; "A program to separate these flows should be taken as soon as possible, particularly in view of the fact that during periods of high run off substantial amounts of overflow are discharged directly into the Boardman River, including significant amounts of Raw Sewage."

> *"The problems of combined sewers are evident in Traverse City."*
>
> *—Sanitary Sewerage and Water Supply Systems (1970)*

Boardman River Natural River Plan (1976) (revised 2002) - This plan and its updates are the guidelines for stewardship of the Boardman River. Our river care champion, The Grand Traverse County Soil Conservation District, maintains this plan as part of their Boardman River Project.

Infiltration/Inflow Analysis (1978)- This report focused on infiltration in the Sanitary sewer system and includes the reference "The Traverse City sewerage system was completely separated in 1973 when the last combined sewers were eliminated."

> *"The Traverse City sewerage system was completely separated in 1973 when the last combined sewers were eliminated."*
>
> *—Infiltration/Inflow Analysis (1978)*

***Greilickville Storm Water Plan (1979)* -** This report provided the basis of design including a 10 year frequency for stormwater systems and 100 year frequency for flood protection with recommendations for stormwater management for the area between M-72 and Grand View Road in Elmwood Township and the City.

Stormwater Management, An Experiment and Demonstration in Traverse City (1980)- This study was a follow up to "Grand Traverse Bay Water Quality Investigations (1974)"which documented water quality concerns at municipal beaches. The report verified that these two BMP's are highly effective in reducing stormwater pollution to Grand Traverse Bay:

- Citizen Education- This best management practice (BMP) included the education of citizens as to how pollutants build up on streets, sidewalks, and lawns to reduce stormwater pollution at its source.
- Street and Catchment Maintenance- This BMP consisted of intensifying the regular street sweeping and catch basin cleaning in the study area.

Currently, the City has partnered with the Watershed Center Grand Traverse Bay to continue the water quality awareness of our citizens and implementation of water quality projects.

Eastern Avenue Drainage Basin Study (1987)- This study examined solutions to drainage issues resulting from September 1986 storm event in the north east part of the City. The initial study was followed by several updates and plans for an area retention basin situated on Eastern Avenue in the vicinity of the water treatment plant.

***Tributary A of Kid's Creek Drainage Basin Study (1988)* -** This study examined solutions to flooding along Tributary A to Kid's Creek in the vicinity of Grand Traverse Commons and the hospital.

***Kid's Creek Stormwater Management Plan (1988)* -** This comprehensive plan addressed existing and future flooding and water quality concerns of Kid's Creek in the City and Garfield Township. The plan served as a catalyst for stormwater management ordinance and regulation in region.

City of Traverse City Code of Ordinances Chapter 1068 Ground-Water Protection and Storm-Water Runoff Control (1991)- The purpose of this chapter is to aid in the prevention of surface and ground-water contamination, to regulate and control the construction and use of storm-water runoff facilities, to control discharges to the public storm drain system, to protect the public health, safety and general welfare and to prevent the pollution, impairment or destruction of a natural resource and the environment of the City and the State. The current version is included in **Appendix F** along with the Guidelines currently used by the City for regulating stormwater runoff.

Mitchell Creek Watershed Protection Strategy (1995)- This study was an effort to balance preservation of the natural resource base while encouraging reasonable local economic development initiatives for the Mitchell Creek Watershed including the tributaries to Mitchell Creek.

Various Wastewater Treatment Facility Reports- Subsequent years to the initial 1933 operational sewage treatment plant have produced many additional reports focused on the wastewater treatment plant and the extent of sewage treatment has evolved to the current facility, a nationally recognized sewage treatment facility completed in 2004, producing highly effective sewage treatment.

The Grand Traverse Bay Watershed Protection Plan (2003) (Updated 2005)- The Grand Traverse Bay Watershed Protection Plan provides a description of the watershed (including such topics as bodies of water, population, land use, municipalities, and recreational activities), summarizes each of the nine sub-watersheds to Grand Traverse Bay, and outlines current water quality conditions in the bay. Within the initial two-year development phase of the protection plan, water quality threats were identified and efforts to address these issues were researched, developed, and prioritized. The plan was prepared by The Watershed Center Grand Traverse Bay, a private non-profit organization, founded in 1990 and devoted to the protection and enhancement of Michigan's Grand Traverse Bay and surrounding watershed through research, education and collaboration with partners (see **Appendix H**).

The Boardman Lake Watershed Study (2003)- This study identified the physical, biological, and built infrastructure resources of the Boardman Lake watershed and evaluated them for potential impacts to the long term water quality of Boardman Lake and the lower reaches of the Boardman River. This study complemented previous and ongoing watershed management plans within the region.

Stormwater Source Identification (2001)- This study quantified mass loading of nutrients and fecal contaminants via urbanized tributaries and stormwater discharges to Grand Traverse Bay.

Public Act 507 (2002) - This Public Act enables local health officials to test, monitor and report beach area water quality. The current version is included in **Appendix F**

Grand Traverse Region Stormwater Management Toolkit (2006) - The Watershed Center Grand Traverse Bay put together a toolkit for local governments and other involved organizations for learning about options for stormwater management. The toolkit is a mix of online resources, books, electronic reports, and articles and information relating to stormwater management and best management practices.

***New Designs for Growth Development Guidebook (2006)* -** The *"Guidebook"* represents a continuation of efforts to demonstrate how development can occur while protecting natural resources. It is designed for appointed and elected officials and developers within the five county Grand Traverse Region.

***Stormwater Management Report (2007)* -** Traverse City completed an analysis of its stormwater collection system in 2007. The objectives of that study were to determine system capacity through hydrologic and hydraulic modeling, delineate drainage area boundaries, review the condition of outfalls and other drainage components, and identify water quality projects that could be constructed to protect the Grand Traverse Bay from stormwater.

Kids Creek Watershed Hydrologic Study (2010) – This study was conducted to better understand the hydrologic characteristics of the Kids Creek Watershed. The evaluation of the hydrologic characteristics of the watershed helped to determine the watershed's critical areas and provided a basis for stormwater management ordinances.

Stormwater Asset Management Plan (2017) – This plan refined the existing inventory and condition rating of the City's Stormwater System assets. It analyzed the flow capacity of underground pipes and identified long term operation and maintenance strategies. It also examined funding needs and funding gaps and offered suggestions for future funding for this critical infrastructure.

1.2 Water Quality Milestones

The City, from its conception to 1931, directly discharges wastewater into the Boardman River and Grand Traverse Bay. In 1931 the City built its first wastewater treatment plant (WWTP) and until 1973, when the City had completed the separation of its storm and waste water sewer systems, the City had a combined storm and waste water sewer system which overflowed into the bay during large storm events. In 1976, the Boardman River Natural Plan was developed, followed by numerous plans and studies which continue to this day and will continue into the future, to help improve water quality. In 1991 the City created the City of Traverse City Code of Ordinances Chapter 1068 Ground-Water Protection and Storm-Water Runoff Control and became a Municipal Enforcing Agency for stormwater and soil erosion. In 2003 the Regional WWTP was upgraded with state of the art integrated membrane bioreactor technology. In 2007 the first large scale stormwater BMP project, which made stormwater quality improvements to 7 locations, was implemented, followed by numerous stormwater BMP projects in the following years and into the future, both public and private. More detailed information about the City's Water Quality Milestones can be found in the timeline on the following page.

Traverse City Water Quality Milestones

1900's
- Direct sewage discharges into river and bay

1931
- Centralized sewage treatment plant WWTP and trunk sewers

1940's
- Combined sewer overflows into river and bay

1945
- Plan to separate sanitary sewer and stormwater systems
- Acquired industrial and commercial properties on West Bay

1950's
- West Bay water pollution creates need to move water intake

1955-66
- Relocate City Water Supply from West to East Grand Traverse Bay

1963
- Excess nutrients and phosphorus into river from WWTP

1966-69
- Upgrade WWTP to reduce nutrients and phosphorus into river

1970
- Combined sewer overflows into river and bay
- Expanded sanitary sewer service into areas surrounding City

1973
- Completed sanitary sewer and stormwater systems separation
- Purchased Morgan McCool property (Open Space)

1976
- Develop Boardman River Natural River Plan

1978
- Infiltration/ Inflow Analysis

1980
- Determined that street sweeping and catch basin cleaning is highly effective for improving water quality

1987
- Eastern Avenue Drainage Basin Study

1988
- Kid's Creek Stormwater Management Plan
- Acquired waterfront property from Oak Street to Division Street

1991
- City of Traverse City Code of Ordinances Chapter 1068 Ground-Water Protection and Storm-Water Runoff Control
- City became Municipal Enforcing Agency for stormwater and soil erosion

2001
- Stormwater Source Identification study

2002
- Public Act 507- beach monitoring for water quality enacted

2003
- The Grand Traverse Bay Watershed Protection Plan (Updated 2005)
- The Boardman Lake Watershed Study
- Regional WWTP Improvement including integrated membrane bioreactor technology

2004
- Groundwater protection and stormwater control ordinance guidelines updated
- City of Traverse City/ Garfield Township Recreation Authority established and Smith-Barney property on West Bay acquired

2005
- Demolished bayfront coal fueled-steam generator power plant

2006
- Grand Traverse Region Stormwater Management Toolkit
- New Designs for Growth Development Guidebook

2007
- "Your Bay, Your Say" Waterfront Plan
- City of Traverse City Stormwater Management Report
- Implemented stormwater BMP projects in 7 locations city-wide

2008
- Grand Traverse Area Water Systems Master Plan (revised 2010)

2010
- Bayfront Plan adopted

2011
- **Bryant Park stormwater project**

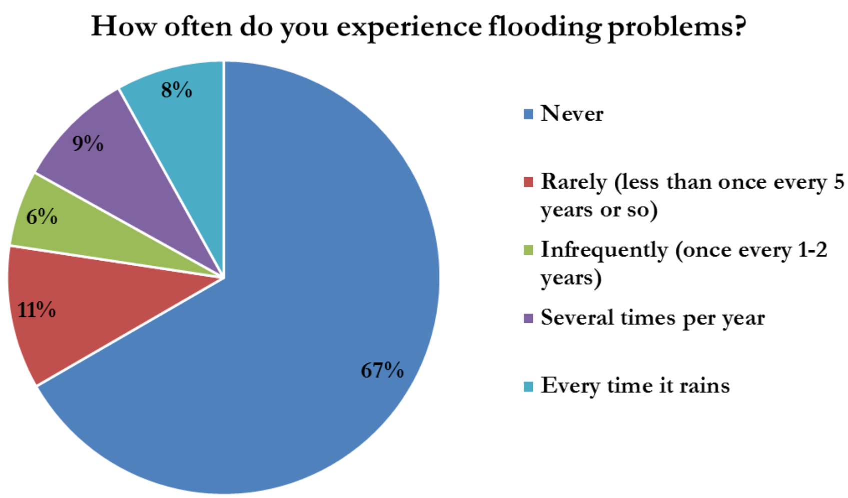
2012
- Brown Bridge Dam removal
- East Bay Park stormwater project

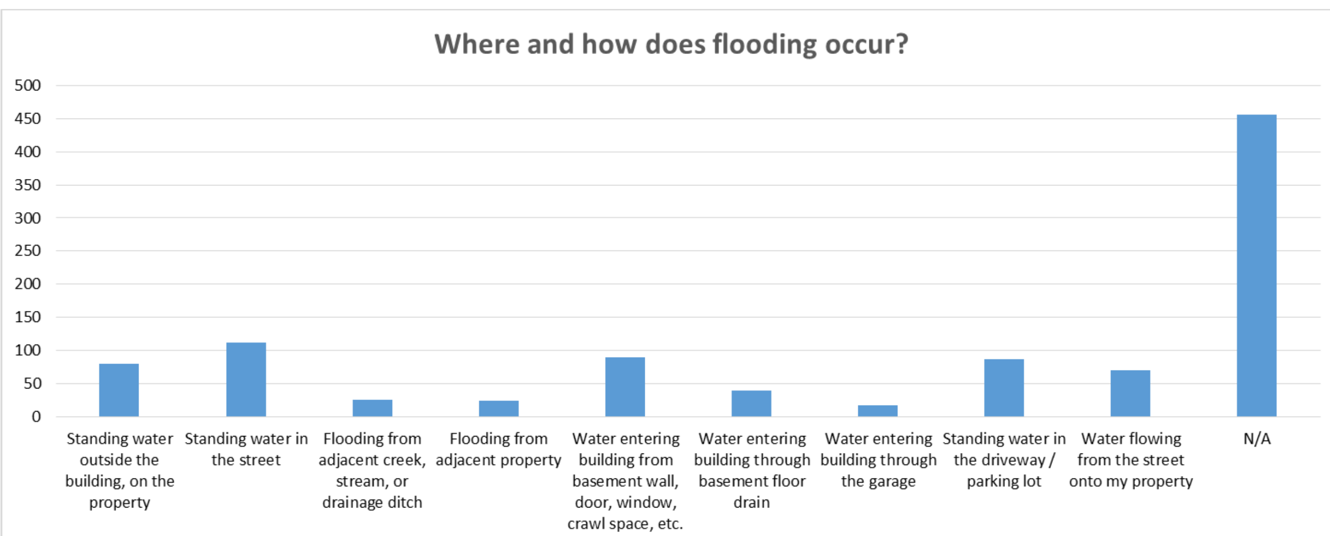
2013
- Boardman River Watershed Prosperity Plan
- Boardman River Plan (not adopted)

2014
- SAW Grant
- Spruce Street and West End Beach trail stormwater project

1.3 Stormwater Management Plan Meetings

The City of Traverse City held more than 7 public meetings and several SAW grant update meetings. These meetings occurred in conjunction with a Flooding Survey, which received more than 1000 responses, with 23% of responders noting flooding concerns. City staff then followed up with the reported flooding based on the survey responses, but found that few related to public infrastructure or were already addressed or included in the Stormwater Management Plan (SMP). The survey responses were matched to the XP-SWMM modeling and confirmed the Kid's Creek and Cedar Street area as the primary location for folding concerns in the City. The survey can be found in **Appendix H** and the results of the Flooding Survey are shown in the following chart and graph:





SECTION 2: ASSET EVALUATION—OPEN CHANNELS AND SHORELINE

Key drainage courses that have a significant impact on the City's stormwater assets were identified through streambank inventories and channel cross section surveying along Kids Creek and its immediate tributaries, along with a shoreline survey of Boardman Lake (within the City Limits). This information was gathered to identify the areas of concern, for hydraulic modeling purposes, and to be transferred to the City's GIS database for future reference.

Watershed Map and Impaired reach of Kids Creek within City Limits (Source: The Watershed Center, 2013. Kids Creek Action Plan)

2.1 Kid's Creek and Immediate Tributaries Survey

The water quality impairment of Kids Creek has been a focus area for the City for years. Groundwork has been laid by the City, the County, the State, the Watershed Center Grand Traverse Bay and others, that the Kids Creek impairment can be addressed directly with a series of management activities and channel projects.

For this study the impaired reach (see figure to right) of Kids Creek was divided into two sub-reaches based on the City's relative impact and capacity to manage the channel, and given the fact that the reaches are very different. The upper, impaired reach from Silver Lake Road to 7th Street has a relatively wide, and intact stream corridor. Below 7th Street, down to the Kids Creek mouth with the Boardman below Front Street, there is little stream corridor as the creek flows through downtown Traverse City.

The City Engineering Department performed the streambank inventories along Kids Creek and its immediate tributaries from the Boardman River to Silver Lake Road in 223 locations. Examples of the filled out field worksheets can be found in **Appendix H.**

The evidence suggests that the persisting habitat impairments upstream of Seventh Street are due both to the impacts of runoff as well diminished transport capacity. While there has been a great deal of focus on both stormwater and sediment as sources of stream impairment, the stream's poor in-stream habitat, particularly from Silver Lake Road to 7th Street seems to be largely a function of poor channel gradient and over-widening. In its sandiest reaches, the stream lacks the power to move anything bigger than sand.

The lower Kids Creek reach, from 7th Street to the Boardman Lake is also plagued with grade issues, sedimentation, misplaced or undersized culverts and a severely under-sized private crossing. There is a narrow corridor and near the Front Street culvert some very poor quality, crushed concrete and stone that also appears to be inhibiting macroinvertebrate diversity as well. Also, the culvert that ties into the Boardman River is wide, promoting very thin normal flow depths, likely inhibiting fish passage. This area also shows some water quality impact from runoff and definitely still requires more attention to water quality, particularly street runoff.

2.1a Lower Kids Creek (7th Street to Boardman River Confluence)

By far and away, the most impacted reach of lower Kids Creek is between 6th Street and the lower crossing on Cedar Street. There are two culvert crossings on Cedar Street and a private crossing between them that together are severely restricting flow and lowering the energy grade line. The upper and lower Cedar Street crossings are shown in Figures 1 and 2, and the private crossing in Figure 3 below. These crossings are full of sediment and have stone and/or wood grade controls, which are impeding flow. This artificially high culvert offset "robs" the channel of fall. The more that the fall down the length of the stream is interrupted, the lower the flow energy and capacity of the channel to move sediment. The impact of the high sediment levels and grade controls in this set of culverts is shown in the profile of Kids Creek during a two-year rain event as run in the USEPA SWMM model of Kids Creek (Figure 4). As shown in the figure, the impact of these crossings for the two-year event as demonstrated by a nearly horizontal water surface profile extends more than 1,500-feet up the channel. For larger events, the impact would extend even further upstream. A solution to this problem would be to reset the upper Front Street culvert to a higher elevation and remove the grade controls in the Cedar Street culverts. The additional fall would increase the flow through the culverts and help clear the sediment.

Figure 1. Looking upstream from the Upper Cedar Street crossing (note heavy sand deposition)

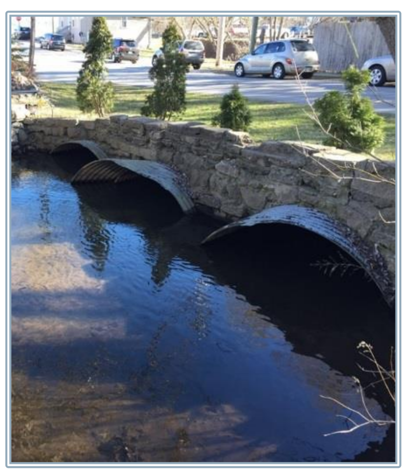


Figure 2. Upstream of the lower Cedar Street Crossing (note sand deposition and culvert filling)

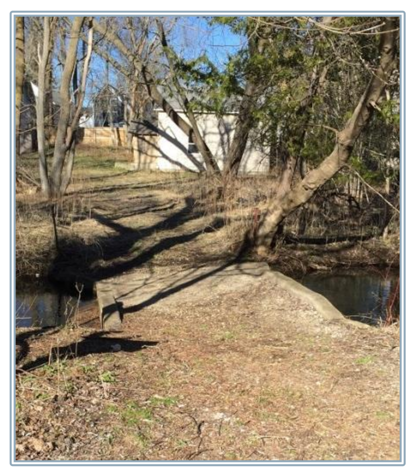


Figure 3. Private crossing between Cedar Street crossings (note that the bridge is at and also below top of bank)

2.1b Upper Kids Creek (7th Street to Silver Lake Road)

Looking at the upper Kids Creek stream profile, one can already identify that the reach downstream of Silver Lake Road (US 31) is where the upper, steeper stream profile flattens out (Figure 5). This is naturally a depositional reach where material that is actively transported above may not be transported below.

Much of the Kids Creek watershed soils are composed of sand so that the majority of sediment the stream has to carry will also be sand. In fact, we would contend that local soil erosion control programs do a decent job keeping large sediment, both particle sizes and volume, releases from getting to the creek. What is now 'delivered' to the creek via most sediment losses, particularly those generated by construction and development tend to have a size classification that is mostly composed of sand and smaller particles such as silts and clays. There is plenty of sand getting back into the channel but probably not much larger sediment, such as gravels.

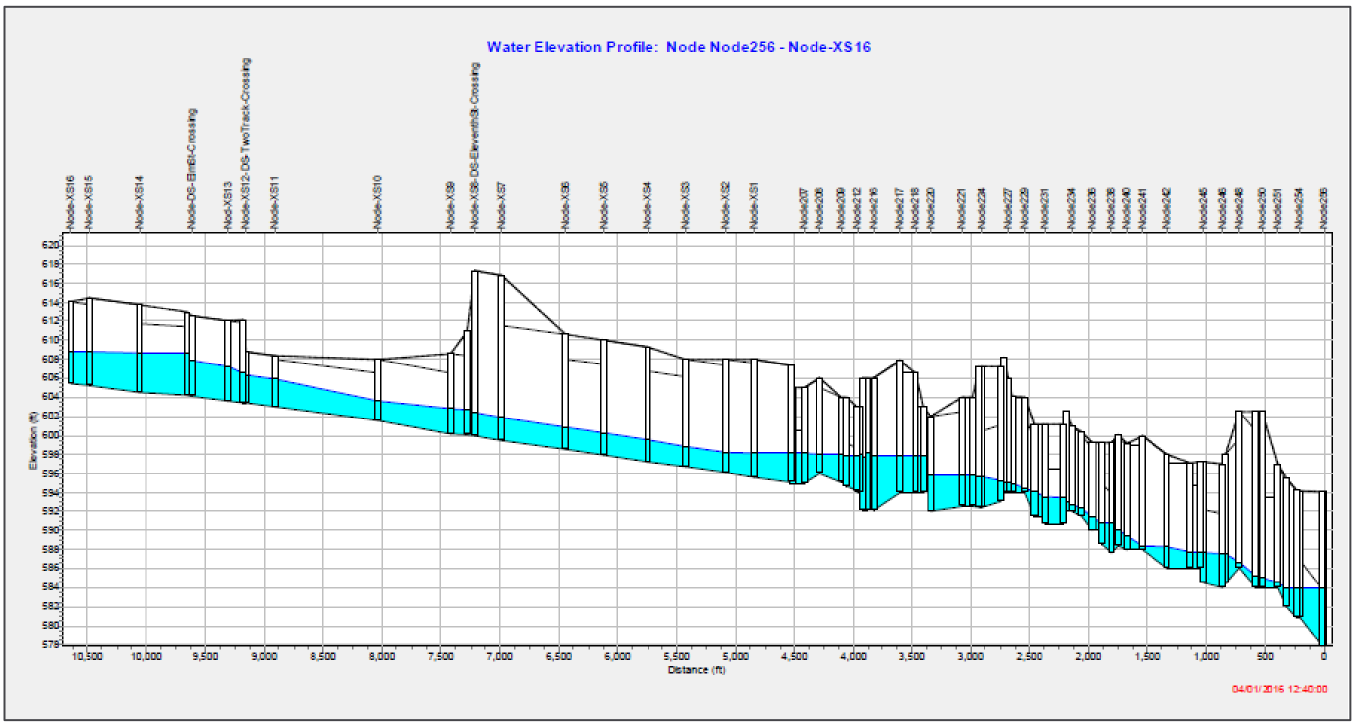


Figure 4. Kids Creek Streambed Profile during 2-year rain event (approximate elevations for Upper Kids Creek)

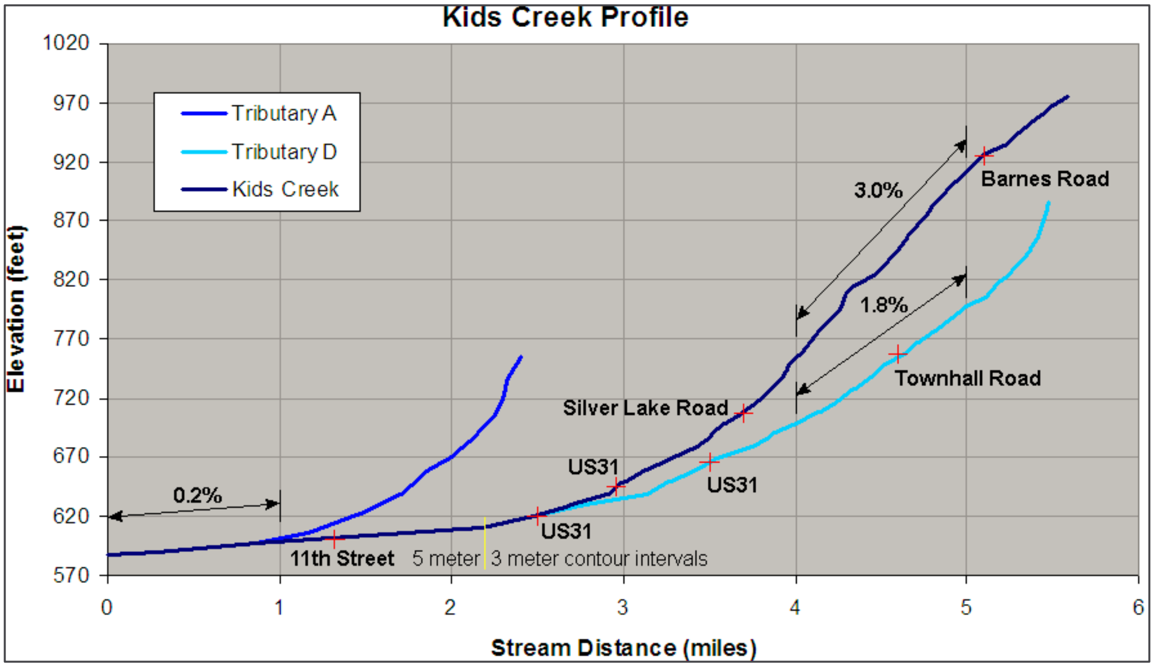


Figure 5. Kids Creek approximate stream bed profile (From: Fongers, D., 2010. Kids Creek Watershed Hydrologic Study, MDEQ)

2.2 Boardman Lake Shoreline Survey

As part of the SAW grant tasks, The Watershed Center (TWC) staff inspected 1.5 miles of shoreline along the north half of Boardman Lake within the City Limits for evidence of erosion, illicit discharges, unstable banks along the shoreline, and other physical characteristics that could impact water quality. This inventory was conducted in Summer 2015 and consisted of a visual inspection of the shoreline by kayak looking for signs of current or potential sources of water quality pollution. Locations of potential pollution sources or spots of concern were noted at 21 sites where GPS points, pictures, and descriptive notes were taken about the site (Table 1). Results were summarized in an Excel spreadsheet and divided into four categories: Erosion Spots, Lack of Riparian Buffer, Stormwater Outfalls, and Boat Launch Runoff with each category having a different type of pollution. Additionally, a map was produced showing noted locations from Excel spreadsheet grouped by the type of pollutant: minor/moderate sediment erosion, nutrients, nutrients/E.coli, stormwater outfall, and stormwater runoff (Figure 6).

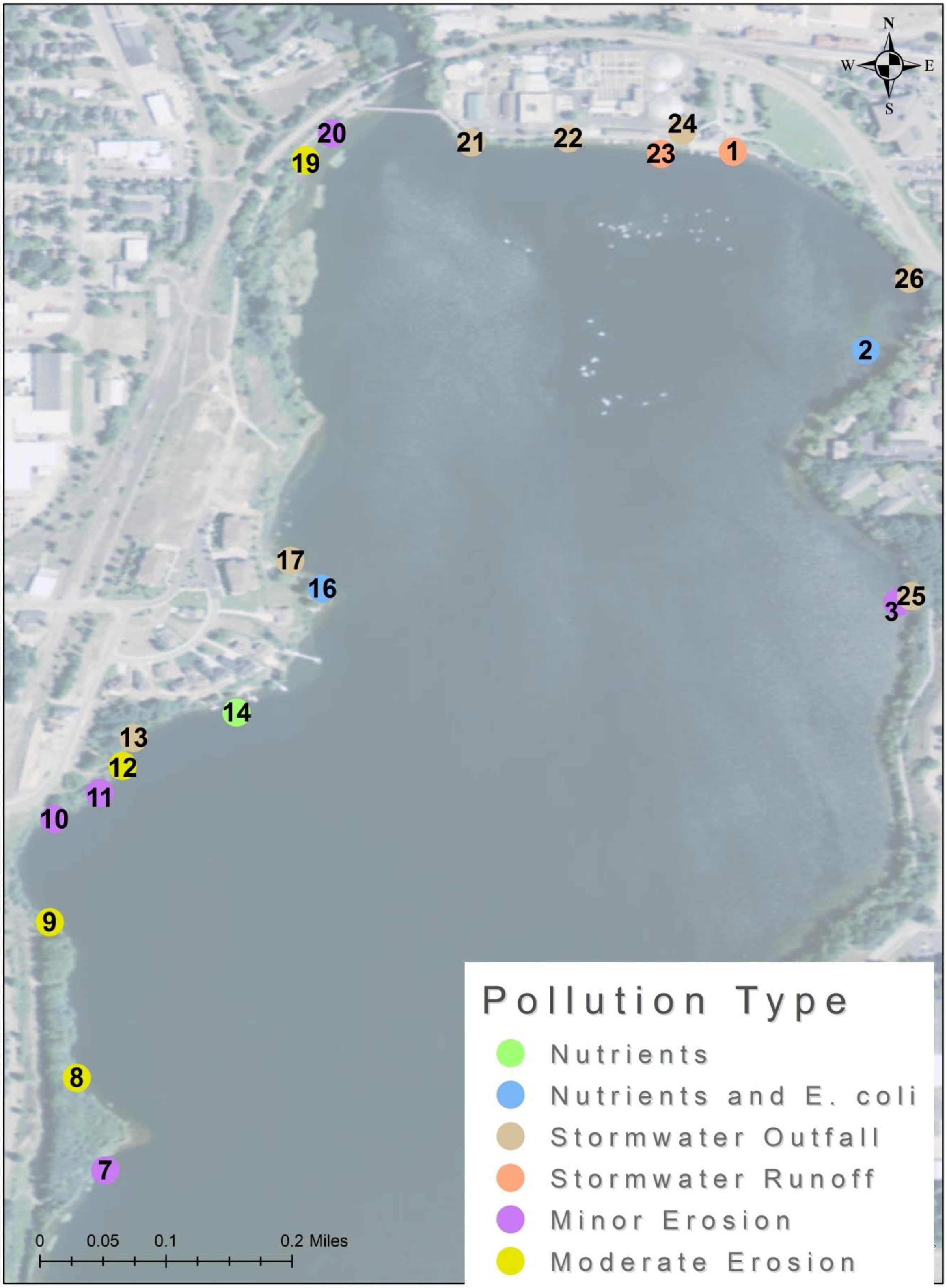
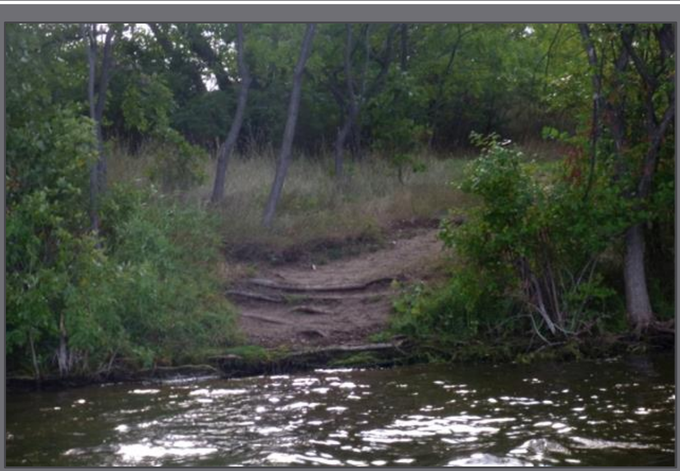


Figure 6. Boardman Lake Shoreline Survey Results grouped by Pollutant Type

Table 1. Shoreline Survey Locations of Concern

Latitude	Longitude	Location ID	Type of Pollutant	Description/Notes
Erosion Spots				
44.75166508	-85.60879125	3	Sediment	MINOR Erosion Foot traffic, Path down to lake from TART trail, erosion
44.74917457	-85.61847361	10	Sediment	MINOR Erosion Foot traffic, Path down to lake, erosion
44.74947497	-85.61794957	11	Sediment	MINOR Erosion Foot traffic, Path down to lake, erosion
44.74978594	-85.61768814	12	Sediment	MODERATE Erosion Foot traffic, Path down to lake, erosion
44.7567456	-85.61558805	19	Sediment	MODERATE Erosion Foot traffic, Path down to lake, erosion
44.74513767	-85.61788671	7	Sediment	MINOR Erosion; Steep bank
44.74620083	-85.6182157	8	Sediment	MODERATE Erosion; Steep bank end point 1
44.74799146	-85.61852323	9	Sediment	MODERATE Erosion; Steep bank end point 2
44.75705154	-85.61528438	20	Sediment	MINOR Erosion
Lack of Riparian Buffer				
44.75455709	-85.60915645	2	Nutrients, Ecoli	Lack of Buffer, Grass down to water's edge, excess plant growth in water, waterfowl congregating
44.75039799	-85.61637746	14	Nutrients	Lack of Buffer, Grass down to water's edge
44.75182199	-85.61539711	16	Nutrients, Ecoli	Lack of Buffer, Grass down to water's edge, excess plant growth in water, waterfowl congregating
Stormwater Outfall Pipes				
44.75010839	-85.61756258	13	Stormwater Outfall	Outlet end broken off of pipe
44.75214427	-85.61576223	17	Stormwater Outfall	Stormwater outfall, black plastic up near hill
44.75694844	-85.61368159	21	Stormwater Outfall	Drain pipe outlet, cladophora present
44.75699471	-85.61257057	22	Stormwater Outfall	Outlet pipe, plastic
44.75708557	-85.61126165	24	Stormwater Outfall	Between launches
44.75173524	-85.60863577	25	Stormwater Outfall	Storm drain outlet under water, long way out
44.75538195	-85.60865614	26	Stormwater Outfall	2 storm drain outlets, both under water, Southern one larger than Northern one
Boat Launch Runoff				
44.75684426	-85.61068045	1	Stormwater Runoff	Boat Launch on North End of Lake
44.75681769	-85.61150548	23	Stormwater Runoff	Boat Launch

No major areas of concern were found in the survey, however there are several areas of minor and moderate erosion along the lake, mostly from foot traffic to access the lake and from steep banks. These are localized areas and aren't contributing large amounts of sediment to the lake (see accompanying photos below).



Examples of minor (right, location 3) and moderate (left, location 12) noted erosion spots on Boardman Lake. Both of these pictured sites are caused by foot traffic, with the picture on the right coming from the TART trail.

Additionally, a few places were noted where there is no riparian buffer along the lake and grass extends all the way to the water's edge (see accompanying photos below). This could lead to excess nutrients and bacteria entering the water, as evidenced by the noted excessive plant/algae growth see in the inventory in this area and waterfowl congregating along the shore (Table 1).

Grassed lawns up to the edge of the lake, such as these condo developments along the west side of the lake (location 14), can add excessive nutrients and bacteria pollution to Boardman Lake.

Seven locations were noted where pipes (ranging from small plastic to larger concrete) outlet to the water. These were noted on the map as well.

Location 13

Location 21

Location 22

Location 17

SECTION 3: CAPACITY ANALYSIS

3.1 Capacity Level of Service

In order to determine where the capacity of a system truly is, an acceptable level of service for different street types had to be outlined. Upon meeting with local stakeholders, the City determined that the following flooding durations and levels, with no damage to property, were tolerable:

Location	Acceptable Level of Service
All City Streets	6 inches or less of water, any duration
Primary Emergency Routes (>5000 ADT)	More than 6 inches, 30 minutes or less
Medium Volume Streets (2000 to 5000 ADT)	More than 6 inches, 1 hour or less
Low Volume Streets (<2000 ADT)	More than 6 inches, 6 hours or less

Increasing the size of pipes in order to meet these criteria is acceptable, but only if the larger pipes allow improvements with water quality. Efforts should first be made to reduce the amount of stormwater runoff entering the system before pipe size is increased.

3.2 Discharge Locations and Drainage Area Boundaries

The City of Traverse City is home to 95 drainage area boundaries and associated points of entry into area bodies of water. Below is a table briefly describing the different boundary areas. Maps of these areas can be found in **Appendices A-D**.

Boundary Zone	Description
A-AZ	Primarily drainage areas in the northwest portion of the City such as the Munson Medical Campus, Slabtown neighborhood, the north portion of Pine St, the warehouse district, and the northeast corner of State St and Washington St
B-BZ	Primarily drainage areas on the central west side of the City such as the neighborhoods south of Fourteenth St, the entire length of Wadsworth St, Front St from Division St to Park St, Locust St north of Eleventh St, and Lake Ave
C-CZ	Primarily drainage areas on the east side of the City such as Airport Industrial Park, Orchard Heights neighborhood, Central High School, the Civic Center, Traverse Heights neighborhood, Oak Park neighborhood, Boardman Ave, State St from Union St to Boardman Ave, and Eighth St from Boardman Ave to Fair St
D-Z	Includes drainage areas throughout the City, including Union south of Thirteenth St, Cass St between Fourteenth St and Lake Ave, Boardman neighborhood, Front St between Munson Ave and East Bay Blvd, Eighth St and the surrounding neighborhoods between Cochlin St and Cromwell St, and the neighborhoods immediately south of the NMC campus

Each drainage boundary also has an expected runoff volume and runoff depth calculated for the 2 year, 5 year, 10 year, and 25 year storm, as well as the area in acres of pavement, residential, forested ground cover, and the total area in acres and for each boundary. Each boundary area also has the percent of the boundary that is considered impervious calculated, along with the average runoff curve number, and average pipe and watershed slope. Using this information, the approximate run-off volumes and peak discharge rate was calculated for the 2 year, 5 year, 10 year, and 25 year storm based on both the watershed and the average pipe slope for each boundary, along with the treatment flow range (1/3 of the unit peak discharge), following the methodology in Chapter 7 of the *MDEQ Soil Erosion and Sedimentation Control Training Manual (Revised 2005)* (see **Appendix H**). Tables for these values can be found in **Appendix E.**

3.3 Stormwater System Modeling

3.3a Modeling

Given the reliability on community wide data sets, as well as the lack of actual hydraulic flow data in the collection system, the computer modeling should be considered a planning level tool suitable for generating wide recommendations related to general stormwater quantities and areas of water quality management. Stormwater modeling was used to identify undersized pipes and to aide in the development of a management strategy for undersized pipes and flooding.

The City Engineering Department completed Geographic Information Systems inventory and mapping of the City's existing storm sewer system for the 2007 Stormwater Management Report. This included more than 1900 drainage structures and manholes, 54 miles of storm sewers open channels and culverts and more than 90 points of entry into area streams, rivers, lakes and the Grand Traverse Bay.

The 2007 report used the Soil Conservation Service (SCS) Curve Number method adapted by the MDEQ in their publications Computing Flood Discharges for Small Ungauged Watersheds and Certified Storm Water Operator and Soil Erosion and Sedimentation Control Inspector/Comprehensive Training Manual to approximate runoff volumes and peak discharge rates. The Runoff Curve Number method is well established in hydrologic engineering and environmental impact analysis. Its simplistic approach does not include the ability to evaluate pollutant loading and incremental effects of adding green infrastructure to urban drainage areas.

Therefore the XP-SWMM software model was used by OHM for preparing the 2017 Stormwater Asset Management Plan. The SWMM Runoff method is ideal for modeling the impacts of Green Infrastructure retrofits, such as bioretention, on peak flows and total runoff volumes. This provides an ideal foundation on which to calculate pollutant reduction and other water quality benefits. The model included 32 of the 95 (33%) drainage areas of the City. As a part of the stormwater system model for the City, OHM also incorporated the open channel flow of Kids Creek into the model.

Since modeling stormwater quality requires the consideration of more frequent (lower magnitude) storm events, such as the 90% event storm and 2-year storm, the SWMM Runoff method is recommended. Fortunately, the SWMM Runoff method can be scaled up to model larger storm events, including but not limited to the 10-year, 50-year, and 100-year recurrence interval storms. It should be noted that the XP-SWMM modeling of less frequent (i.e. 5-year /10-year) events yielded, in several cases, higher peak discharge rates as compared to the 2007 results. This is likely due to the inclusion of directly-connected impervious surfaces, such as roadways, parking lots, and driveways, which immediately contribute stormwater runoff to the collection system.

With the varied results between the 2007 method and the XP-SWMM model results, Prince and Lund was hired by the City of Traverse City to complete an Independent Technical Review (ITR) of the XP-SWMM model. Prince-Lund created their own "Modified City Model" using EPA SWMM and the information provided by OHM for four of the City's stormwater systems. Prince-Lund found that using EPA SWMM (free version) as opposed to XP SWMM led to a number of difficulties, such as not being able to export data, not being able to interface with GIS, and not having the ability to quickly and easily adjust and add/subtract variables. Despite these difficulties, Prince-Lund found similar peak flow values to those found by OHM for four drainage areas:

- Pine Street
- Hannah Avenue
- Bryant Park/Garfield Avenue
- 14th Street

The ITR is further detailed in **Appendix H**. The ITR created a cursory link between the XP-SWMM model and the 2007 calculations for the peak discharge rate. This link is intended to be used until such time as the City can purchase the XP-SWMM software and complete input of the data for all of the drainage areas. The comparisons are shown in Figures 7, 8, and 9.

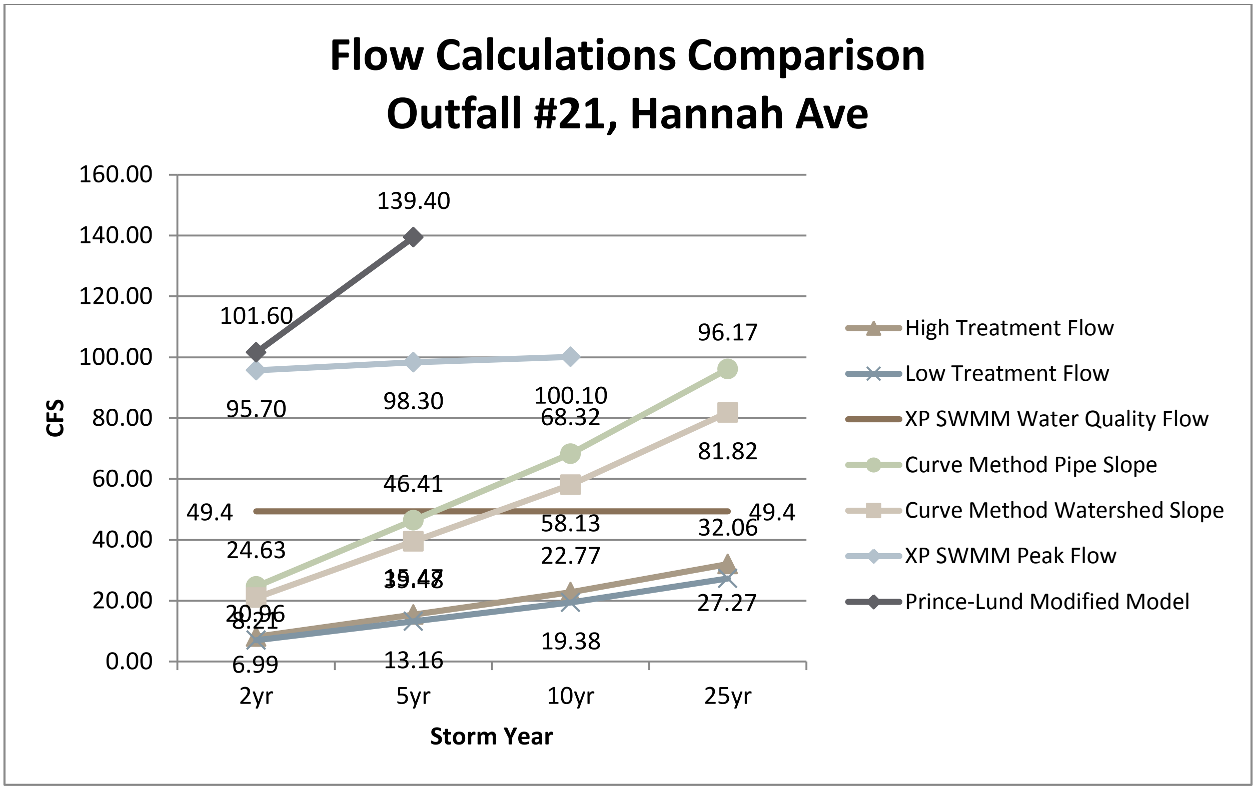


Figure 7. Flow Calculations Comparison for Outfall #21, Hannah Ave

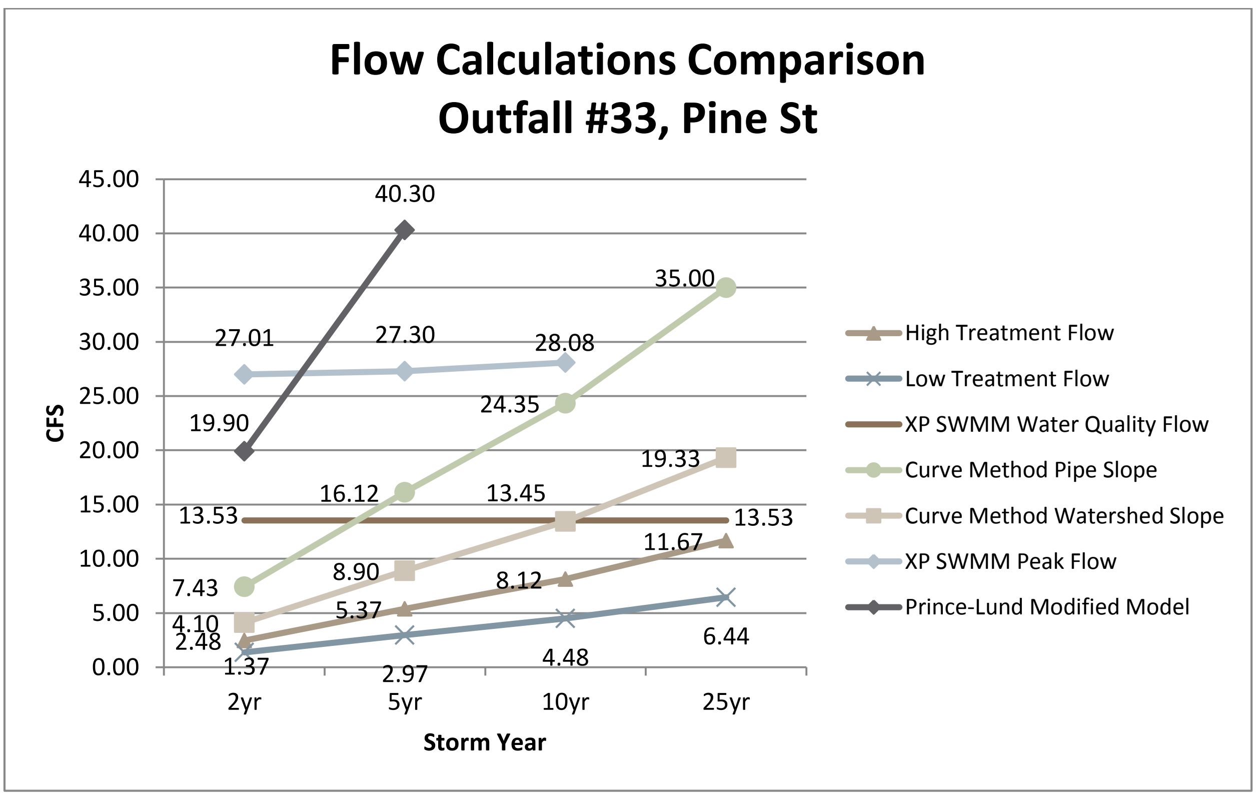


Figure 8. Flow Calculations Comparison for Outfall #33, Pine St

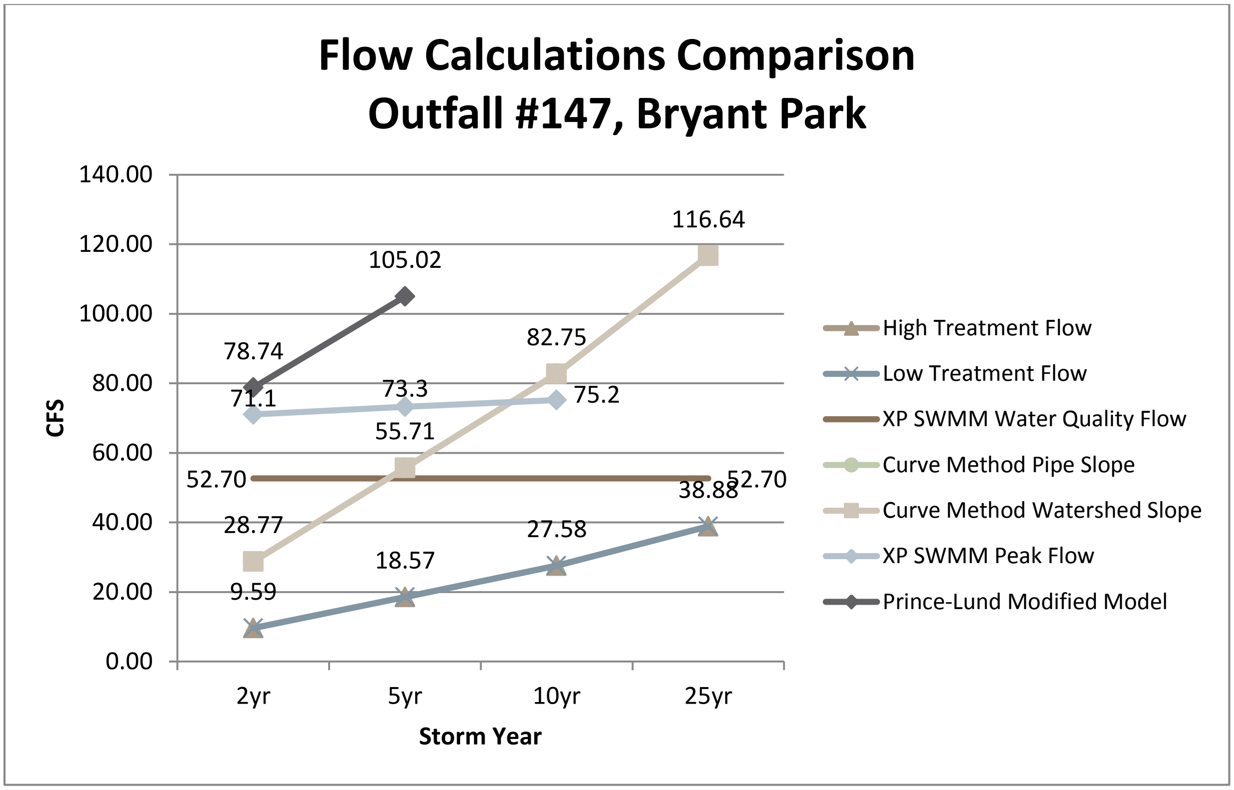


Figure 9. Flow Calculations Comparison for Outfall #147, Bryant Park

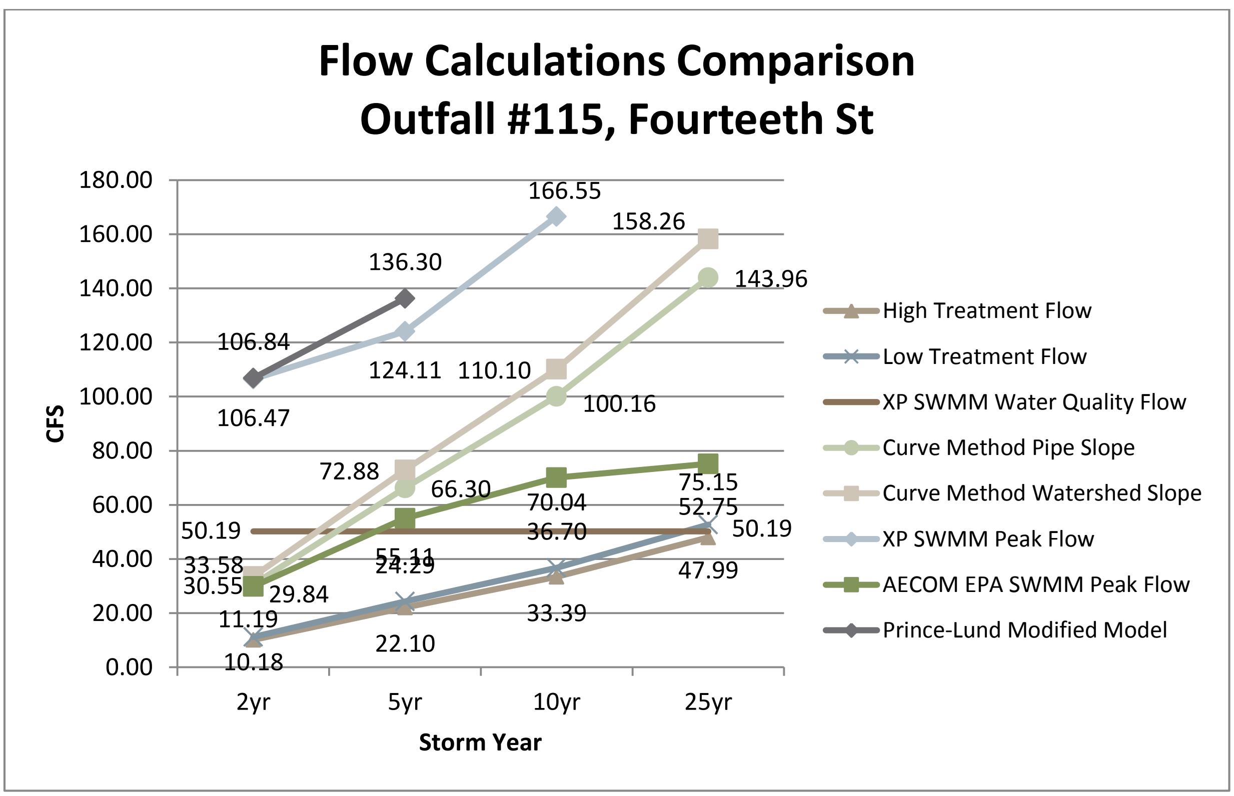


Figure 10. Flow Calculations Comparison for Outfall #33, Pine St

AECOM created an EPA-SWMM stormwater system model for Fourteenth Street drainage area. Unlike Prince-Lund's model, AECOM found the peak flow rates to be more similar to those found by the 2007 City Model than those found by OHM. A comparison of these three models and the 2007 City Model can be found in Figure 10.

OHM's stormwater system model found that there are areas of the City that experience flooding that is not within the City's acceptable Level of Service parameters. These areas are shown in Figure 11 and Figure 12, outlined in light blue. However, it should be noted that OHM's model does not account for the existing and future private on-site stormwater systems, which currently effect 554 parcels/properties within the City Limits (see **Appendix G** for a map showing the private stormwater on-site stormwater systems), and needs further calibration using actual storm events in order to confirm the model results are within 15% of actual stormwater runoff volumes and 20% of actual peak flow rates. Also, the predicted flooding areas were not identified by respondents of the Flooding Survey.

Until the City is able to create their own model for all of the stormwater sewer systems in the City, the 2007 City Model treatment values had to be converted to equivalent XP SWMM treatment values in order to determine what treatment types are appropriate for each stormwater sewer system. The conversion factors were determined by Prince-Lund as being a range between 1 and 2, with 1 being for very complex, globular stormwater sewer systems and 2 being for very simple, linear systems. Each system that was not included in the XP SWMM model was then reviewed and assigned a conversion factor so that an equivalent water quality flow number could be calculated. The equivalent water quality flow numbers are the average of the 2 year, 5 year, 10 year, and 25 year high treatment flow range times the designated conversion factor. Table 7-3a and Table 7-3b showing the calculated XP SWMM or equivalent water quality flow value can be found in **Appendix E.**

It should also be noted that the standard practice of using the 90-Percent Annual Non-Exceedance Storm method for statistically evaluating water quality storm events results in Traverse City having a 90 percent storm value of 0.78 inches. OHM used a value of 1" in their modeling. However, this method of determining the water quality storm value does not take into account any storm event that results in an accumulation of 0.1 inches or less, which account for 44% of the storms in the Traverse City area.

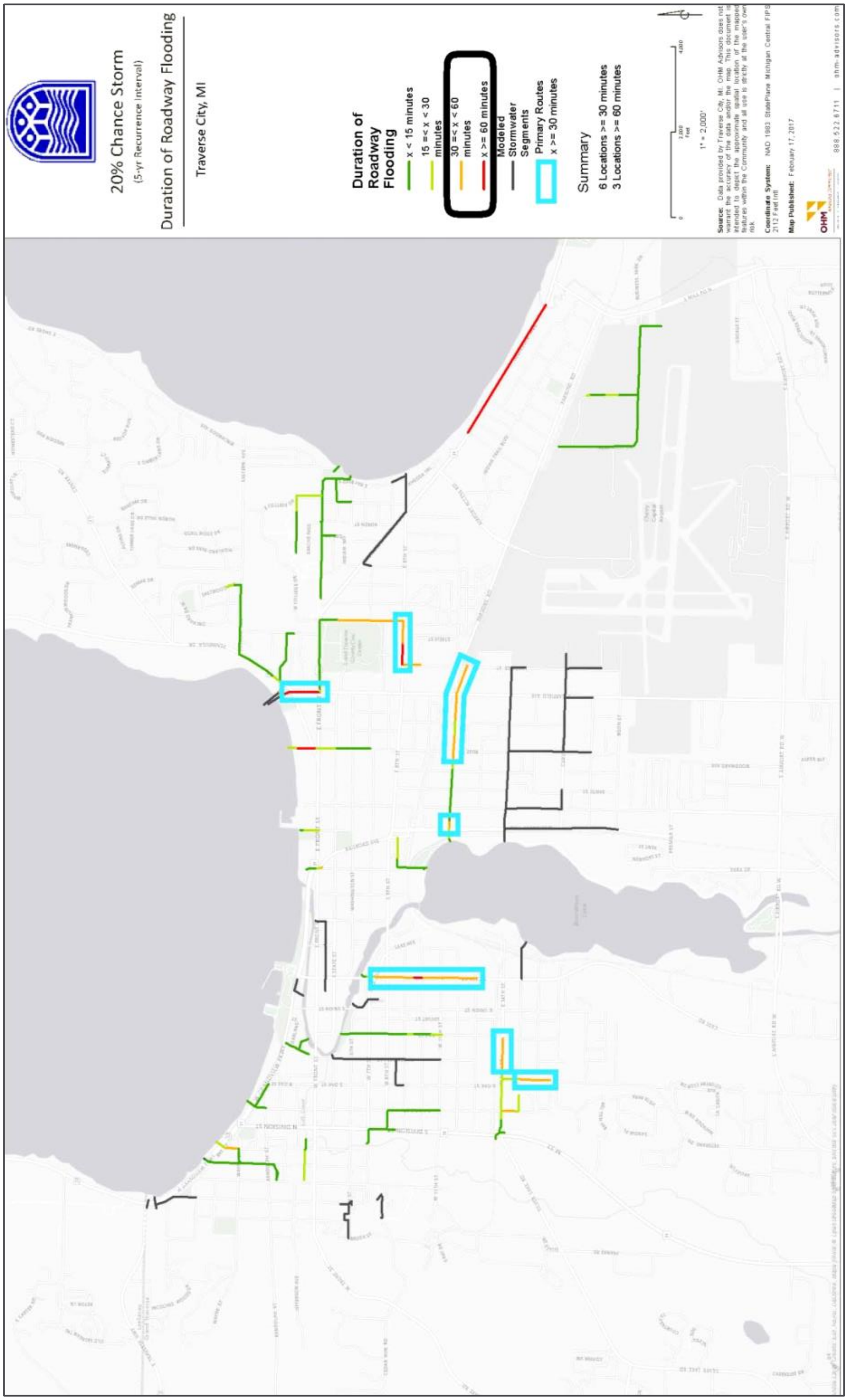


Figure 11. Model results, based on duration of flooding for a 5 year storm event

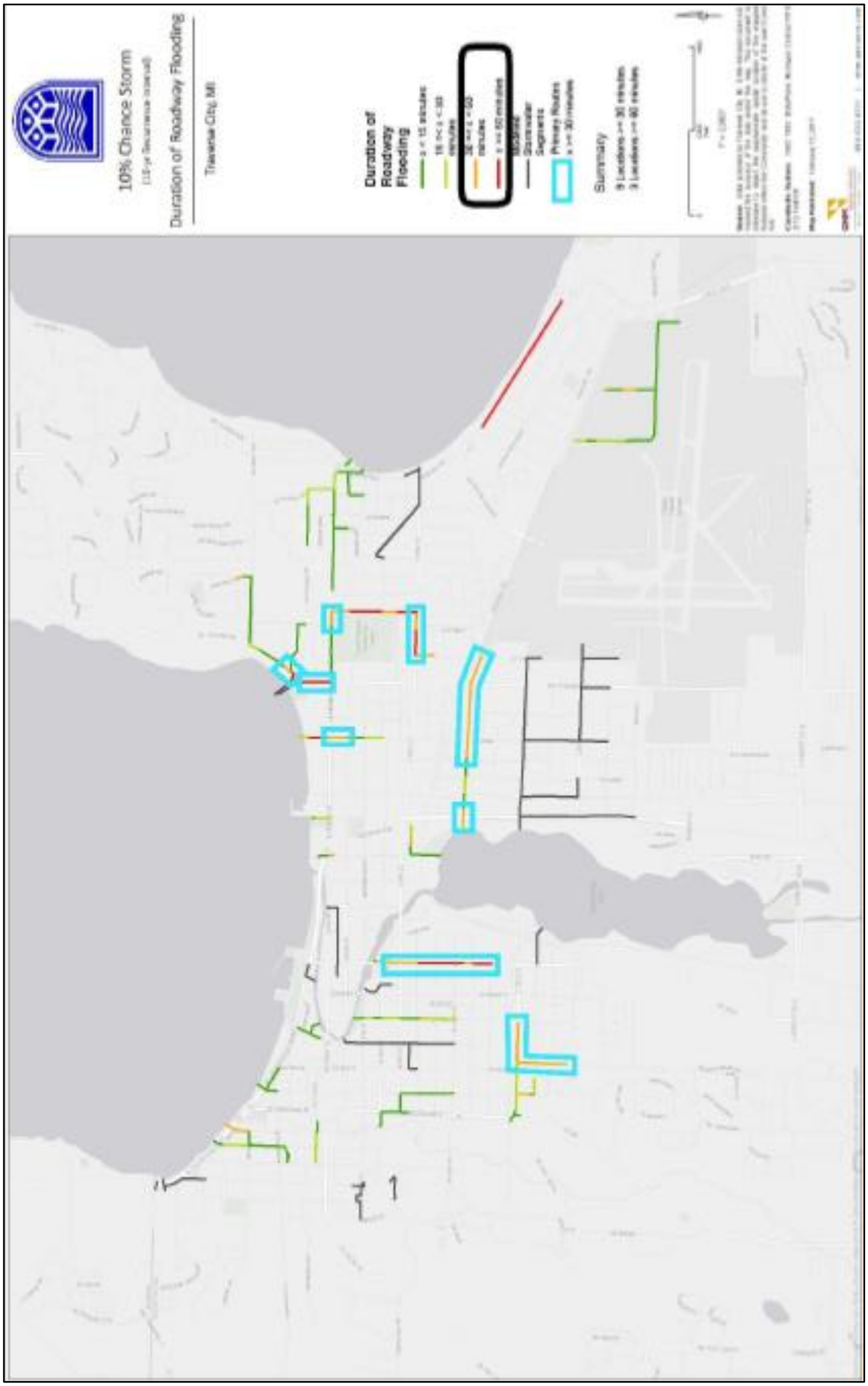


Figure 12. Model results, based on duration of flooding for a 10 year storm event

3.3b 90-Percent Annual Non-Exceedance Storms for Water Quality Treatment

3.3b.1 History and Methodology

Upon further review, it was found that the standard practice within the industry for statistically evaluating storm events has become the 90-Percent Annual Non-Exceedance Storm method. The standard was originally developed by Schueler (1987) [a]. This method eliminates all rainfall data recorded less than 0.1 inches and analyzes the remaining data. This technical publication is out of print however, a simple explanation is found in an EPA (2015) [b] publication. "The rainfall from minor storms may be entirely stored in surface depressions and eventually lost to evaporation or infiltration. As a result, no runoff is produced. Schueler further elaborated on the 90-Percent storm in the document Design of Stormwater Filtering Systems (1996)[d] for the Chesapeake Research Consortium. The 90-Percent Storm method was now applied to the east coast and the State of New Mexico for Water Quality Treatment.

3.3b.2 Qualifying the Practice

The original intent of the 90-Percent storm was to help better define the method of determining a storm and treating a majority of the storm events within a given area. Per Schueler's (1996)[d] publication, "Additional rainfall frequency analysis is required for more complete reliance on this value. If a particular jurisdiction has the resources and long term data, a complete RFS should be conducted and the 90% rule applied to establish a local water quality precipitation value." It is also recognized that as the storm event increases over the maximum treated storm the treatment condition largely decreases. This is due to the amount of volume passing through the system as well as treatment system efficiencies decreasing as flow rates increase.

3.3b.3 State Practices

The Michigan Department of Environmental Quality (MDEQ) BMP Manual[e] provides rainfall data from 1948 to 1999 calculating the 90-Percent Non-Exceedance Storm for ten areas of Michigan. It was found in a technical memorandum (2006)[c] that, area #3 (Kalkaska), has a 90-Percent storm value of 0.77 inches. The state allows the use of these regional numbers or a conservative alternative of 1.0 inches of runoff over the entire site.

3.3b.4 Findings

To affirm the findings through the MDEQ, The City of Traverse City added to the MDEQ 2006 data of 2001 through 2016. The City then plotted the rainfall events on a graph and locating the 90% storm value of 0.45, shown below in Figure 13. This was followed up with additional analysis utilizing the 90-percent storm. The storm events less than 0.1 inches were eliminated from the data series and plotted, yielding 0.78 as shown in Figure 14. Remembering the 90-Percent Non-Exceedance Storm value is 0.77 inches with data collected from May of 1948 to Dec. of 1999. In adding data from Jan of 2001 to Jan of 2017 (attached), no noticeable change has been noted. An additional item of interest includes the percentage of storms in the Traverse City area less than 0.1 inches. The Traverse City area storms less than 0.1 inches are approximately 44% of the areas storm events.

Therefore, based on these findings, it is recommended that the stormwater guideline of 0.78 inches for the 90% design storm be incorporated into the City stormwater ordinance for water quality considerations.

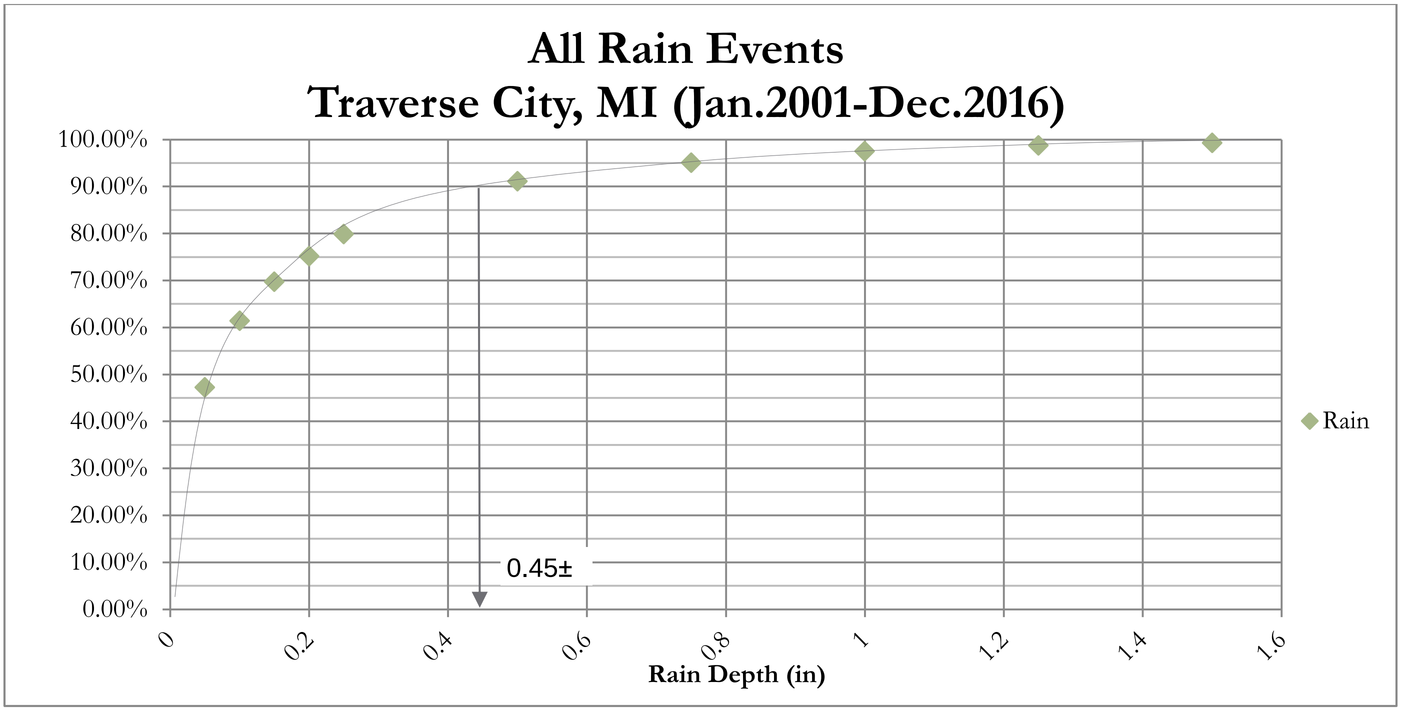


Figure 13. Rainfall events in Traverse City including all rainfall events.

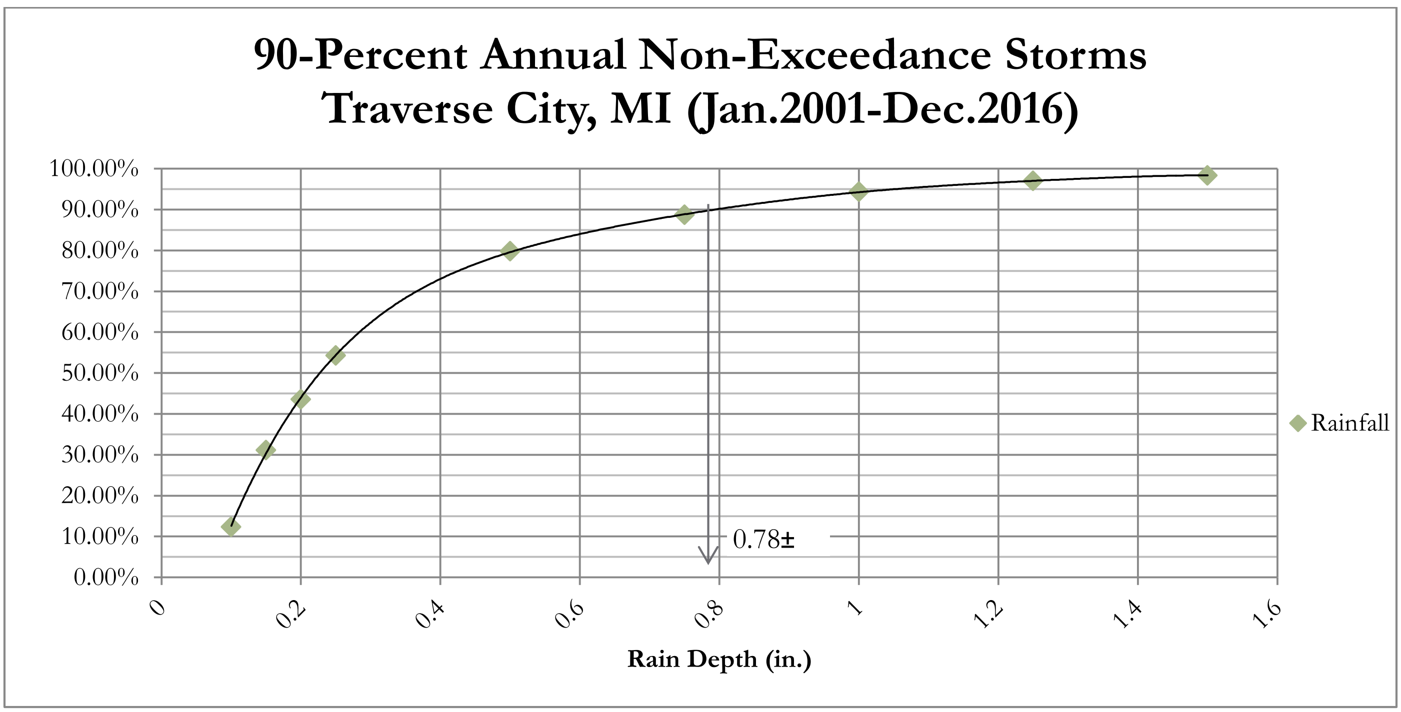


Figure 14. Rainfall events in Traverse City excluding rainfall events less than 0.1 inches.

3.4 Kids Creek Surveying and Modeling

Detailed survey and hydrologic and hydraulic modeling were conducted on the downstream sub-reach of Kids Creek from 7th Street down to the Boardman Lake. Preliminary survey and modeling were conducted on the reach from Silver Lake Road to 7th Street. The upper watershed of Kids Creek above Silver Lake Road is shown in Figure 15 below. Note that almost all the contributing area to the impaired reach above 7th Street comes from outside the City limits.

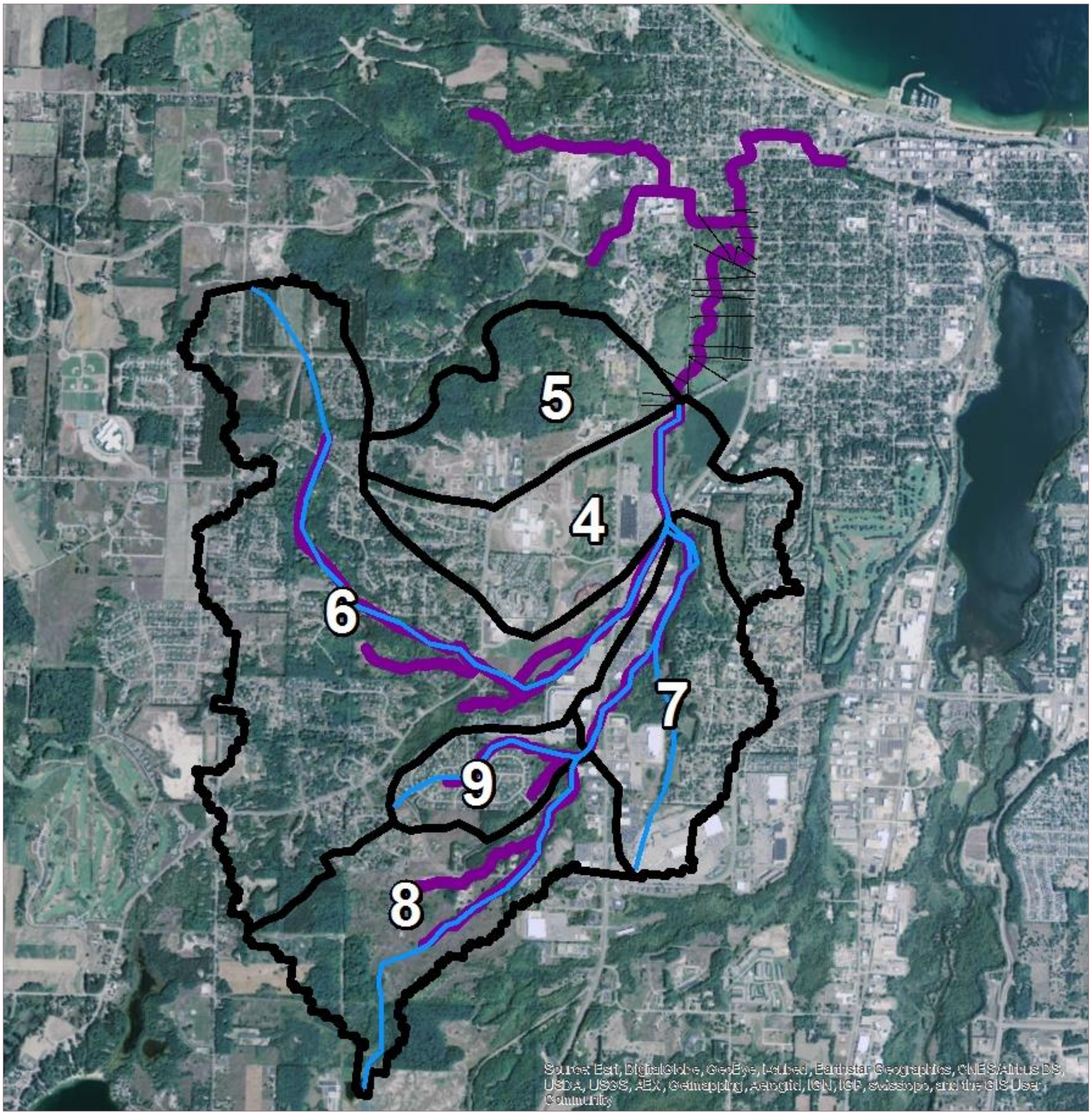


Figure 15. Kids Creek subwatersheds above Silver Lake Road (and outside of City limits)

The goal of this survey was aimed at establishing more heterogeneous stream bed habitat with a larger variety of bed sediment sizes. Part of this larger bed sediment will come from increasing transport capacity and part will likely need to be either imported or by uncovering coarse sediment underneath sand. More transport capacity comes from increasing stream power. Total stream power and unit stream power can both be increased independently. Total power is the product of the weight of the water and the slope it slides down. Total unit power is total power divided by the width of flow. Total power is increased either with a higher flow and/or higher bed slope. An increase in unit width stream power can be achieved with narrowing the channel; that is, the same amount of power is forced through a smaller area.

The bed profile from the survey is shown in Figure 16. Note that the bed elevations upstream of 7th Avenue are approximate and are primarily based on 2-ft contour maps and some limited survey in the creek. What is quickly apparent from the hydraulic profile shown along the channel is the extent to which the culverts at Cedar Street alter the hydraulic profile. Showing the profile from 7th to the Boardman River shows this more clearly (Figure 17).

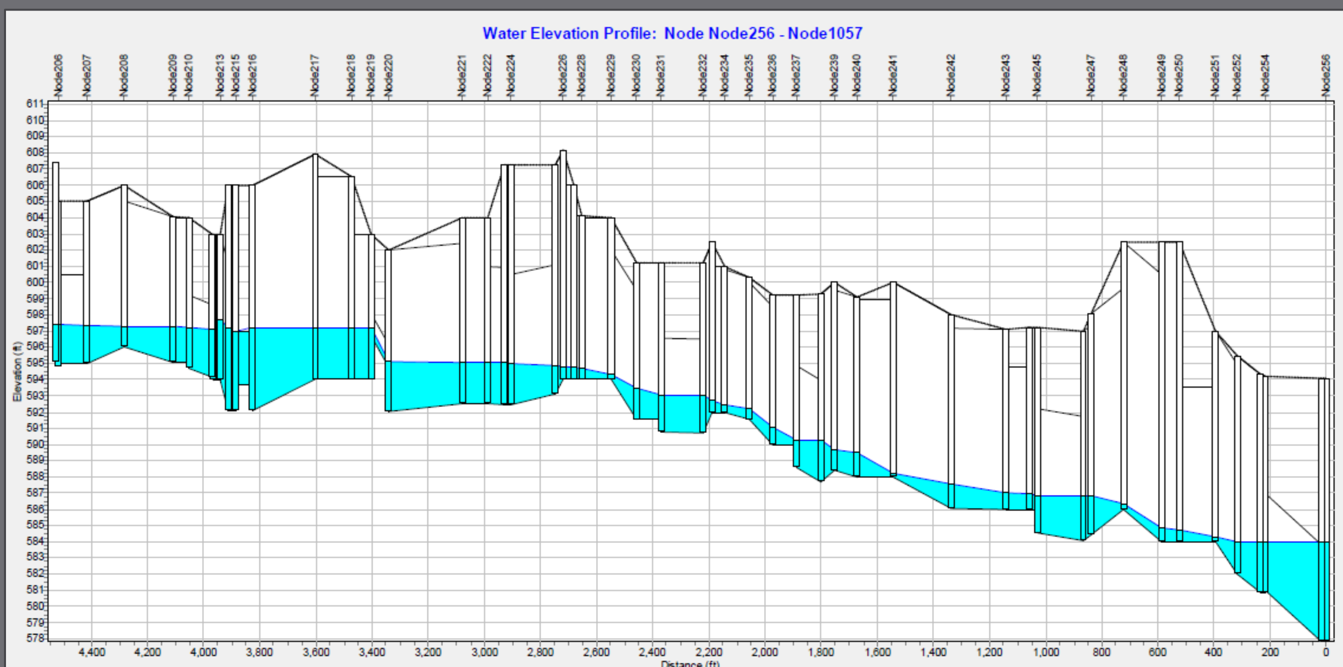


Figure 16. Profile from Seventh Street Crossing (between model nodes 206-207) to Boardman River. Note undersized and high crossing at lower Cedar Creek culvert (between model nodes 219-220).

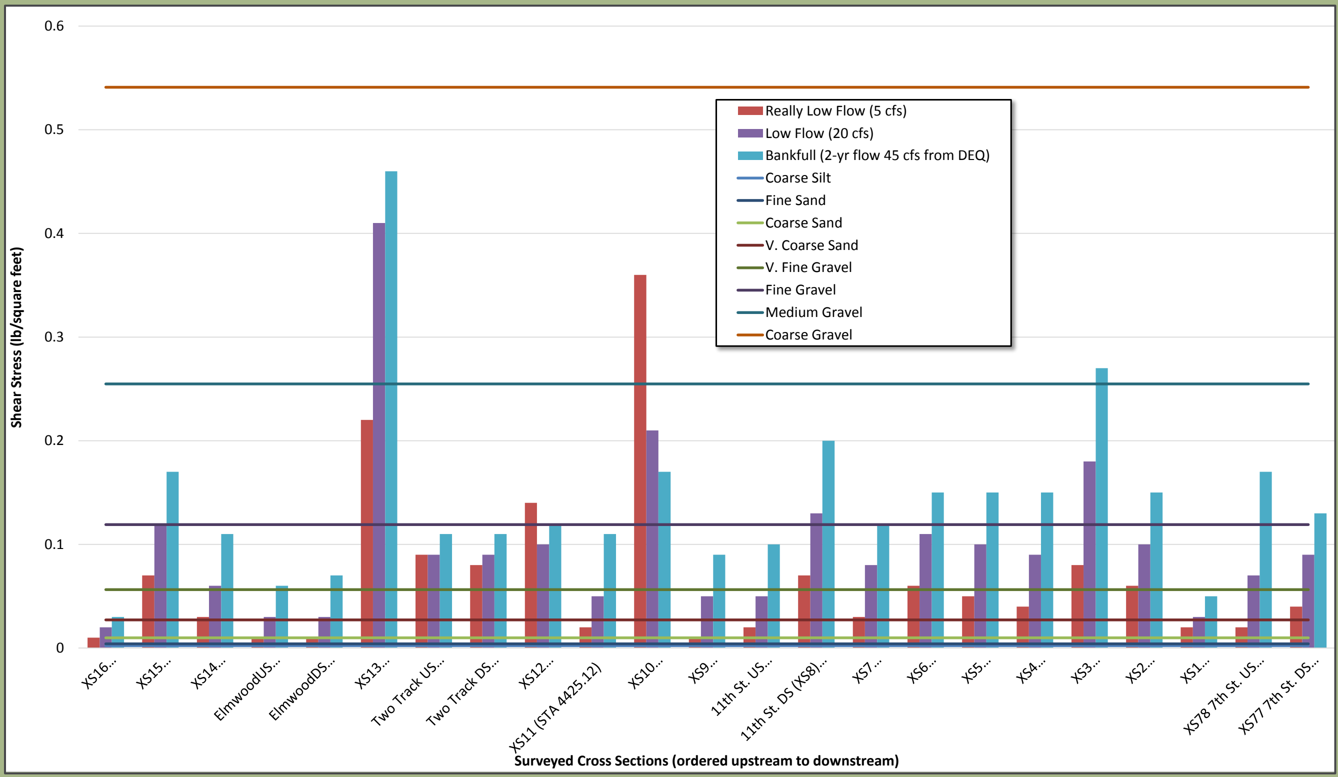


Figure 17. Incipient motion analysis results, showing maximum sized particle mobility along Kids Creek from Silver Lake Road to 7th Street, assuming an average bed slope along the entire reach of 0.17%

This kind of change to the hydraulic profile is crucial to sediment transport. The average slope of Kids Creek from Silver Lake Road to 7th Street is approximately 0.17%. This slope can be sufficient to move sand, as long as the channel dimensions are small enough to maintain a reasonable unit stream power. Looking at cross-section data and applying that average stream gradient (refer to Figure 18) one can see that at bankfull flow – the flow theoretically doing the most work to shape the channel, on average most cross-sections can potentially move up to fine gravel (4-8 mm), but few can move even medium-sized gravel (8-16 mm). It is these larger particle sizes from fine gravel on up, that help create the kind of bed heterogeneity that are also going to retain a wider variety of macroinvertebrates.

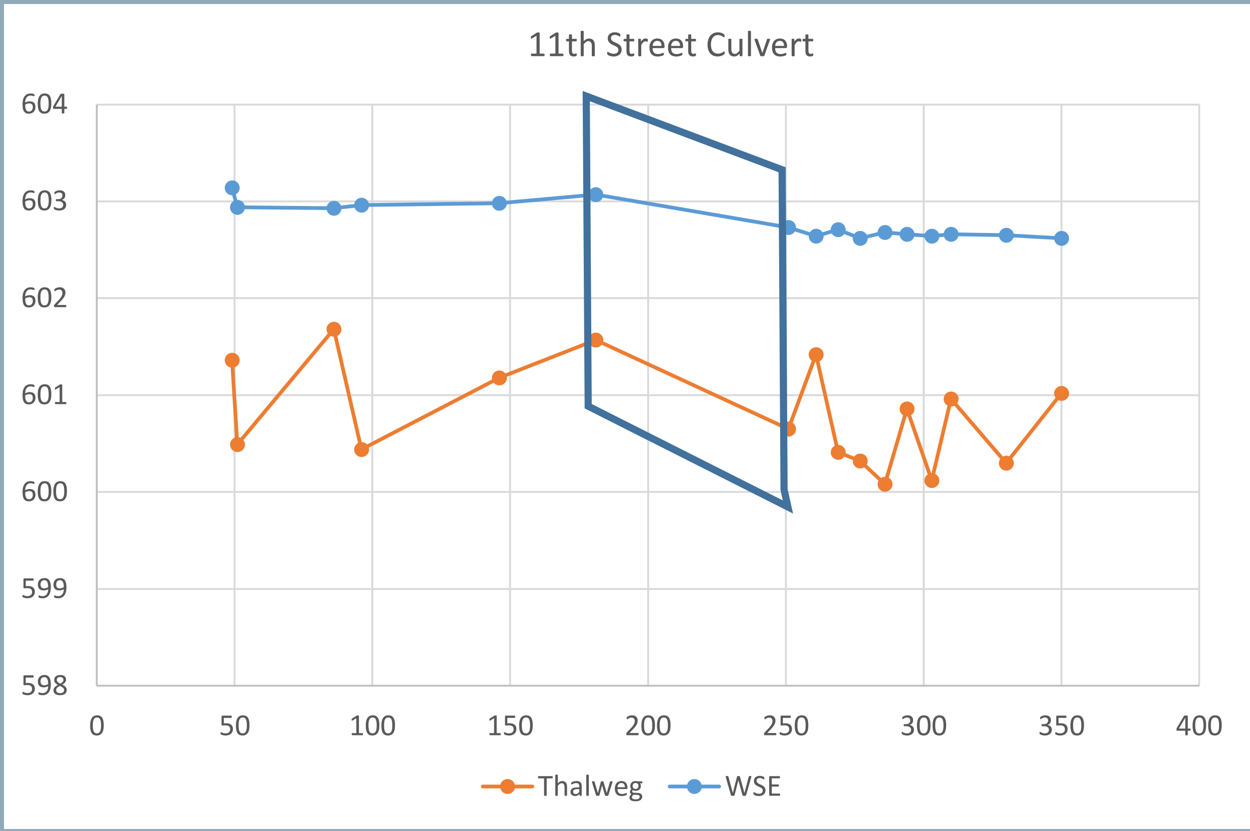


Figure 18. Bed profile and water surface shots in Kids Creek at the 11th Street culvert (April 5, 2017).

However, Kids Creek has a distinct pool-riffle pattern, like most natural channels in lower Michigan. This pool-riffle pattern means that the channel bed rises up to the riffles and falls again into the pools. Looking at flow at the very local scale, water moving through a pool bottom actually rises up against a local adverse slope to reach the top of a riffle. The overall slope of the channel is maintained by the riffles and the riffles are typically where the coarser bed material is found. However, when a downstream riffle or obstruction such as woody debris or culvert increases head loss or raises the bed, even by inches, the impact of that obstruction can reach hundreds of feet upstream. When a downstream riffle elevation is above the upstream riffle, it will tend to diminish the stream power over that upstream riffle.

The hypothesis is that Kids Creek, particularly in the Silver Lake to 7th Street, on average has sufficient power to move sand and fine gravel but due to over-widening in some places, wood and culvert obstructions acting as grade controls, bed slopes and flow area have reduced transport capacity in multiple locations. For instance, some recently-taken bed profile shots upstream and downstream of the 11th Street culvert, show how the culvert raises the bed profile. In this case, it is not more than a foot, however, a foot rise can impact almost 600-ft back upstream. The culvert is also too narrow, adding to head losses that will affect flow and sediment transport capacity within and upstream of the culvert.

SECTION 4: WATER QUALITY CONSIDERATIONS

One of the primary goals of the City is to "protect and improve the quality of water resources within the City that effect water quality in Grand Traverse Bay and its watershed", which was first declared in the Grand Traverse Bay Watershed Plan. There are a number of ways that the City can reach this goal. First is to strengthen City regulations by ensuring that the regulations address water quality. The City's existing Ground-Water Protection and Stormwater Control Ordinance Guidelines, see **Appendix F**, should be regularly updated to meet current best management practices (BMPs) and should be incorporated into the City's stormwater ordinance. An ordinance which regulates the use of open loop geothermal systems within the City should also be created as a way to reach this goal.

4.1 Stormwater Management

Stormwater management is a key component to ensuring the longevity of storm water treatment systems and maintaining healthy natural water sources such as rivers, lakes, streams, and the Grand Traverse Bay. Stormwater management is a combination of stormwater treatment and stormwater system maintenance, as well as policies to help encourage the infiltration of stormwater before it reaches catchbasins, stormwater treatment systems, or surface waters.

"To protect and improve the quality of water resources within the City that effect water quality in Grand Traverse Bay and its watershed"

~ Grand Traverse Bay Watershed Plan

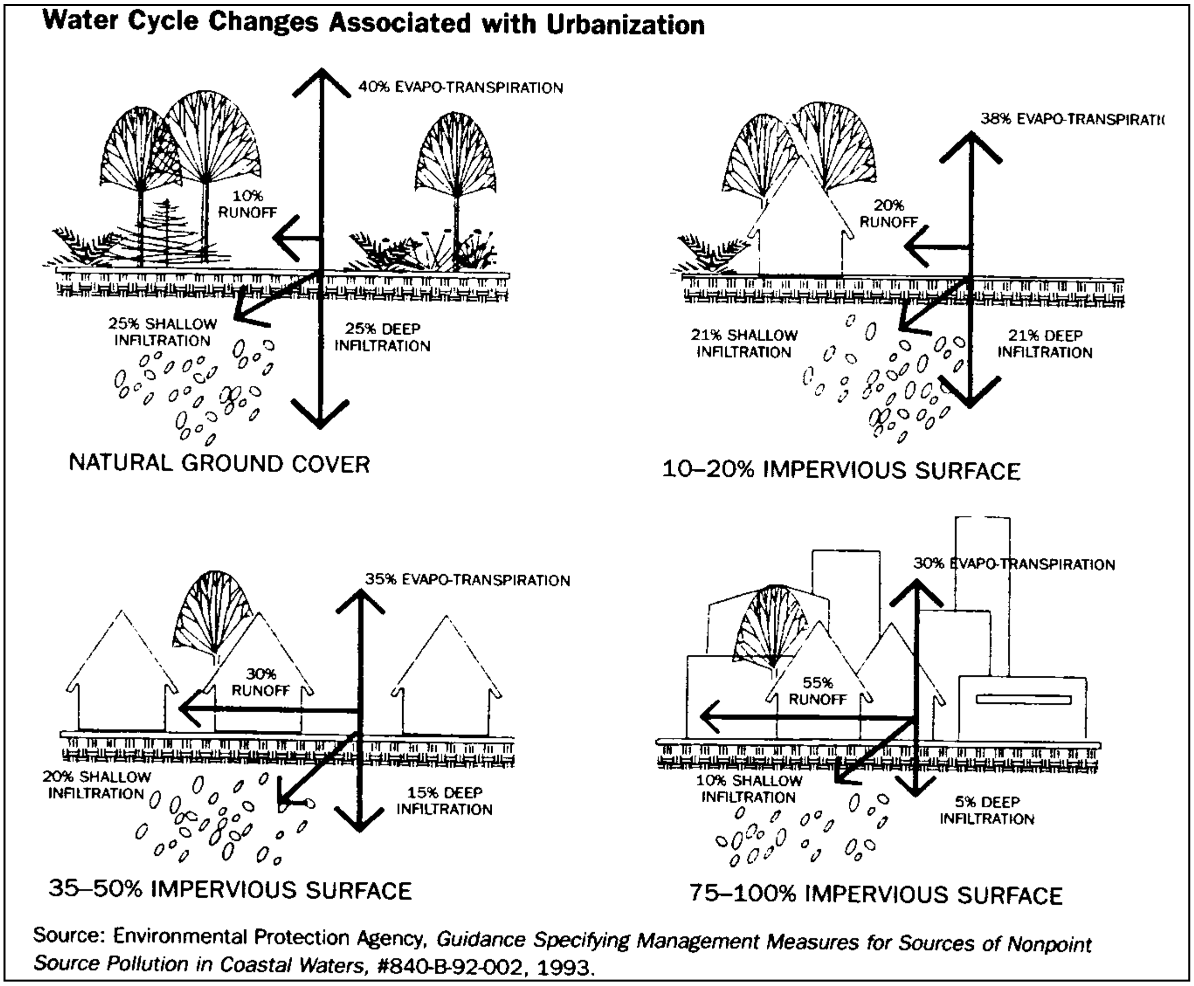


Figure 19. Water Cycle Changes Associated with Urbanization

The City currently uses a number of BMPs as a way to protect and improve water quality, such as street sweeping and the use of catch basin sumps. A table of currently installed and implemented stormwater BMPs within the City can be found on the following page (Table 2). Although the use of BMPs is an important part of any proposed City project, maintenance of the BMPs is crucial. In many cases, if a BMP is not properly maintained, it may lead to the BMP no longer improving water quality or a clog in the stormwater sewer system. Therefore, consideration of how the BMP will be maintained and ensuring that a regular maintenance schedule is adhered to is pivotal when looking at different BMP options for any given project. Along with BMPs, river bank stability and green infrastructure (Low Impact Development) should be considered for all applicable projects, public and private, within the City Limits.

Table 2. Currently Installed/Implemented Stormwater BMP

		Stormwater Quantity Functions			Stormwater Quality Functions							
	Stormwater BMP	Volume	GW Recharge	Peak Rate	TSS	TP	Nitrogen*	Hydrocarbons	Temp	Cost	Maintenance	Winter Performance
Runoff Volume/ Infiltration	**Drywell**	MEDIUM	HIGH	MEDIUM	HIGH**	MED/HIGH	LOW/MED	MED/HIGH	HIGH	MEDIUM	LOW/MED	HIGH
	Infiltration Trench	MEDIUM	HIGH	LOW/MED	HIGH**	MED/HIGH	LOW/MED	MED/HIGH	HIGH	MEDIUM	LOW/MED	HIGH
	Pervious Pavement	HIGH	HIGH	MED/HIGH	HIGH**	MED/HIGH	LOW	LOW/MED	HIGH	MEDIUM	HIGH	MEDIUM
	Rain Garden	MED/HIGH	MED/HIGH	MEDIUM	HIGH	MEDIUM	MEDIUM	MED/HIGH	HIGH	MEDIUM	MEDIUM	MEDIUM
	Vegetated Swale	LOW/MED	LOW/MED	LOW/MED	MED/HIGH	LOW/HIGH	MEDIUM	MED/HIGH	MEDIUM	LOW/MED	LOW/MED	MEDIUM
	Infiltration Basin	HIGH	HIGH	HIGH	HIGH**	MED/HIGH	MED (NO_3)	MED/HIGH	HIGH	LOW/MED	LOW/MED	MED/HIGH
	Tree Box	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW/MED	LOW/MED	MEDIUM	HIGH	MEDIUM	MEDIUM	MEDIUM
	Nutrient Separating Baffle Box	HIGH	HIGH	HIGH	HIGH**	MED/HIGH	LOW	MED/HIGH	HIGH	HIGH	MEDIUM	HIGH
	Subsurface Infiltration Bed	HIGH	HIGH	HIGH	HIGH**	MED/HIGH	LOW	MED/HIGH	HIGH	HIGH	MEDIUM	HIGH
Runoff Quality/ Non-infiltration	**Hydrodynamic Device**	N/A	N/A	N/A	VARIES	VARIES	VARIES	VARIES	NONE	MED/HIGH	VARIES	HIGH
	Constructed Wetland	LOW	LOW	HIGH	HIGH	MEDIUM	MEDIUM	MED/HIGH	LOW/MED	HIGH	LOW/MED	MED/HIGH
	Traverse City Outlet Cover w/ Microbial Skirt	N/A	N/A	N/A	HIGH	LOW	LOW	MED/HIGH	NONE	LOW	LOW	HIGH
	Helical Filter	N/A	N/A	N/A	HIGH	MEDIUM	MEDIUM	LOW/MED	LOW	MED/HIGH	HIGH	MEDIUM
	Detention Pond/Basin	LOW	LOW	HIGH	MEDIUM	MEDIUM	LOW	MEDIUM	LOW	HIGH	LOW/HIGH	MED/HIGH
	Sediment Trap	LOW	LOW	HIGH	MEDIUM	LOW	LOW	LOW	NONE	MEDIUM	MEDIUM	MED/HIGH
	Traverse City Screen	N/A	N/A	N/A	HIGH	MEDIUM	MEDIUM	MEDIUM	NONE	MEDIUM	HIGH	MEDIUM
	Fall/Spring Leaf Pickup*	N/A	N/A	N/A	HIGH	MED/HIGH	MED/HIGH	LOW	N/A	MEDIUM	MEDIUM	N/A
	Street Sweeping*	N/A	N/A	N/A	HIGH	MED/HIGH	MED/HIGH	MED/HIGH	N/A	MED/HIGH	HIGH	LOW
	Catchbasin Sump	LOW	LOW	HIGH	MEDIUM	LOW	LOW	LOW	NONE	MEDIUM	MEDIUM	HIGH
Restoration	**Riparian Buffer Restoration**	LOW/MED	LOW/MED	LOW/MED	MED/HIGH	MED/HIGH	MED/HIGH (NO_3)	MED/HIGH	MED/HIGH	LOW/MED	LOW	HIGH
	Native Revegitation	VARIES	VARIES	LOW/MED	HIGH	HIGH	MED/HIGH	HIGH	MEDIUM	LOW/MED	LOW	MEDIUM

*Reported at TN except as noted as (NO_3)

**This assumes TSS loads and their debris have been managed properly before entering the BMP to prevent clogging

***Stormwater Quality Preventative Maintenance Measure

4.1a Stormwater Best Management Practice (BMP)

There are currently dozens of stormwater management BMP's to choose from to meet stormwater management goals. The list grows as technologies and testing of installed BMP's continues to develop. No single BMP can address all stormwater quality issues. Each type has unique effectiveness and limitations depending on the site specific characteristics, the intensity of stormwater events, and the ease of maintaining the system.

There are a number of low impact development (LID) options, options that mimic the natural environment, that have been proven to be effective stormwater management tools. These options include: green roofs, rain gardens, drainage swales, leaching basins, and permeable pavement. One benefit of most LID methods is that they allow stormwater to infiltrate back into the water table, which uses the soil and plants as natural filters, instead of entering a municipal stormwater system. The most prevalent limitation of most LID options is that the area required for LID methods to treat the desired volume of stormwater is often too great to be used as the only stormwater treatment option in highly developed areas. Some LID options are also weather dependent and may not be effective in the spring, when runoff can be at its peak, in areas that experience harsher winters due to the ground being frozen.

BMP's for municipal stormwater sewer systems also exist. These options include stormwater treatment units that can be installed in manholes to filter out debris and/or oils from stormwater before reaching an outlet to surface water. The benefit of these systems is that many municipalities already have an extensive stormwater sewer network, and these systems allow for treatment of existing systems with little to no change to the existing stormwater sewer network.

Often, it is most practical and sometimes most effective to use a combination of LID methods and stormwater sewer BMP's for stormwater management. These options include retention basins with stormwater sewer overflows, stormwater sewers connected to leaching basins, or raingardens surrounding raised catchbasins with outlets protected by filtration systems installed in manholes.

4.2 Storm Drain Monitoring

It is important to note when looking at water quality results from stormdrains whether or not discharge or flow measurements were taken during sampling. Most stormwater samples are taken using the 'grab sample' method, which are only taken once during a rain event and represent a snapshot in time of the water quality at that particular storm drain. However, during rain events there are typically fluctuating volumes of water and concentrations of different types of pollutants coming out of a drain, which in turn will affect the pollutant load coming out of each drain (pollutant load calculated by multiplying volume by concentration). The higher the concentration of pollutant or the volume of water coming out of the drain, the higher the pollutant load.

Only thorough sampling during multiple rain events will lead to a clear picture of pollutant loadings to a watershed. Care should be taken not to make broad assumptions on stormwater quality in an urban area based solely on grab samples taken at a particular time during a rain event. In lieu of a potentially time consuming and expensive stormwater monitoring program, the use of models can be an effective way to approximate the amount of pollution to a watershed from stormdrains. Additionally, results from similar urban areas that have done stormwater monitoring can also be used to approximate pollutant loads.

A wide variety of water quality parameters have been tested in stormdrains throughout the City of Traverse City, with some testing dating back to 1980. However, a thorough stormwater analysis, including discharge and flow volumes, has not been conducted on a city-wide basis to date. Water quality results from a select number stormdrains in the City from 2009-2015 were averaged from 10 locations for Nitrate, Total Phosphorus (TP), and Total Suspended Solids (TSS). Results were as follows:

- TP average = 0.10 mg/l (100ug/L)
- Nitrate average - 0.47 mg/L
- TSS average = 96 mg/L

Data sources are from TWC-led studies including stormdrain testing program with City of Traverse City funds (2009), GLRI Project at Bryant Park (2011/2012), and BMP effectiveness testing at GLRI East Bay Park project (2013-2015).

Comparisons of stormwater results were also made on select storm drains with data from the 1990s to more recent results from 2009 and after - 8th Street, Bryant Park, East Bay Park (north and south drains), and Hannah Park. At these select sites Nitrates appear to have increased since the 1990s, TP has decreased, TSS was inconclusive (see Table below). Again, caution should be taken when comparing stormwater results where only grab samples were taken.

Location	Timeframe	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)
8th Street	Historic	0.01	0.27	30
	Recent	0.56	0.1	49
Bryant Park	Historic	0.10	0.20	43
	Recent	0.66	0.08	68
East Bay Par (north)	Historic	0.29	0.56	76
	Recent	0.29	0.12	47
East Bay Park (south)	Historic	4.5	0.20	n/a
	Recent	n/a	0.09	145
Hannah Park	Historic	0.01	0.46	91
	Recent	0.42	0.095	59

**Historic - 1991, 1992, 2000*
**Recent - 2009-2015*

4.2a Comparisons to local water quality monitoring of Boardman River and Grand Traverse Bay

Water quality results from surrounding waters in the Boardman River and Grand Traverse Bay reveal much lower levels of TP and Nitrogen than those found in stormwater samples. In general we are most concerned with Total Phosphorus (TP) levels in local waters because it's the growth limiting nutrient for the bay. This is because nitrogen/phosphorus ratios exceed 10:1 in Grand Traverse Bay and therefore Phosphorus input will drive plant growth. In general, TP values greater than 0.01 mg/L (10 ug/L) in water bodies such as lakes and rivers are indicative of impaired water quality and contribute to increased plant growth. Phosphorus levels in Grand Traverse Bay (as stated in 2005 GTBWPP) are 0.005 mg/L (5 ug/L), which are well below that threshold and indicate excellent water quality and oligotrophic conditions. In contrast, TP values in storm drains range between 0.03 - 0.2 mg/L, with an average of about 0.1 mg/L (see table above). This is an average of twenty times higher than water in Grand Traverse Bay.

Additional water quality information summarized in Section 2.4 of The Boardman River Watershed Prosperity Plan (BRWPP) show that nutrient levels are relatively low in the river and have been on a continual decline since the 1960s. A historical trend station was placed in the Boardman River at Beitner Road by the MDEQ in the 1960s, which gathered a wide variety of data over the years. A summary of TP and total nitrate/nitrite results show the gradual decline of nutrients at this station since it was installed. Specifically, TP has fallen from 0.029 mg/L from the historical record to more recent levels of 0.007 mg/L. Higher readings were also observed at the mouth of the Boardman River and range from 0.021-0.054 mg/L (average of 0.035 mg/L). Total phosphorus levels along Kids Creek, the largest tributary to the Boardman River, averaged 0.027 mg/L. The mouth of the Boardman River and Kids Creek both receive large amounts of stormwater input from the City of Traverse City and on the average have TP levels 3-4 times lower (respectively) than the levels measured in storm drain outputs. Additionally, to control eutrophication, the USEPA recommends that total phosphorus not exceed 0.05mg/L in a stream at a point where it enters a lake or reservoir. Kids Creek and the Boardman River are both below this threshold, but stormdrain samples are not. (http://pubs.usgs.gov/circ/circ1136/circ1136.html#CONCERNS)

Location	TP Level (mg/L)
GT Bay	0.005
Boardman River	0.035
Kids Creek	0.027
Storm Drains	0.100

The GTBWPP also states that TP levels are higher at nearshore areas than offshore. This is most likely due to runoff from urban areas and nutrient inputs along the shoreline from streams and stormdrain outlets. The effect of the nutrient inputs on the nearshore zone of west Grand Traverse Bay can be seen in a 2009 study TWC conducted on macrophyte bed growth in the bay (TWC 2010. *Grand Traverse Bay Macrophyte Bed and Sediment Survey Final Report.* Available from the Watershed Center Grand Traverse Bay at: (231) 935-1514). TWC conducted aquatic plant surveys in Grand Traverse Bay in 1991, 1998, and 2009, and completed a variety of water and sediment testing for nitrogen and phosphorus at locations with and without macrophyte beds and the mouths of several tributaries to the bay. These surveys showed a six-fold increase in the number of plant beds identified between 1991 and 2009 (1991: 64 beds; 1998: 124 beds; 2009: 402 beds). Most of the macrophyte beds were concentrated in embayments, such as Northport and Omena bays, as well as the southern end of west

Kids Creek winds through the City, often carving its way along streets and through back yards

Grand Traverse Bay, where the Boardman River drains. This growth is attributed to rapid development and nutrient flushing from stormwater inputs, particularly the amount of phosphorus entering the bay.

The overall message is that our water quality in the Grand Traverse Region of a very high quality and levels of TP in stormwater are three to 10 times higher than the receiving water body it goes into. Therefore we must do better to protect the Bay and streams/lakes in the watershed from degradation.

4.2b Bacteria (*E.coli*) Levels in Storm Drains

Bacteria levels of *E. coli* in stormdrains are high throughout the City of Traverse City during rain events. A summary of results from 11 outfalls confirm this (8th Street, Bryant Park - 2 locations, East Bay Park - 2 locations, Hannah Park, Holiday Inn, Hope Street, Maple Street, Sunset Park, and West End Beach). The highest results were noted at 8th Street, Bryant Park, East Bay Park, Sunset Park.

EPA recommends measuring recreational water quality by the abundance of *Escherichia coli* (*E. coli*), which is a common intestinal organism, so the presence of *E. coli* in water indicates that fecal pollution has occurred. However, the kinds of *E. coli* measured in recreational water do not generally cause disease; rather, they are an indicator for the potential presence of other disease causing pathogens. EPA studies indicate that when the numbers of *E. coli* in fresh water exceed water quality standards, swimmers are at increased risk of developing gastroenteritis (stomach upsets) from pathogens carried in fecal pollutions. The presence of *E. coli* in water does indicate what kinds of pathogens may be present, if any. If more than 300 *E. coli/1*00mL of water are present in a single sample, or if more than 130 *E. coli/100*mL of water in 5 samples over 30 days, the water is considered unsafe for swimming.

The Watershed Center monitored both the Boardman River and Kids Creek from 2002-2004 (TWC 2004). *E. coli* levels at the mouth of the Boardman were relatively low; out of 44 samples over three years, only one registered above state Water Quality Standards for full body contact (300 col/100mL), and the average reading was 88 col/100mL. However, Kids Creek did have elevated *E. coli* levels; out of 41 samples collected over three years, 17 samples were above 300 col/100mL, and the average of all results was 327 col/100mL

E. coli is a major problem in stormdrains in the City of Traverse City as discussed in the GTBWPP. Many stormdrains outlet adjacent to public lands as well, with many of the public lands being designated beach areas, which have the potential to negatively impact public health. The source of much of this pollution is from pet waste runoff and wildlife and waterfowl droppings. Stormdrains, especially on east side of Traverse City, have large numbers of raccoons living in them. In fact, the City has done camera work in drains and found multiple piles of raccoon droppings; and city workers cleaning out fire hydrants routinely see raccoon families coming in and out of catch basins.

4.3 Kids Creek Water Quality Recommendations

The recommendations fall into three categories:

- Programmatic – Traverse City stormwater program recommendations
- Infrastructure improvements – primarily culvert replacements
- Stream improvements – stream restoration projects

4.3a Programmatic Recommendations

The City shall strengthen its groundwater/storm water ordinance by incorporating design into ordinance form. Another programmatic recommendation would be to develop a Kids Creek monitoring program. For instance, currently wood in and around the channel is only attended to when it becomes a problem, for instance, clogging up a culvert. All natural channels in wooded areas have downed trees. These downed trees create their own microhabitats and should not just be pulled from the channel without consideration of the wood's function and impact on stream health. Some of the stream restoration recommendations following include strategic placement of wood in the channel for narrowing overwide reaches. In order to pre-emptively manage wood in the City's stormwater system, City staff should perform at least an annual inspection of the channel including wood either in the channel, or wood that is about to be "recruited" into the channel. The inspection would be about both sustaining habitat as well as pre-emptively managing wood that could become a problem for the City's stormwater system downstream. Kids Creek should be thought of both as an element of the City's stormwater system as well as a natural system and managed to benefit both. They do not have to be mutually exclusive goals.

4.3b Infrastructure Improvements

These infrastructure improvements center on culverts and culvert replacements. The recommended culvert replacements in the upstream Kids Creek reach include:

1. Elmwood crossing, just below Silver Lake Road
2. The two-track road crossing on the continuation of 14th Street
3. The 11th Street culvert
4. The pedestrian pathway crossing, just north of 11th Street
5. The Upper Front Street culvert

The upstream crossing replacements (items 1-4 above) are necessary both to improve the stream channel slope and improve sediment transport capacity to help address the creek's impairment. The upper Front Street culvert replacement would address sediment transport capacity at the Cedar Street and private crossing as well as flow capacity and would help make the Cedar Street culverts significantly less prone to filling. These culvert replacements are further described in the 2017 Stormwater Asset Management Plan recently prepared for the City.

4.3c Kids Creek Stream Improvements

The recommended improvements for Kids Creek are based on improving stream function and ecology; however, they are also predicated on either improving flood frequencies or at least not degrading them. Because the recommended improvements also have the potential to improve or even lift the impairment on Kids Creek, they would be good candidates for securing outside funding. Every outside funding source we are familiar with also requires or recommends match funds. The recommended improvements to Kids Creek have the potential to deliver several different kinds of benefits. For instance, while the projects could improve sediment transport and natural habitat, they have the potential to also increase flood frequencies as well. With this range of benefits, the City can build an appeal to the community for public funding. This public funding can then act as match to go after grant funds to complete the stream habitat improvements.

4.3c.1 Lower Kids Creek Stream Improvements

There are a set of projects in the lower portion of Kids Creek that would help with lifting the impairment in the creek. The highest priority project is to replace both Cedar Street crossings and the private driveway crossing between them. These crossings need to be lowered an enlarged to increase both water and sediment transport downstream. This reach is severely degraded both completely filled in with sand as well as over-widened. This area also floods frequently. Final design of this set of improvements would have to also manage the increased flow capacity and might potentially require some grade improvements downstream as well as increasing floodplain storage in the reach between the Cedar Street culverts. With care during planning, design and construction, this reach could become significantly improved, both from stream and flood protection perspective as well as from an aesthetic perspective.

Additionally, the outlet culvert of Kids Creek at its confluence of the Boardman River is wide and relatively steep (See Figure 20), resulting in shallow flow. We recommend that some "roughening" of the culvert be undertaken to enhance fish passage back up Kids Creek (Figure 21). This roughening could be the installation of stones that would function both to raise low flow elevations and provide resting spots for fish as they begin their trip back upstream in Kids Creek. This has become a standard practice to improve passage through culverts with reliable guidance documents.

Figure 20. Downstream end of Kids Creek (Wadsworth Street culvert) at the Boardman River. Flow depth is less than 6-inches deep

Figure 21. Example of Culvert bottom roughening (USFS photo)

4.3c.2 Upper Kids Creek Stream Improvements

Upper Kids Creek improvements would include both culvert replacements as well as a series of in-stream improvements that would help introduce habitat variability as well as create a series of "self-cleaning" riffles that would have a gravel bed (refer to Figures 22 and 23). The culvert replacement projects would provide more flow capacity for flow up to bankfull flow. New culvert design and additional floodplain storage would be created to limit peak flows for large events (>10-year return period) to current peak flows to limit impacts downstream impacts downtown.

Figure 22. Recommended riffle improvements (in brown), culvert replacements (in purple) and floodplain storage improvements (in green) on Kids Creek from Silver Lake Street to above 11th Street

Figure 23. Recommended riffle improvements (in brown), culvert replacements (in purple) and floodplain storage improvements (in green) on Kids Creek from 11th Street to 7th Street

As part of this planning process for upper Kids Creek, both the Tributary A daylighting project as well as some numerical experiments on potential improvements in Kids Creek were reviewed. The goal of these tasks is to develop a set of design criteria for "self-cleaning" riffles. For instance, Figure 24 on the next page shows two installed riffles on Tributary A. Based on the design both of these riffles were created with imported cobble. After more than four years from installation, the cobble is completely covered by sand, while the other riffle is still relatively clean. The second riffle can, at least up to this point considered "self-cleaning", that is, the coarse material is not being buried by finer material.

Figure 24. Conditions of installed riffle cobble on two designed riffles on Tributary A daylighting project. On the left, visible cobble; on the right no cobble visible due to sand deposition.

With the numerical experiment, a set of model runs where the total flow area of Kids Creek cross-sections were systematically changed and also either two or four inches of additional height for existing riffles was added were run. This experiment demonstrates that as the slope over the riffle increases or the channel cross-sectional area is decreased, stream power goes up and the size of a particle that would theoretically be mobile over the riffle goes up (Figure 25). With sufficient power over the riffle, sand cannot accumulate.

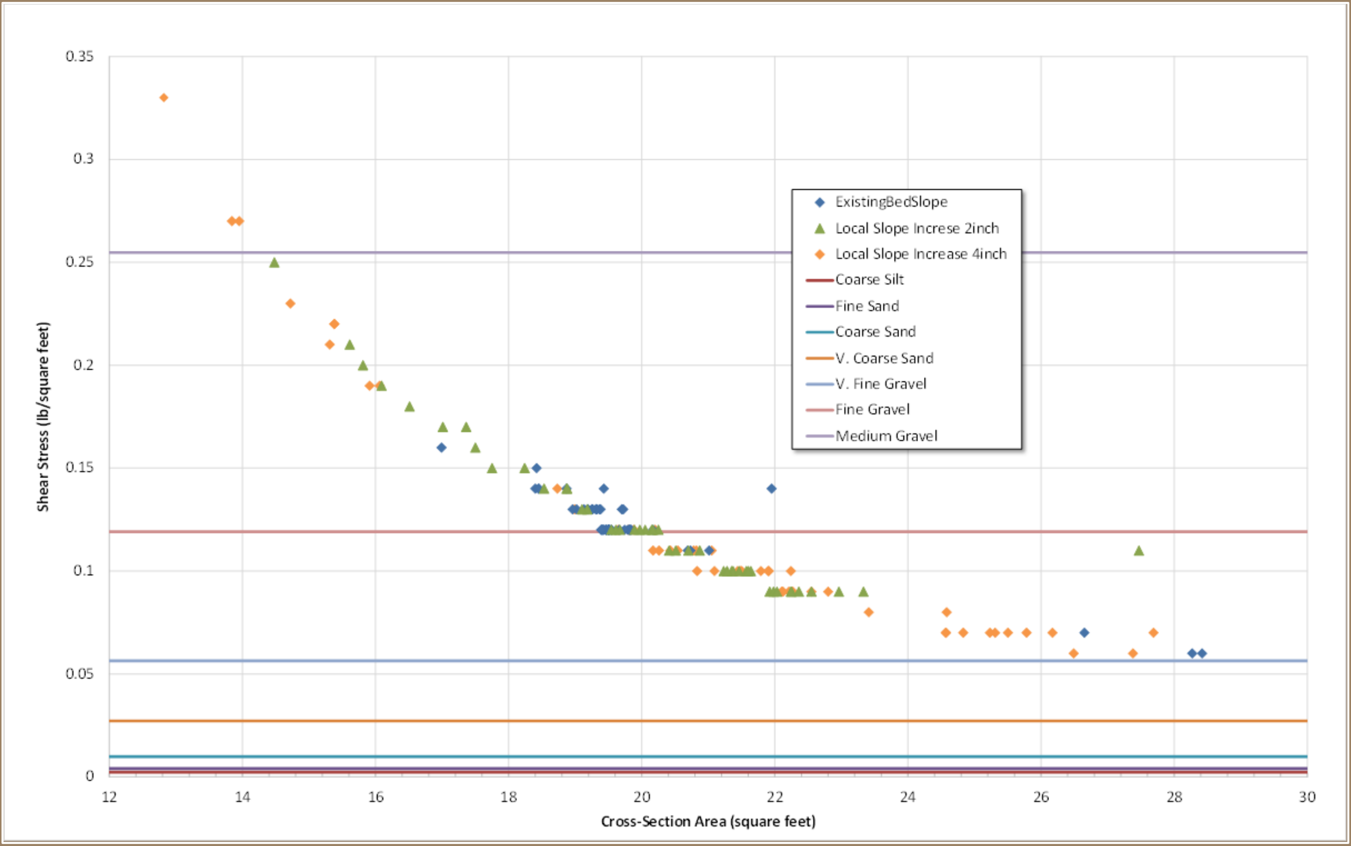


Figure 25. Change in shear stress and mobile particle size based on decreasing cross-section area and increasing slope over riffles on upper reach of Kids Creek

Final design of the stream improvements would require more detailed information, including a detailed, integrated geomorphic assessment that includes a longitudinal profile with thalweg shots at each stream feature such as each riffles and pools, along with representative cross-sections at each stream feature; a particle size assessment at selected stream features, and a linked hydrologic, hydraulic and sediment transport model that incorporates all the data from the assessment. It is also recommended that collection of some of the same data at representative riffles on Tributary A be completed, since the starting condition of that stream is so well-defined. The index derived from these parallel analyses is a shear stress/particle size mobilization metric that can be used to define channel characteristics, at riffles in particular.

SECTION 5: CAPITAL IMPROVEMENT PLAN (CIP)

Based on the findings of the stormwater sampling outlined in the previous section, the City's main focus with regard to stormwater quality should be with reducing total phosphorus (TP) and E. Coli while increasing the quantity and quality of stormwater sampling. With this in mind, all applicable future projects, public and private, should consider the use of BMPs and green infrastructure to improve water quality within the City. All projects need to consider operational and maintenance requirements and cost. Projects need to consider available maintenance equipment and trained staff.

Along with the general maintenance and upkeep of stormwater quality utilities, municipalities should have a number of environmental stewardship programs in place. Environmental stewardship programs are programs aimed to increase the quality of the environment and prevent higher cost maintenance and environmental concerns down the road. These programs are sometimes a collaborative effort between the City and property owners, such as leaf pickup, or are the sole responsibility of the City, such as catchbasin cleanout. The City of Traverse City currently has a number of environmental stewardship programs in place. These programs include:

- **Fall Leaf Pickup**
  - To reduce the amount of leaves entering the storm system and to prevent the clogging of catchbasin inlets and storm sewers
- **Spring Cleanup**
  - To reduce the amount of organic matter entering the storm system, which clogs existing treatment systems and can lead to algae plumes
- **Annual Clean Up and Green Up Recycling Event**
  - Residents may bring a number of items to be recycled, repurposed, or reused to a designated location in the City for collection, free of charge
- **Street Sweeping**
  - To reduce the amount of road sediment and debris from entering the storm system during rain events. A map showing street sweeping routes and frequencies can be found in **Appendix G**.
- **Catch Basin Cleanout**
  - To remove suspended solids including nutrients, pathogens and toxins which was demonstrated to be effective in reducing mass emissions of pollutants associated with solids via stormwater
  - The City invests $270,000 to $350,000 annually towards street sweeping, catch basin cleaning, and cleaning water quality treatment systems

5.1 Determining BMPs for Future Investment Projects

The City currently has a number of stormwater BMPs installed, with an investment of $1,805,000 in BMPs (not including maintenance and prevention items such as street sweeping, brush pick up, and catchbasin cleaning) since 2003. A map showing the locations of these improvements can be found in **Appendix G.** Using the installation cost of these devices and the XP SWMM model or equivalent water quality flow values, the City Engineering Department evaluated each of the stormwater sewer systems and determined a treatment type and associated cost for each stormwater sewer system. Using this information, an estimated $4,314,000 is needed to ensure that each stormwater sewer system has an appropriate stormwater BMP installed. A breakdown of the proposed BMPs and installation costs for each of the stormwater sewer systems can be found in the following table (Table 3).

Table 3. Stormwater Quality Treatments Based on Water Quality Flow

Boundary	XP SWMM/ *Equivalent* Water Quality Flow	Existing Treatment Type/ *Proposed Improvement*	Area (acres)	Proposed Improvement Cost
A	13.53	**Aqua Swirl (AS - 8)**	45.69	
AA	*7.10*	*Drywell, Traverse City Outlet Cover*	5.37	$ 50,000.00
AB	*1.25*	*Munson Campus*	1.73	
AC	*0.84*	*Munson Campus*	1.64	
AD	*5.87*	*Munson Campus*	3.66	
AE	7.70	*Munson Campus*	16.38	
AF	1.43	*Munson Campus*	2.78	
AG	17.96	**Aqua Swirl AS-5**	100.52	
AH	*0.76*	*Traverse City Outlet Cover*	0.85	$ 8,500.00
AI	9.52	**Suntree Nutrient Separating Baffle Box**	71.59	
AI	16.88	**(see above)**	71.59	
AJ	*6.36*	*Drywell, Traverse City Outlet Cover*	9.36	$ 20,000.00
AK	*6.27*	**Traverse City Outlet Cover w/Aluminum Hatch/3' sump (In Parking Lot Only),** *Oil Grit Separator*	22.74	$ 50,000.00
AL	*0.69*	*Traverse City Outlet Cover*	0.49	$ 8,500.00
AM	*1.02*	*Traverse City Outlet Cover*	0.73	$ 8,500.00
AN	8.39	**Underground Infiltration (In Parking Lot Only),** *Oil Grit Separator*	20.07	$ 50,000.00
AO	11.31	*Drywell, Traverse City Outlet Cover*	38.41	$ 60,000.00
AP	*1.15*	*Traverse City Outlet Cover*	2.26	$ 8,500.00
AQ	7.57	*Munson Campus*	19.11	
AR	*2.90*	*Traverse City Outlet Cover*	2.77	$ 8,500.00
AS	*3.17*	*Drywell, Traverse City Outlet Cover*	5.39	$ 20,000.00
AT	*5.48*	*Drywell, Traverse City Outlet Cover*	10.09	$ 20,000.00
AU	14.52	*Oil Grit Separator, Drywell, Traverse City Outlet Cover (MDOT)*	65.94	$ 70,000.00
AV	*2.17*	*Traverse City Outlet Cover*	2.10	$ 8,500.00
AW	*6.95*	*Drywell, Traverse City Outlet Cover*	8.66	$ 20,000.00
AX	*6.89*	*Traverse City Outlet Cover*	7.32	$ 8,500.00
AX	*7.66*	*Traverse City Outlet Cover*	7.32	$ 8,500.00
AY	*5.16*	*Oil Grit Separator, Drywell, Traverse City Outlet Cover*	23.57	$ 70,000.00
AZ	*1.75*	*Drywell, Traverse City Outlet Cover*	2.32	$ 20,000.00
B	*9.26*	**Settling - STC 2400 - Stormceptor, Leaching Basins w/2' and 3' Sumps**	14.38	
BA	*3.28*	**Traverse City Outlet Cover in Catchbasin into Oil Grit Separator**	3.51	

Boundary	XP SWMM or *Equivalent*	Existing Treatment Type/ *Proposed Improvement*	Area (acres)	Proposed Improvement Cost
	Water Quality Flow			
BB	*6.45*	**Drywells, Traverse City Outlet Cover in Manhole w/3ft sump**	5.35	
BE	*3.51*	*Drywell, Traverse City Outlet Cover*	5.25	$ 20,000.00
BF	*7.40*	**Drywell, Traverse City Outlet Cover**	6.72	
BG	19.10	*Oil Grit Separator, Traverse City Outlet Cover*	4.60	$ 180,000.00
BH	19.10	*(see above)*	88.79	
BI	*9.86*	*Rain Gardens, Traverse City Outlet Cover*	22.71	$ 50,000.00
BJ	*0.85*	*Traverse City Outlet Cover*	1.58	$ 8,500.00
BK	7.69	*Vegetated Swales, Drywell, Traverse City Outlet Cover*	58.35	$ 50,000.00
BM	50.19	*Tree Boxes, Drywells, Oil Grit Separator, Traverse City Outlet Cover (Grant Applied For)*	177.53	$ 430,000.00
BN	*0.17*	*Traverse City Outlet Cover*	0.14	$ 8,500.00
BO	*0.15*	*Traverse City Outlet Cover*	0.09	$ 8,500.00
BP	*0.32*	*Traverse City Outlet Cover*	0.18	$ 8,500.00
BQ	*7.35*	**Traverse City Outlet Cover in Manhole w/2ft Sump, Contech - Model CDS3030**	7.86	
BR	*2.23*	**Traverse City Outlet Cover w/2ft Sump, AquaSwirl AS-3, Rain Gardens**	1.22	
BS	*0.67*	**40' x 15' Stone Drainbed**	0.35	
BT	*1.56*	*Permeable Pavement, Traverse City Outlet Cover (Farmer's Market)*	0.98	$ 300,000.00
BU	0.66	*Drywell, Traverse City Outlet Cover*	1.41	$ 20,000.00
BV	*3.48*	*Tree Boxes, Traverse City Outlet Cover*	3.12	$ 58,000.00
BW	*2.61*	*Tree Boxes, Traverse City Outlet Cover*	4.54	$ 107,500.00
BX	*2.75*	*Tree Boxes, Traverse City Outlet Cover*	3.50	$ 41,500.00
BY	*1.74*	*Drywell, Traverse City Outlet Cover (Lot K Permeable Pavement)*	1.52	$ 20,000.00
BZ	*1.62*	*Tree Box, Traverse City Outlet Cover*	4.93	$ 25,000.00
BZ	*1.62*	*Tree Box, Traverse City Outlet Cover*	4.93	$ 25,000.00
C	5.52	**Swirl (CDS Technologies PSWC 30 - 20) Left handed, Aqua-Swirl Separator Unit**	14.14	
CA	*1.31*	**Aqua-Swirl Separator Unit**	2.38	
CB	*10.37*	*Drywells, Traverse City Outlet Cover*	13.85	$ 70,000.00
CE	13.68	*Oil Grit Separator, Drywell, Traverse City Outlet Cover*	25.70	$ 250,000.00
CF	*4.54*	*Drywell, Traverse City Outlet Cover*	8.23	$ 20,000.00
CG	*2.47*	*Drywell, Traverse City Outlet Cover*	2.27	$ 20,000.00
CH	*4.08*	*Drywell, Traverse City Outlet Cover*	5.54	$ 20,000.00
CI	19.90	*Drywells, Rain Gardens, Oil Grit Separator, Traverse City Outlet Cover*	36.21	$ 100,000.00
CJ	7.60	*Drywells, Traverse City Outlet Cover, Oil Grit Separator*	23.75	$ 85,000.00

Boundary	XP SWMM or *Equivalent* Water Quality Flow	Existing Treatment Type/ *Proposed Improvement*	Area (acres)	Proposed Improvement Cost
CK	*12.74*	*Drywells, Oil Grit Separator, Traverse City Outlet Cover*	64.39	$ 74,500.00
CL	24.50	**6ft Downstream Defender, Settling Tanks/Screen Filter Treatment System, Chambered Filtration System**	149.55	
CM	36.80	*Vegetated Swales, Drywells, Traverse City Outlet Cover*	135.19	$ 245,000.00
CN	8.90	*Rain Gardens, Traverse City Outlet Cover*	9.27	$ 13,500.00
CO	52.70	**Underground Detention, TC Screen, Hydo-separator**	147.32	
CP	*56.13*	*Vegetated Swales, Rain Gardens, Traverse City Outlet Cover*	262.83	$ 210,000.00
CQ	58.30	*Vegetated Swales, Rain Gardens, Traverse City Outlet Cover*	930.86	$ 29,500.00
CS	18.00	*Vegetated Swales, Drywell, Traverse City Outlet Cover*	113.85	$ 38,000.00
CT	49.40	*Vegetated Swales, Drywells, Oil Grit Separator, Traverse City Outlet Cover*	151.49	$ 250,000.00
CU	84.50	*Vegetated Swales, Drywells, Oil Grit Separator, Traverse City Outlet Cover*	399.04	$ 256,500.00
CV	*2.69*	*Vegetated Swales, Rain Gardens, Traverse City Outlet Cover*	8.79	$ 20,500.00
CW	*1.81*	*Rain Gardens, Traverse City Outlet Cover*	7.37	$ 13,500.00
CX	*5.69*	*Vegetated Swales, Rain Gardens, Traverse City Outlet Cover*	18.31	$ 14,500.00
CY	12.53	*Oil Grit Separator System, Traverse City Outlet Cover*	79.66	$ 58,500.00
CZ	*3.33*	*Drywell, Traverse City Outlet Cover*	4.76	$ 20,000.00
D	24.39	**Swirl (Contech VS - 70), 4ft Downstream Defender**	108.53	
E	35.40	**6ft & 8 ft Downstream Defenders, Settling Tank/ Screen Filter Treatment System, Helix Filtration Treatment System**	60.23	
F	31.40	**Swirl (8ft Downstream Defender), Filtration**	134.13	
G	11.60	**Swirl (6ft Downstream Defender), Filtration**	31.43	
H	*4.32*	*Vegetated Swales, Rain Gardens, Traverse City Outlet Cover*	26.88	$ 26,500.00
I	*1.32*	*Traverse City Outlet Cover*	7.73	$ 8,500.00
J	*6.31*	*Drywells*	13.50	$ 48,500.00
K	*7.39*	*Traverse City Outlet Cover*	11.69	$ 8,500.00
L	*2.10*	**Drywell**	1.35	
M	*0.52*	*Traverse City Outlet Cover*	0.43	$ 8,500.00
N	*3.14*	**Aqua Swirl (AS-2 w/H-20 Lid)**	1.65	
P	*1.19*	*Traverse City Outlet Cover*	0.57	$ 8,500.00
Q	*2.07*	*Traverse City Outlet Cover*	1.29	$ 8,500.00
R	*1.76*	*Traverse City Outlet Cover*	1.01	$ 8,500.00

Boundary	XP SWMM or *Equivalent*	Existing Treatment Type/ *Proposed Improvement*	Area (acres)	Proposed Improvement Cost
	Water Quality Flow			
S	*0.83*	*Traverse City Outlet Cover*	0.72	$ 8,500.00
T	*1.07*	*Traverse City Outlet Cover*	0.57	$ 8,500.00
V	*2.05*	*Drywell, Traverse City Outlet Cover*	2.45	$ 20,000.00
V	*2.05*	*Drywell, Traverse City Outlet Cover*	2.45	$ 20,000.00
W	*12.50*	*Tree Boxes, Drywells, Oil Grit Separator, Traverse City Outlet Cover*	25.39	$ 214,500.00
X	*1.52*	*Drywell, Traverse City Outlet Cover*	1.21	$ 20,000.00
Z	6.06	*Drywells, Traverse City Outlet Cover*	18.22	$ 56,500.00
			TOTAL=	**$ 4,314,000.00**

Considerations for prioritization of sites to receive stormwater quality improvements should include attention to areas that are:

- Near public beaches and parks
- Adjacent to surface waters
- Known for water quality issues
- In Central Business Districts
- Easily funded by grants

5.2 Grand Traverse Watershed Center Grants

Currently, a 4-mile portion of Kids Creek, located in an urban area on the west side of Traverse City, is on the State's 303(d) Impaired Waters List due to the 'Other Indigenous Aquatic Life' Designated Use not being met (i.e. poor macroinvertebrate community). This is mainly due to sedimentation, flow regime alteration, and other human-caused sources. Although a Total Maximum Daily Load (TMDL) plan for Kids Creek is not currently scheduled to be drafted as part of the MDEQ's 2016-2022 "Prioritization Framework for the Long-Term Vision for Assessment, Restoration, and Protection under the Clean Water Act Section 303(d) Program," it remains on the 303(d) non-attainment list as needing a TMDL. Kids Creek is an important spawning stream, nursery stream, and coldwater contributor to Grand Traverse Bay and has self-sustaining populations of Brook Trout and Brown Trout, as well as migratory populations of Chinook Salmon, Coho Salmon, and steelhead.

In 2013, The Watershed Center Grand Traverse Bay (TWC) began a large-scale Kids Creek Restoration Project with the goal of reducing the impact of stormwater and sedimentation on Kids Creek and its tributaries so it could be removed from the State's 303(d) Impaired Waters List. Working in partnership with the MDEQ, TWC completed a draft Kids Creek Action Plan in 2013 to address stormwater and sediment inputs and their effects on Kids Creek. The action plan provided a prioritized list of BMPs that would decrease both the input and effects of stormwater and sediment to the creek as well as improve in-stream habitat for macroinvertebrates and fish communities. Restoration methods outlined in the plan follow general guidelines and recommendations from the Grand Traverse Bay Watershed Protection Plan. Over the past several years, TWC has been working with MDEQ, EPA, and other local partners to implement this action plan as part of our Kids Creek Restoration Project.

To date, TWC has received more than $4.2 million in MDEQ, EPA-Great Lakes Restoration Initiative (GLRI), and private funding to implement key portions of the Kids Creek Action Plan as part of the Kids Creek Restoration Project. Thus far, much of the project work has focused on reducing stormwater inputs to Kids Creek from urban areas using green infrastructure and low impact development techniques. However, the next phase of the restoration project includes work within the channel to restore in-stream habitat and provide floodplain storage during periods of high flow. This work is critical to restore and protect the habitat necessary for thriving fish and macroinvertebrate communities in the creek, which will be a key factor in getting the impairment lifted. Several projects with these components are already planned or completed along Kids Creek including daylighting 900 feet of Kids Creek Tributary A to a new 1,275 foot channel and establishment of 27,000 square feet of vegetated floodplain (completed September 2013); restoring natural stream function, connecting the floodplain, and installing a riparian buffer on Kids Creek Tributary AA (planned 2017) and Kids Creek Tributary A (downstream from daylighting site, planned for 2018); and creating a wetland floodplain area adjacent to a ditch conveying runoff to Kids Creek from a major storm drain outfall in the City of Traverse City (GLRI proposal submitted January 2017, planned for 2019 construction).

In an effort to make improvements to known Kids Creek problem areas in the City, TWC has secured two grants. One grant is from the EPA Great Lakes Restoration Initiative for making improvements to Kids Creek as it follows 14th St in stormdrains. The other is from the National Fish and Wildlife Foundation for the improvement of the natural stream function and habitat of Kids Creek between 7th St and Silver Lake Rd. These projects will continue the important stream restoration activities to improve natural stream function and in-stream habitat described above, which are key components to the impairment to the creek being lifted.

5.2a Kids Creek 14th Street Stormdrain Project

This project will improve water quality and reduce stormwater and sediment inputs to Kids Creek, an impaired stream reach in the Grand Traverse Bay watershed. A wetland floodplain area will be created adjacent to a ditch conveying runoff to Kids Creek from a major storm drain outfall in the City of Traverse City. This wetland area will receive stormwater as it flows down the conveyance ditch and help reduce peak flows and sediment input to Kids Creek. This project will continue work on the large-scale Kids Creek Restoration Project by implementing BMPs to improve water quality and reduce stormwater and sediment inputs to Kids Creek, with the goal of removing the creek from the State's 303(d) Impaired Waters List.

5.2b Kids Creek between 7th Street and Silver Lake Road Restoration Project

This project will continue work on the large-scale Kids Creek Restoration Project in the Grand Traverse Bay watershed by implementing BMPs to improve water quality and reduce stormwater and sediment inputs to Kids Creek, with the goal of removing the creek from the State's 303(d) Impaired Waters List. Specifically, to improve natural stream function and improve in-stream habitat on a 5,400-foot (1 mile) section of Kids Creek by installing riffle-pool enhancements, placing large wood in the stream, connecting the stream to its floodplain, removing an unnecessary culvert, and narrowing the stream channel using natural, bioengineering techniques.

On a broader scale, this project will not only help reduce the impairment on a 303(d) listed stream section, it will also help meet the goals of the Great Lakes Restoration Initiative (GLRI), specifically working towards three Measures of Progress under the Habitats and Species section in the GLRI Action Plan II that state:

- Number of acres of other habitats in the Great Lakes basin protected, restored, and enhanced by GLRI-funded projects (2019 target - 207,000 acres)
- Number of miles of Great Lakes shoreline and riparian corridors protected, restored and enhanced by GLRI-funded projects (2019 target - 300 miles)
- Number of GLRI-funded projects that promote populations of native non-threatened and non-endangered species self-sustaining in the wild.

5.3 Grand Traverse Bay Watershed Protection Plan and Boardman Lake Watershed Study

Both the Grand Traverse Bay Watershed Protection Plan and Boardman Lake Watershed Study were reviewed and recommendations for updating the two documents were referred to the Grand Traverse Bay Watershed Center.

Some of the tasks recommended for the Grand Traverse Bay Watershed Protection Plan include: additional shoreline protection and restoration efforts, best management practices for road stream crossings, zoning and land use plan and ordinance development, utilization of low impact development (LID) standards, and shoreline and nutrient monitoring. Likewise, many of the same tasks recommended for the Grand Traverse Bay Watershed Protection Plan were recommended for the Boardman Lake Watershed Study, but with a focus on the Boardman Lake Watershed. The recommended updates to the plan are to meet current needs and implement the latest trends in stormwater management for water quality purposes.

APPENDIX A

Stormwater Boundary Areas A to AZ

"A-AZ" Storm Water Boundaries

Created September 26, 2007

City of Traverse City Engineering Department
2007 Storm Water Management Report

This map is based on a digital database from the City of Traverse City. The City of Traverse City cannot accept any responsibility for errors, omissions or positional accuracy. There are no warranties expressed or implied.

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APPENDIX B

Stormwater Boundary Areas B to BZ

"B-BZ" Storm Water Boundaries

Created September 26, 2007

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APPENDIX C

Stormwater Boundary Areas C to CZ

"C-CZ" Storm Water Boundaries

Created September 26, 2007

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APPENDIX D

Stormwater Boundary Areas D to Z

"D-Z" Storm Water Boundaries

Created September 26, 2007

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APPENDIX E

Runoff Calculations

Rainfall Values from Figure 7-2, Zone 3 (Inches)

2 Year	5 Year	10 Year	25 Year
2.09	2.70	3.21	3.89

Table 7-1: Average Runoff Curve Number (Acres)

Boundary	Hydrologic Soil Group B				
	Pavement 98	Residential 75	Forested 55	Total	Average Curve Number
A	1115.54	756.08	1332.44	3204.06	70.13
AA	296.16	66.58	80.28	443.02	82.51
AB	24.43	73.44	27.85	125.72	72.47
AC	38.85	1.84	66.86	107.56	65.72
AD	260.40	8.15	49.28	317.83	86.80
AE	474.96	503.42	265.13	1243.52	75.92
AF	65.88	110.62	34.53	211.04	76.05
AG	1603.92	814.82	4030.89	6449.63	64.16
AH	33.52	6.12	23.61	63.24	74.16
AI	1253.02	734.65	2695.57	4683.24	65.42
AJ	273.00	119.99	273.82	666.81	71.21
AK	919.91	281.08	528.10	1729.09	76.05
AL	31.80	0.00	9.26	41.06	83.32
AM	48.34	0.00	13.14	61.48	83.97
AN	930.41	279.66	376.77	1586.84	79.05
AO	1031.14	517.84	1154.35	2703.34	70.37
AP	53.67	4.65	90.58	148.90	65.99
AQ	782.22	255.05	425.16	1462.43	76.52

Boundary	Hydrologic Soil Group B				
	Pavement 98	Residential 75	Forested 55	Total	Average Curve Number
AR	117.71	40.57	56.67	214.95	77.53
AS	103.81	83.97	176.55	364.32	67.61
AT	227.12	164.86	306.81	698.79	69.23
AU	1504.25	1003.15	2046.62	4554.03	69.07
AV	101.06	25.74	39.70	166.51	79.43
AW	269.45	121.87	235.83	627.15	72.40
AX	315.14	107.40	146.86	569.40	77.81
AY	531.93	441.08	674.54	1647.55	69.89
AZ	67.73	30.20	67.27	165.21	71.30
B	540.05	262.64	295.08	1097.77	76.35
BA	123.77	65.93	75.01	264.72	75.51
BB	249.42	100.97	80.05	430.44	80.50
BE	111.61	93.39	157.75	362.74	69.07
BF	375.91	110.25	77.61	563.77	83.93
BG	95.57	86.44	135.88	317.90	69.13
BH	1871.89	1503.56	2730.54	6106.00	68.77
BI	621.24	381.24	620.59	1623.07	71.48
BJ	62.31	16.85	39.84	119.00	75.09
BK	1085.93	433.37	2282.04	3801.35	65.15
BM	4109.19	3661.99	4772.43	12543.60	70.66
BN	6.76	1.85	2.75	11.36	79.09
BP	12.13	3.04	1.11	16.27	88.25
BQ	310.83	174.17	129.93	614.93	78.27
BR	90.63	6.81	11.29	108.73	89.06
BS	27.12	1.82	2.80	31.74	90.19
BT	71.88	2.46	11.61	85.94	87.94

Boundary	Hydrologic Soil Group B				
	Pavement 98	Residential 75	Forested 55	Total	Average Curve Number
BU	96.35	2.57	21.39	120.31	85.55
BV	118.34	140.17	2.23	260.73	83.65
BW	109.82	241.35	11.29	362.46	79.77
BX	85.20	156.14	30.22	271.56	77.57
BY	70.98	32.76	19.78	123.52	81.22
BZ	39.04	18.11	235.73	292.88	59.46
C	532.13	241.91	301.54	1075.58	76.08
CA	105.77	34.96	46.11	186.84	78.38
CB	521.77	258.70	278.93	1059.41	76.52
CE	1190.89	761.41	186.72	2139.03	83.23
CF	356.35	154.26	139.39	650.01	79.00
CG	110.06	37.92	35.36	183.34	80.71
CH	243.92	90.45	101.54	435.91	78.67
CI	1431.75	467.89	845.12	2744.76	75.79
CJ	725.34	316.45	666.99	1708.79	71.96
CK	1817.94	943.75	1828.91	4590.60	71.30
CL	6118.12	1686.48	3554.64	11359.23	75.96
CM	3625.98	1690.55	4160.97	9477.50	70.10
CO	4043.57	2299.05	4147.03	10489.65	71.21
CP	3438.73	1512.81	11416.35	16367.89	62.28
CQ	19558.46	3071.04	37968.44	60597.94	65.10
CS	2818.81	1152.40	3834.68	7805.89	68.56
CT	4796.80	1889.01	4254.66	10940.47	72.22
CU	9876.47	3613.33	13754.27	27244.07	68.27
CV	57.60	33.72	426.16	517.48	58.90
CW	0.56	0.02	405.05	405.64	55.03

Boundary	Hydrologic Soil Group B				
	Pavement 98	**Residential 75**	**Forested 55**	**Total**	**Average Curve Number**
CX	199.33	124.81	803.42	1127.56	61.60
CY	1408.37	337.71	3343.50	5089.57	63.89
CZ	114.84	79.87	138.54	333.25	70.07
D	3142.04	1600.33	3032.01	7774.38	71.64
E	1032.36	734.96	2194.05	3961.37	65.78
F	38.77	1.84	7353.94	7394.56	55.13
G	851.13	457.61	915.17	2223.90	70.77
H	494.56	275.48	998.59	1768.63	65.81
I	19.76	138.16	312.63	470.54	60.89
J	359.99	92.17	473.09	925.25	68.52
K	253.51	155.82	386.32	795.65	68.07
L	109.37	7.96	6.77	124.10	92.25
M	27.04	6.59	3.72	37.35	86.57
N	125.70	16.42	8.38	150.49	90.99
P	47.44	2.08	3.15	52.67	92.55
R	76.75	1.79	10.91	89.46	88.97
S	38.80	3.54	15.17	57.51	79.99
T	43.86	2.80	4.48	51.14	90.31
V	98.09	43.06	48.12	189.26	77.25
W	665.65	497.77	658.02	1821.43	71.73
X	64.28	22.51	13.84	100.63	83.32
Z	661.11	222.06	468.38	1351.56	74.17

Table 7-2: Expected Runoff Volume (Cubic Feet)

Boundary	2 Year	5 Year	10 Year	25 Year
A	42791	92879	140314	201681
AA	14092	22610	30386	40112
AB	2173	4093	6027	8483
AC	992	2258	3660	5555
AD	12388	18875	24697	31622
AE	25269	45782	65819	91386
AF	4775	8361	11766	16188
AG	53638	127710	209810	322925
AH	1223	2260	3272	4542
AI	43400	98754	160085	242986
AJ	10707	20735	30797	43407
AK	39121	68502	96399	132631
AL	1365	2183	2912	3809
AM	2028	3242	4327	5658
AN	41825	71408	98878	132469
AO	35977	78089	117971	169565
AP	1368	3113	5046	7659
AQ	32886	57584	81035	111492
AR	5072	8856	12449	16887
AS	4225	8803	13810	20441
AT	9380	19420	29533	42358
AU	61273	126855	192915	276687
AV	4368	7458	10326	13835
AW	10848	20439	30092	42355
AX	13388	23376	32860	44574
AY	21906	45353	68970	98920

Boundary	2 Year	5 Year	10 Year	25 Year
AZ	2649	5130	7620	10740
B	24739	43319	60959	83871
BA	5409	9799	14088	19561
BB	12092	19991	27522	36644
BE	4881	10105	15367	22039
BF	18604	29747	39695	51911
BG	4273	8847	13454	19296
BH	76069	161162	243677	356169
BI	25963	50277	74674	105253
BJ	2445	4430	6369	8843
BK	35373	80489	130477	198046
BM	166262	360880	545186	783624
BN	299	511	707	948
BO	322	482	621	794
BP	698	1044	1346	1720
BQ	15799	26522	36732	49822
BR	4924	7268	9302	11744
BS	1496	2185	2784	3500
BT	3519	5286	6878	8758
BU	4452	6841	9031	11731
BV	8633	13804	18420	24088
BW	9468	16164	22383	29987
BX	6405	11183	15719	21323
BY	3715	6072	8214	10864
BZ	1284	4064	7257	11609
C	24326	42596	59943	82473
CA	4794	8048	11145	15117
CB	23822	41714	58701	80764

Boundary	2 Year	5 Year	10 Year	25 Year
CE	71178	113811	151872	198609
CF	17143	29269	40528	54296
CG	5137	8493	11692	15568
CH	11143	18706	25907	35139
CI	55869	101222	145523	202050
CJ	27155	52585	78102	110084
CK	73623	142572	211754	298465
CL	230712	417996	600937	834363
CM	126615	274823	415180	596759
CN	6290	14127	22368	33166
CO	168448	326201	484488	682883
CP	111626	276681	472266	747993
CQ	564296	1284026	2081474	3159381
CS	97533	206638	312437	456670
CT	189720	357443	526267	740733
CU	341846	724250	1095066	1600592
CV	2017	6553	12061	19509
CW	1156	4018	8187	13691
CX	6512	17941	30833	48176
CY	39618	86755	157316	238576
CZ	4454	9667	14605	20992
D	124095	240311	356921	503077
E	36509	83075	134669	204409
F	21039	73123	148982	249148
G	29432	63882	96508	138716
H	16292	37072	60096	91218
I	2188	6452	11894	18935
J	11569	24510	37059	54167

Boundary	2 Year	5 Year	10 Year	25 Year
K	10013	21215	32076	46884
L	6533	9247	11647	14429
M	1459	2224	2909	3725
N	7030	10266	13082	16450
P	2764	3911	4927	6103
Q	4363	6648	8698	11138
R	3804	5694	7337	9377
S	1498	2558	3541	4745
T	2407	3515	4479	5632
V	4482	7826	11000	14922
W	29036	56228	83512	117710
X	3345	5349	7137	9334
Z	26129	48289	69920	97041

Table 7-3a: Unit Peak Discharge (cfs) Using Pipe Slope

		Unit Peak Discharge (cfs)									
		Pipe Slope									
		Curve Method				Conver-sion Factor	XP-SWMM Model (*or Equivalent*)			Pipe Size (in)	Pipe Capacity (CFS)
Bound-ary	Outfall	2 Yr	5 Yr	10 Yr	25 Yr		2 Yr	5 Yr	10 Yr		
A	33	7.43	16.12	24.35	35.00	N/A	27.01	27.30	28.08	30.00	15.50
AA	29	5.60	8.98	12.07	15.93	2.00	11.20	17.96	24.14	12.00	3.50
AB	91	0.87	1.65	2.42	3.41	1.80	1.57	2.96	4.36	15.00	--
AC	83	0.40	0.91	1.47	2.23	2.00	0.80	1.82	2.94	24.00	--
AD	87	4.98	7.59	9.93	12.72	2.00	9.97	15.18	19.87	--	--
AE	93	10.16	18.41	26.47	36.76	N/A	25.85	34.81	40.25	36.00	20.00
AF	92	1.77	3.11	4.37	6.02	N/A	6.25	7.10	8.89	30.00	--
AG	2	13.21	31.45	51.67	79.53	N/A	44.29	47.58	50.57	36.00	35.00
AH	3	0.49	0.91	1.32	1.83	2.00	0.98	1.82	2.63	--	--
AI	4	8.35	19.00	30.79	46.74	N/A	22.11	29.80	36.06	36.00	55.00
AI	4.1	8.35	19.00	30.79	46.74	N/A	27.12	27.57	27.97	36.00	55.00
AJ	149	4.30	8.33	12.37	17.43	1.80	7.74	14.99	22.26	15.00	--
AK	5	7.95	13.92	19.59	26.96	1.10	8.75	15.32	21.55	24.00	10.00
AL	6	0.55	0.88	1.17	1.53	2.00	1.10	1.76	2.34	12.00	3.90
AM	7	0.82	1.30	1.74	2.28	2.00	1.63	2.61	3.48	10.00	--
AN	61	10.29	17.57	24.32	32.59	N/A	24.98	26.65	28.56	30.00	20.00
AO	70	9.40	20.41	30.83	44.32	N/A	31.94	42.41	52.71	24.00	20.00
AP	87	0.55	1.25	2.03	3.08	2.00	1.10	2.50	4.06	--	--
AQ	90	12.43	21.76	30.63	42.14	N/A	25.08	34.96	45.62	42.00	100.00
AR	89	2.04	3.56	5.01	6.79	2.00	4.08	7.12	10.01	15.00	2.92
AS	88	1.70	3.54	5.55	8.22	2.00	3.40	7.08	11.11	6.00	--
AT	75	3.40	7.04	10.71	15.36	1.80	6.12	12.67	19.27	12.00	3.00
AU	76	11.01	22.79	34.65	49.70	N/A	36.72	45.08	55.15	36.00	45.00
AV	84	1.76	3.00	4.15	5.56	1.80	3.16	5.40	7.48	6.00	--
AW	71	4.36	8.22	12.10	17.04	2.00	8.73	16.44	24.21	10.00	--
AX	136	5.38	9.40	13.22	17.93	1.80	9.69	16.92	23.79	12.00	3.19
AX	138	5.38	9.40	13.22	17.93	2.00	10.77	18.80	26.43	12.00	3.84
AY	69	4.80	9.95	15.12	21.69	1.20	5.76	11.93	18.15	24.00	10.00
AZ	72	1.07	2.06	3.06	4.32	2.00	2.13	4.13	6.13	12.00	2.09
B	32	6.46	11.30	15.91	21.89	2.00	12.91	22.61	31.81	21.00	20.00
BA	68	2.18	3.94	5.67	7.87	2.00	4.35	7.88	11.33	8.00	2.20
BB	135	4.86	8.04	11.07	14.74	2.00	9.73	16.08	22.14	12.00	--
BE	66	1.96	4.06	6.18	8.86	2.00	3.93	8.13	12.36	12.00	1.50
BF	65	6.56	10.49	14.00	18.30	1.80	11.81	18.88	25.19	8.00	--
BG	35	1.72	3.56	5.41	7.76	N/A	47.09	55.18	67.72	36.00	40.00
BH	35	11.94	25.31	38.26	55.93	N/A	47.09	55.18	67.72	36.00	40.00
BI	25	6.66	12.90	19.16	27.00	1.80	11.99	23.22	34.48	21.00	22.00
BJ	25	0.63	1.14	1.63	2.27	1.80	1.13	2.05	2.94	21.00	22.00
BK	117	8.72	19.84	32.17	48.83	N/A	24.05	29.45	30.19	24.00	15.00

		Curve Method				Conver-sion Factor	XP-SWMM Model (*or Equivalent*)			Pipe Size (in)	Pipe Capacity (CFS)
Bound-ary	**Outfall**	**2 Yr**	**5 Yr**	**10 Yr**	**25 Yr**		**2 Yr**	**5 Yr**	**10 Yr**		
BM	115	30.55	66.30	100.16	143.96	N/A	106.47	124.11	166.55	48.00	50.00
BN	63	0.12	0.21	0.28	0.38	2.00	0.24	0.41	0.57	--	--
BO	64	0.13	0.19	0.25	0.32	2.00	0.26	0.39	0.50	--	--
BP	62	0.28	0.42	0.54	0.69	2.00	0.56	0.84	1.08	12.00	--
BQ	60	6.01	10.08	13.96	18.94	1.80	10.81	18.15	25.14	21.00	13.00
BR	34	1.98	2.92	3.74	4.72	2.00	3.96	5.85	7.48	10.00	--
BS	52	0.60	0.88	1.12	1.41	2.00	1.20	1.76	2.24	8.00	1.91
BT	54	1.42	2.13	2.77	3.52	1.90	2.69	4.04	5.26	10.00	4.24
BU	51	1.78	2.73	3.61	4.69	N/A	2.17	2.88	3.19	36.00	--
BV	53	3.47	5.55	7.41	9.69	1.60	5.56	8.88	11.85	18.00	11.50
BW	49	3.81	6.50	9.00	12.06	1.00	3.81	6.50	9.00	15.00	--
BX	45	2.58	4.50	6.32	8.58	1.50	3.86	6.75	9.48	15.00	8.00
BY	30	1.49	2.44	3.30	4.37	1.80	2.69	4.40	5.95	15.00	--
BZ	132	0.52	1.63	2.92	4.67	2.00	1.03	3.27	5.84	12.00	--
BZ	133	0.52	1.63	2.92	4.67	2.00	1.03	3.27	5.84	6.00	--
C	31	8.80	15.42	21.69	29.85	N/A	16.78	21.76	27.12	30.00	35.00
CA	27	1.92	3.23	4.47	6.06	1.00	1.92	3.23	4.47	18.00	8.00
CB	41	9.04	15.82	22.27	30.64	1.60	14.46	25.32	35.63	18.00	10.50
CE	42	11.88	19.00	25.35	33.16	N/A	43.71	55.41	65.31	54.00	90.00
CF	23	5.52	9.42	13.04	17.47	1.20	6.62	11.30	15.65	24.00	10.00
CG	24	2.07	3.42	4.70	6.26	1.80	3.72	6.15	8.46	12.00	6.33
CH	26	4.29	7.19	9.96	13.51	1.40	6.00	10.07	13.95	15.00	4.40
CI	22	11.39	20.64	29.67	41.20	N/A	22.70	24.30	2.90	30.00	20.00
CJ	8	9.43	18.27	27.14	38.25	N/A	23.10	29.40	36.30	30.00	12.00
CK	9	15.50	30.01	44.57	62.82	1.00	15.50	30.01	44.57	21.00	18.00
CL	11	17.80	32.24	46.35	64.36	N/A	30.20	31.00	31.70	36.00	35.00
CM	10	28.08	60.95	92.08	132.35	N/A	58.40	59.10	59.80	30.00	40.00
CN	17	2.52	5.66	8.96	13.28	N/A	8.90	8.90	8.90	15.00	4.00
CO	147	28.77	55.71	82.75	116.64	N/A	71.10	73.30	75.20	48.00	80.00
CP	122	23.37	57.93	98.88	156.60	2.00	46.74	115.86	197.75	12.00	--
CQ	19	50.30	114.45	185.53	281.60	N/A	141.80	169.00	180.30	54.00	80.00
CS	145	9.25	19.60	29.63	43.31	N/A	18.40	18.60	18.80	30.00	15.00
CT	21	24.63	46.41	68.32	96.17	N/A	95.70	98.30	100.10	36.00	37.00
CU	20	40.49	85.79	129.72	189.60	N/A	197.30	229.10	259.10	66.00	250.00
CV	113	0.81	2.64	4.85	7.85	2.00	1.62	5.27	9.70	21.00	26.00
CW	114	0.47	1.62	3.29	5.51	2.00	0.93	3.23	6.59	18.00	30.00
CX	148	2.39	6.58	11.31	17.67	1.80	4.30	11.85	20.36	12.00	5.90
CY	1	15.93	34.89	63.27	95.96	N/A	36.93	38.49	39.87	24.00	29.00
CZ	77	1.79	3.89	5.87	8.44	2.00	3.58	7.78	11.75	10.00	2.60
D	28	19.83	38.40	57.03	80.38	N/A	80.61	106.52	108.25	24.00	15.00
E	16	7.60	17.30	28.05	42.57	N/A	91.50	105.00	146.20	36.00	45.00
F	18	3.46	12.01	24.48	40.93	N/A	37.40	39.50	40.10	30.00	26.00
G	36	7.75	16.82	25.41	36.52	N/A	26.90	34.70	59.60	24.00	10.00
H	152	4.13	9.39	15.22	23.10	1.00	4.13	9.39	15.22	30.00	18.00
I	94	0.88	2.60	4.78	7.62	1.00	0.88	2.60	4.78	12.00	--

Boundary	Outfall	Curve Method 2 Yr	Curve Method 5 Yr	Curve Method 10 Yr	Curve Method 25 Yr	Conversion Factor	XP-SWMM Model (*or Equivalent*) 2 Yr	XP-SWMM Model (*or Equivalent*) 5 Yr	XP-SWMM Model (*or Equivalent*) 10 Yr	Pipe Size (in)	Pipe Capacity (CFS)
J	79	3.44	7.29	11.02	16.11	2.00	6.88	14.58	22.04	12.00	--
K	119	4.03	8.53	12.90	18.86	2.00	8.05	17.07	25.80	24.00	10.00
L	126	2.63	3.72	4.68	5.80	1.50	3.94	5.58	7.03	--	--
M	-	0.59	0.89	1.17	1.50	1.50	0.88	1.34	1.76	--	--
N	47	2.83	4.13	5.26	6.62	2.00	5.66	8.26	10.52	12.00	--
P	46	1.11	1.57	1.98	2.45	2.00	2.22	3.15	3.96	12.00	--
Q	43	1.75	2.67	3.50	4.48	2.00	3.51	5.35	7.00	--	--
R	44	1.53	2.29	2.95	3.77	2.00	3.06	4.58	5.90	--	--
S	40	0.60	1.03	1.42	1.91	2.00	1.21	2.06	2.85	--	--
T	39	0.97	1.41	1.80	2.27	2.00	1.94	2.83	3.60	--	--
V	67	1.80	3.15	4.42	6.00	1.60	2.88	5.04	7.08	10.00	1.40
V	68	1.80	3.15	4.42	6.00	1.60	2.88	5.04	7.08	8.00	2.00
W	38	7.60	14.72	21.86	30.81	2.00	15.20	29.43	43.71	30.00	--
X	55	1.35	2.15	2.87	3.75	1.80	2.42	3.87	5.17	10.00	2.50
Z	5.1	10.14	18.74	27.13	37.66	N/A	17.09	21.01	27.09	30.00	40.00

Key

XX.XX Pipe Capacity is less than 2 yr Curve Method Unit Peak Discharge

XX.XX Pipe Capacity is less than 2 yr XP SWMM Unit Peak Discharge

Table 7-3b: Unit Peak Discharge (cfs) Using Watershed Slope

Unit Peak Discharge (cfs)

Watershed Slope

Boundary	Outfall	Curve Method 2 Yr	Curve Method 5 Yr	Curve Method 10 Yr	Curve Method 25 Yr	Conversion Factor	XP-SWMM Model (*or Equivalent*) 2 Yr	XP-SWMM Model (*or Equivalent*) 5 Yr	XP-SWMM Model (*or Equivalent*) 10 Yr	Pipe Size (in)	Pipe Capacity (CFS)
A	33	4.10	8.90	13.45	19.33	N/A	27.01	27.30	28.08	30.00	15.50
AA	29	4.13	6.63	8.91	11.76	2.00	8.26	13.25	17.81	12.00	3.50
AB	91	0.82	1.55	2.28	3.21	1.80	1.48	2.79	4.11	15.00	--
AC	83	0.40	0.91	1.47	2.23	2.00	0.80	1.82	2.94	24.00	--
AD	87	4.98	7.59	9.93	12.72	2.00	9.97	15.18	19.87	--	--
AE	93	7.64	13.85	19.91	27.64	N/A	25.85	34.81	40.25	36.00	20.00
AF	92	1.92	3.36	4.73	6.51	N/A	6.25	7.10	8.89	30.00	--
AG	2	7.83	18.65	30.63	47.15	N/A	44.29	47.58	50.57	36.00	35.00
AH	3	0.49	0.91	1.32	1.83	2.00	0.98	1.82	2.63	--	--
AI	4	8.43	19.18	31.09	47.19	N/A	22.11	29.80	36.06	36.00	55.00
AI	4.1	8.43	19.18	31.09	47.19	N/A	27.12	27.57	27.97	36.00	55.00
AJ	149	3.65	7.08	10.51	14.81	1.80	6.58	12.74	18.92	15.00	--
AK	5	8.70	15.23	21.44	29.49	1.10	9.57	16.76	23.58	24.00	10.00
AL	6	0.55	0.88	1.17	1.53	2.00	1.10	1.76	2.34	12.00	3.90
AM	7	0.81	1.30	1.73	2.26	2.00	1.62	2.59	3.46	10.00	--
AN	61	8.53	14.57	20.18	27.03	N/A	24.98	26.65	28.56	30.00	20.00
AO	70	7.22	15.68	23.69	34.05	N/A	31.94	42.41	52.71	24.00	20.00
AP	87	0.55	1.25	2.03	3.08	2.00	1.10	2.50	4.06	--	--
AQ	90	11.64	20.38	28.68	39.46	N/A	25.08	34.96	45.62	42.00	100.00
AR	89	1.46	2.54	3.57	4.85	2.00	2.91	5.09	7.15	15.00	2.92
AS	88	1.44	3.00	4.70	6.96	2.00	2.88	5.99	9.40	6.00	--
AT	75	2.17	4.48	6.82	9.78	1.80	3.90	8.07	12.27	12.00	3.00
AU	76	4.73	9.78	14.88	21.34	N/A	36.72	45.08	55.15	36.00	45.00
AV	84	1.76	3.00	4.15	5.56	1.80	3.16	5.40	7.48	6.00	--
AW	71	4.36	8.22	12.10	17.04	2.00	8.73	16.44	24.21	10.00	--
AX	136	5.38	9.40	13.22	17.93	1.80	9.69	16.92	23.79	12.00	3.19
AX	138	5.38	9.40	13.22	17.93	2.00	10.77	18.80	26.43	12.00	3.84
AY	69	3.26	6.76	10.28	14.74	1.20	3.92	8.11	12.33	24.00	10.00
AZ	72	1.07	2.06	3.06	4.32	2.00	2.13	4.13	6.13	12.00	2.09
B	32	4.13	7.23	10.18	14.00	2.00	8.26	14.46	20.35	21.00	20.00
BA	68	2.12	3.83	5.51	7.65	2.00	4.23	7.67	11.02	8.00	2.20
BB	135	3.54	5.86	8.07	10.74	2.00	7.09	11.72	16.13	12.00	--
BE	66	1.96	4.06	6.18	8.86	2.00	3.93	8.13	12.36	12.00	1.50
BF	65	6.33	10.12	13.51	17.67	1.80	11.40	18.22	24.32	8.00	--
BG	35	1.72	3.56	5.41	7.76	N/A	47.09	55.18	67.72	36.00	40.00
BH	35	5.87	12.43	18.80	27.47	N/A	47.09	55.18	67.72	36.00	40.00
BI	25	4.59	8.89	13.20	18.60	1.80	8.26	16.00	23.76	21.00	22.00

		Curve Method				Conver-sion Factor	XP-SWMM Model (*or Equivalent*)			Pipe Size (in)	Pipe Capacity (CFS)
Boundary	**Outfall**	**2 Yr**	**5 Yr**	**10 Yr**	**25 Yr**		**2 Yr**	**5 Yr**	**10 Yr**		
BJ	25	0.43	0.78	1.13	1.56	1.80	0.78	1.41	2.03	21.00	22.00
BK	117	7.70	17.52	28.40	43.10	N/A	24.05	29.45	30.19	24.00	15.00
BM	115	33.58	72.88	110.10	158.26	N/A	106.47	124.11	166.55	48.00	50.00
BN	63	0.12	0.21	0.28	0.38	2.00	0.24	0.41	0.57	--	--
BO	64	0.13	0.19	0.25	0.32	2.00	0.26	0.39	0.50	--	--
BP	62	0.28	0.42	0.54	0.69	2.00	0.56	0.84	1.08	12.00	--
BQ	60	5.76	9.66	13.38	18.15	1.80	10.36	17.40	24.09	21.00	13.00
BR	34	1.96	2.89	3.70	4.67	2.00	3.92	5.78	7.40	10.00	--
BS	52	0.60	0.88	1.12	1.41	2.00	1.20	1.76	2.24	8.00	1.91
BT	54	1.42	2.13	2.77	3.52	1.90	2.69	4.04	5.26	10.00	4.24
BU	51	1.49	2.29	3.03	3.94	N/A	2.17	2.88	3.19	36.00	--
BV	53	3.04	4.87	6.50	8.49	1.60	4.87	7.79	10.39	18.00	11.50
BW	49	3.81	6.50	9.00	12.06	1.00	3.81	6.50	9.00	15.00	--
BX	45	2.51	4.38	6.16	8.36	1.50	3.76	6.57	9.24	15.00	8.00
BY	30	1.49	2.44	3.30	4.37	1.80	2.69	4.40	5.95	15.00	--
BZ	132	0.52	1.63	2.92	4.67	2.00	1.03	3.27	5.84	12.00	--
BZ	133	0.52	1.63	2.92	4.67	2.00	1.03	3.27	5.84	6.00	--
C	31	5.72	10.01	14.09	19.38	N/A	16.78	21.76	27.12	30.00	35.00
CA	27	1.93	3.24	4.48	6.08	1.00	1.93	3.24	4.48	18.00	8.00
CB	41	7.06	12.37	17.41	23.95	1.60	11.30	19.79	27.85	18.00	10.50
CE	42	14.56	23.28	31.06	40.62	N/A	43.71	55.41	65.31	54.00	90.00
CF	23	5.28	9.02	12.49	16.74	1.20	6.34	10.83	14.99	24.00	10.00
CG	24	1.87	3.10	4.26	5.68	1.80	3.37	5.57	7.67	12.00	6.33
CH	26	4.30	7.21	9.99	13.55	1.40	6.02	10.10	13.98	15.00	4.40
CI	22	15.33	27.77	39.93	55.44	N/A	22.70	24.30	2.90	30.00	20.00
CJ	8	4.88	9.45	14.03	19.77	N/A	23.10	29.40	36.30	30.00	12.00
CK	9	9.94	19.25	28.58	40.29	1.00	9.94	19.25	28.58	21.00	18.00
CL	11	20.97	38.00	54.63	75.85	N/A	30.20	31.00	31.70	36.00	35.00
CM	10	27.30	59.26	89.52	128.67	N/A	58.40	59.10	59.80	30.00	40.00
CN	17	1.63	3.66	5.80	8.59	N/A	8.90	8.90	8.90	15.00	4.00
CO	147	28.77	55.71	82.75	116.64	N/A	71.10	73.30	75.20	48.00	80.00
CP	122	21.72	53.85	91.91	145.57	2.00	43.45	107.69	183.82	12.00	--
CQ	19	23.32	53.06	86.01	130.55	N/A	141.80	169.00	180.30	54.00	80.00
CS	145	22.03	46.68	70.58	103.16	N/A	18.40	18.60	18.80	30.00	15.00
CT	21	20.96	39.48	58.13	81.82	N/A	95.70	98.30	100.10	36.00	37.00
CU	20	28.25	59.86	90.50	132.28	N/A	197.30	229.10	259.10	66.00	250.00
CV	113	0.81	2.64	4.85	7.85	2.00	1.62	5.27	9.70	21.00	26.00
CW	114	0.47	1.62	3.29	5.51	2.00	0.93	3.23	6.59	18.00	30.00
CX	148	2.62	7.22	12.40	19.38	1.80	4.71	12.99	22.32	12.00	5.90
CY	1	8.77	19.22	34.84	52.84	N/A	36.93	38.49	39.87	24.00	29.00
CZ	77	1.63	3.54	5.34	7.68	2.00	3.26	7.07	10.68	10.00	2.60
D	28	15.21	29.46	43.75	61.67	N/A	80.61	106.52	108.25	24.00	15.00
E	16	6.35	14.45	23.43	35.56	N/A	91.50	105.00	146.20	36.00	45.00

		Curve Method				Conver-sion Factor	XP-SWMM Model (*or Equivalent*)			Pipe Size (in)	Pipe Capacity (CFS)
Bound-ary	**Outfall**	**2 Yr**	**5 Yr**	**10 Yr**	**25 Yr**		**2 Yr**	**5 Yr**	**10 Yr**		
F	18	3.31	11.51	23.45	39.22	N/A	37.40	39.50	40.10	30.00	26.00
G	36	5.73	12.43	18.78	26.99	N/A	26.90	34.70	59.60	24.00	10.00
H	152	5.01	11.40	18.48	28.04	1.00	5.01	11.40	18.48	30.00	18.00
I	94	0.88	2.60	4.78	7.62	1.00	0.88	2.60	4.78	12.00	--
J	79	3.44	7.29	11.02	16.11	2.00	6.88	14.58	22.04	12.00	--
K	119	4.03	8.53	12.90	18.86	2.00	8.05	17.07	25.80	24.00	10.00
L	126	2.63	3.72	4.68	5.80	1.50	3.94	5.58	7.03	--	--
M	-	0.59	0.89	1.17	1.50	1.50	0.88	1.34	1.76	--	--
N	47	2.83	4.13	5.26	6.62	2.00	5.66	8.26	10.52	12.00	--
P	46	1.11	1.57	1.98	2.45	2.00	2.22	3.15	3.96	12.00	--
Q	43	1.75	2.67	3.50	4.48	2.00	3.51	5.35	7.00	--	--
R	44	1.53	2.29	2.95	3.77	2.00	3.06	4.58	5.90	--	--
S	40	0.60	1.03	1.42	1.91	2.00	1.21	2.06	2.85	--	--
T	39	0.97	1.41	1.80	2.27	2.00	1.94	2.83	3.60	--	--
V	67	1.80	3.15	4.42	6.00	1.60	2.88	5.04	7.08	10.00	1.40
V	68	1.80	3.15	4.42	6.00	1.60	2.88	5.04	7.08	8.00	2.00
W	38	7.60	14.72	21.86	30.81	2.00	15.20	29.43	43.71	30.00	--
X	55	1.35	2.15	2.87	3.75	1.80	2.42	3.87	5.17	10.00	2.50
Z	5.1	10.14	18.74	27.13	37.66	N/A	17.09	21.01	27.09	30.00	40.00

Key

XX.XX Pipe Capacity is less than 2 yr Curve Method Unit Peak Discharge

XX.XX Pipe Capacity is less than 2 yr XP SWMM Unit Peak Discharge

Table 7-4: Water Quality Flow

Boundary	Outfall #	High Treatment Flow Range (1/3 Unit Peak Discharge)				Conversion Factor	XP SWMM (*or Equivalent**)
		2 Year	5 Year	10 Year	25 Year		Water Quality Flow
A	33	2.48	5.37	8.12	11.67	XP SWMM	13.53
AA	29	1.87	2.99	4.02	5.31	2.00	*7.10*
AB	91	0.29	0.55	0.81	1.14	1.80	*1.25*
AC	83	0.13	0.30	0.49	0.74	2.00	*0.84*
AD	87	1.66	2.53	3.31	4.24	2.00	*5.87*
AE	93	3.39	6.14	8.82	12.25	XP SWMM	7.70
AF	92	0.59	1.04	1.46	2.01	XP SWMM	1.43
AG	2	4.40	10.48	17.22	26.51	XP SWMM	17.96
AH	3	0.16	0.30	0.44	0.61	2.00	*0.76*
AI	4	2.78	6.33	10.26	15.58	XP SWMM	9.52
AI	4.1	2.78	6.33	10.26	15.58	XP SWMM	16.88
AJ	149	1.43	2.78	4.12	5.81	1.80	*6.36*
AK	5	2.65	4.64	6.53	8.99	1.10	*6.27*
AL	6	0.18	0.29	0.39	0.51	2.00	*0.69*
AM	7	0.27	0.43	0.58	0.76	2.00	*1.02*
AN	61	3.43	5.86	8.11	10.86	XP SWMM	8.39
AO	70	3.13	6.80	10.28	14.77	XP SWMM	11.31
AP	87	0.18	0.42	0.68	1.03	2.00	*1.15*
AQ	90	4.14	7.25	10.21	14.05	XP SWMM	7.57
AR	89	0.68	1.19	1.67	2.26	2.00	*2.90*
AS	88	0.57	1.18	1.85	2.74	2.00	*3.17*
AT	75	1.13	2.35	3.57	5.12	1.80	*5.48*
AU	76	3.67	7.60	11.55	16.57	XP SWMM	14.52
AV	84	0.59	1.00	1.38	1.85	1.80	*2.17*
AW	71	1.45	2.74	4.03	5.68	2.00	*6.95*
AX	136	1.79	3.13	4.41	5.98	1.80	*6.89*
AX	138	1.79	3.13	4.41	5.98	2.00	*7.66*
AY	69	1.60	3.32	5.04	7.23	1.20	*5.16*
AZ	72	0.36	0.69	1.02	1.44	2.00	*1.75*
B	32	2.15	3.77	5.30	7.30	2.00	*9.26*
BA	68	0.73	1.31	1.89	2.62	2.00	*3.28*
BB	135	1.62	2.68	3.69	4.91	2.00	*6.45*
BE	66	0.65	1.35	2.06	2.95	2.00	*3.51*
BF	65	2.19	3.50	4.67	6.10	1.80	*7.40*
BG	35	0.57	1.19	1.80	2.59	XP SWMM	19.10
BH	35	3.98	8.44	12.75	18.64	XP SWMM	19.10
BJ	25	0.21	0.38	0.54	0.76	1.80	*0.85*
BK	117	2.91	6.61	10.72	16.28	XP SWMM	7.69

Boundary	Outfall #	High Treatment Flow Range (1/3 Unit Peak Discharge)				Conversion Factor	XP SWMM (*or Equivalent*)*
		2 Year	5 Year	10 Year	25 Year		Water Quality Flow
BM	115	10.18	22.10	33.39	47.99	XP SWMM	50.19
BN	63	0.04	0.07	0.09	0.13	2.00	*0.17*
BO	64	0.04	0.06	0.08	0.11	2.00	*0.15*
BP	62	0.09	0.14	0.18	0.23	2.00	*0.32*
BQ	60	2.00	3.36	4.65	6.31	1.80	*7.35*
BR	34	0.66	0.97	1.25	1.57	2.00	*2.23*
BS	52	0.20	0.29	0.37	0.47	2.00	*0.67*
BT	54	0.47	0.71	0.92	1.17	1.90	*1.56*
BU	51	0.59	0.91	1.20	1.56	XP SWMM	0.66
BV	53	1.16	1.85	2.47	3.23	1.60	*3.48*
BW	49	1.27	2.17	3.00	4.02	1.00	*2.61*
BX	45	0.86	1.50	2.11	2.86	1.50	*2.75*
BY	30	0.50	0.81	1.10	1.46	1.80	*1.74*
BZ	132	0.17	0.54	0.97	1.56	2.00	*1.62*
BZ	133	0.17	0.54	0.97	1.56	2.00	*1.62*
C	31	2.93	5.14	7.23	9.95	XP SWMM	5.52
CA	27	0.64	1.08	1.49	2.02	1.00	*1.31*
CB	41	3.01	5.27	7.42	10.21	1.60	*10.37*
CE	42	3.96	6.33	8.45	11.05	XP SWMM	13.68
CF	23	1.84	3.14	4.35	5.82	1.20	*4.54*
CG	24	0.69	1.14	1.57	2.09	1.80	*2.47*
CH	26	1.43	2.40	3.32	4.50	1.40	*4.08*
CI	22	3.80	6.88	9.89	13.73	XP SWMM	19.90
CJ	8	3.14	6.09	9.05	12.75	XP SWMM	7.60
CK	9	5.17	10.00	14.86	20.94	1.00	*12.74*
CL	11	5.93	10.75	15.45	21.45	XP SWMM	24.50
CM	10	9.36	20.32	30.69	44.12	XP SWMM	36.80
CN	17	0.84	1.89	2.99	4.43	XP SWMM	8.90
CO	147	9.59	18.57	27.58	38.88	XP SWMM	52.70
CP	122	7.79	19.31	32.96	52.20	2.00	*56.13*
CQ	19	16.77	38.15	61.84	93.87	XP SWMM	58.30
CS	145	3.08	6.53	9.88	14.44	XP SWMM	18.00
CT	21	8.21	15.47	22.77	32.06	XP SWMM	49.40
CU	20	13.50	28.60	43.24	63.20	XP SWMM	84.50
CV	113	0.27	0.88	1.62	2.62	2.00	*2.69*
CW	114	0.16	0.54	1.10	1.84	2.00	*1.81*
CY	1	5.31	11.63	21.09	31.99	XP SWMM	12.53
CZ	77	0.60	1.30	1.96	2.81	2.00	*3.33*
D	28	6.61	12.80	19.01	26.79	XP SWMM	24.39
E	16	2.53	5.77	9.35	14.19	XP SWMM	35.40

Boundary	Outfall #	High Treatment Flow Range (1/3 Unit Peak Discharge)				Conversion Factor	XP SWMM (*or Equivalent**)
		2 Year	5 Year	10 Year	25 Year		Water Quality Flow
F	18	1.15	4.00	8.16	13.64	XP SWMM	31.40
G	36	2.58	5.61	8.47	12.17	XP SWMM	11.60
H	152	1.38	3.13	5.07	7.70	1.00	*4.32*
I	94	0.29	0.87	1.59	2.54	1.00	*1.32*
J	79	1.15	2.43	3.67	5.37	2.00	*6.31*
K	119	1.34	2.84	4.30	6.29	2.00	*7.39*
L	126	0.88	1.24	1.56	1.93	1.50	*2.10*
M	-	0.20	0.30	0.39	0.50	1.50	*0.52*
N	47	0.94	1.38	1.75	2.21	2.00	*3.14*
P	46	0.37	0.52	0.66	0.82	2.00	*1.19*
Q	43	0.58	0.89	1.17	1.49	2.00	*2.07*
R	44	0.51	0.76	0.98	1.26	2.00	*1.76*
S	40	0.20	0.34	0.47	0.64	2.00	*0.83*
T	39	0.32	0.47	0.60	0.76	2.00	*1.07*
V	67	0.60	1.05	1.47	2.00	1.60	*2.05*
V	68	0.60	1.05	1.47	2.00	1.60	*2.05*
W	38	2.53	4.91	7.29	10.27	2.00	*12.50*
X	55	0.45	0.72	0.96	1.25	1.80	*1.52*
Z	5.1	3.38	6.25	9.04	12.55	XP SWMM	6.06

Table 7-5: Low Treatment Flow Range (1/3 of Unit Peak Discharge)

Boundary	Low Treatment Flow Range			
	2 Year	5 Year	10 Year	25 Year
A	1.37	2.97	4.48	6.44
AA	1.38	2.21	2.97	3.92
AB	0.27	0.52	0.76	1.07
AC	0.13	0.30	0.49	0.74
AD	1.66	2.53	3.31	4.24
AE	2.55	4.62	6.64	9.21
AF	0.64	1.12	1.58	2.17
AG	2.61	6.22	10.21	15.72
AH	0.16	0.30	0.44	0.61
AI	2.81	6.39	10.36	15.73
AJ	1.22	2.36	3.50	4.94
AK	2.90	5.08	7.15	9.83
AL	0.18	0.29	0.39	0.51
AM	0.27	0.43	0.58	0.75
AN	2.84	4.86	6.73	9.01
AO	2.41	5.23	7.90	11.35
AP	0.18	0.42	0.68	1.03
AQ	3.88	6.79	9.56	13.15
AR	0.49	0.85	1.19	1.62
AS	0.48	1.00	1.57	2.32
AT	0.72	1.49	2.27	3.26
AU	1.58	3.26	4.96	7.11
AW	1.45	2.74	4.03	5.68
AX	1.79	3.13	4.41	5.98
AY	1.09	2.25	3.43	4.91
AZ	0.36	0.69	1.02	1.44
B	1.38	2.41	3.39	4.67
BA	0.71	1.28	1.84	2.55
BB	1.18	1.95	2.69	3.58
BE	0.65	1.35	2.06	2.95
BF	2.11	3.37	4.50	5.89
BG	0.57	1.19	1.80	2.59
BH	1.96	4.14	6.27	9.16
BI	1.53	2.96	4.40	6.20
BJ	0.14	0.26	0.38	0.52
BK	2.57	5.84	9.47	14.37
BM	11.19	24.29	36.70	52.75

Boundary	Low Treatment Flow Range			
	2 Year	5 Year	10 Year	25 Year
BN	0.04	0.07	0.09	0.13
BO	0.04	0.06	0.08	0.11
BP	0.09	0.14	0.18	0.23
BQ	1.92	3.22	4.46	6.05
BR	0.65	0.96	1.23	1.56
BS	0.20	0.29	0.37	0.47
BT	0.47	0.71	0.92	1.17
BU	0.50	0.76	1.01	1.31
BV	1.01	1.62	2.17	2.83
BX	0.84	1.46	2.05	2.79
BY	0.50	0.81	1.10	1.46
BZ	0.17	0.54	0.97	1.56
C	1.91	3.34	4.70	6.46
CA	0.64	1.08	1.49	2.03
CB	2.35	4.12	5.80	7.98
CE	4.85	7.76	10.35	13.54
CF	1.76	3.01	4.16	5.58
CG	0.62	1.03	1.42	1.89
CH	1.43	2.40	3.33	4.52
CI	5.11	9.26	13.31	18.48
CJ	1.63	3.15	4.68	6.59
CK	3.31	6.42	9.53	13.43
CL	6.99	12.67	18.21	25.28
CM	9.10	19.75	29.84	42.89
CN	0.54	1.22	1.93	2.86
CO	9.59	18.57	27.58	38.88
CP	7.24	17.95	30.64	48.52
CQ	7.77	17.69	28.67	43.52
CS	7.34	15.56	23.53	34.39
CT	6.99	13.16	19.38	27.27
CU	9.42	19.95	30.17	44.09
CV	0.27	0.88	1.62	2.62
CW	0.16	0.54	1.10	1.84
CY	2.92	6.41	11.61	17.61
CZ	0.54	1.18	1.78	2.56
D	5.07	9.82	14.58	20.56
E	2.12	4.82	7.81	11.85
F	1.10	3.84	7.82	13.07
G	1.91	4.14	6.26	9.00
H	1.67	3.80	6.16	9.35

Boundary	Low Treatment Flow Range			
	2 Year	**5 Year**	**10 Year**	**25 Year**
I	0.29	0.87	1.59	2.54
J	0.66	1.40	2.11	3.08
K	1.08	2.29	3.46	5.06
L	0.88	1.24	1.56	1.93
M	0.20	0.30	0.39	0.50
N	0.91	1.32	1.69	2.12
P	0.37	0.52	0.66	0.82
Q	0.58	0.89	1.17	1.49
R	0.51	0.76	0.98	1.26
S	0.20	0.34	0.47	0.64
T	0.32	0.47	0.60	0.76
V	0.58	1.02	1.43	1.95
W	2.30	4.45	6.60	9.31
X	0.45	0.72	0.96	1.25
Z	2.14	3.95	5.71	7.93

Steps in Chapter 7 of the MDEQ Soil Erosion and Sedimentation Control Training Manual

1. **Identify Soil Type**
   - All soils within the City Limits are assumed to be Hydrologic Soil Group B
2. **Evaluate Surface Conditions**
   - Use **Table 7-1 in Appendix E**: each boundary has the areas broken up into the number of acres considered pavement, residential, and forested, along with the calculated Average Runoff Curve Number
3. **Determine Runoff Volume**
   - Use **Table 7-2 in Appendix E** for the expected runoff volume for the 2 year, 5 year, 10 year, and 25 year storm
4. **Determine Unit Peak Discharge**
   - Use **Table 7-3a in Appendix E** for the estimated unit peak discharge rate using the average pipe slope for the 2 year, 5 year, 10 year, and 25 year storm
   - Use **Table 7-3b in Appendix E** for the estimated unit peak discharge rate using the average watershed slope for the 2 year, 5 year, 10 year, and 25 year storm
5. **Determine the Treatment Flow Range**
   - Use **Table 7-6 in Appendix E** for the high end of the treatment flow range (1/3 of the higher unit peak discharge, using pipe slope versus watershed slope) for the 2 year, 5 year, 10 year, and 25 year storm
   - Use **Table 7-5 in Appendix E** for the low end of the treatment flow range (1/3 of the lower unit peak discharge, using pipe slope versus watershed slope) for the 2 year, 5 year, 10 year, and 25 year storm
6. **Design Stormwater Treatment System**
   - Design the stormwater treatment system based on the determined treatment flow range
   - Examine low impact development options as well as conventional BMP treatment options

APPENDIX F

Environmental Regulations

Traverse City Ground-Water Protection and Stormwater Control Ordinance Guidelines

PREAMBLE

The guidelines were developed to be used in conjunction with the Traverse City Ground-Water Protection and Storm-Water Runoff Control Ordinance. These guidelines will be updated as needed to reflect the new technology and best management practices available to deal with ground-water protection and storm-water runoff on sites within the City of Traverse City.

A. GROUND-WATER PROTECTION

1. General-purpose floor drains shall be allowed only if they are connected to: an on-site holding tank; to the public sanitary sewer system with approved oil separator system or; a system authorized through a State ground-water discharge permit.

2. Secondary containment for above-ground areas where hazardous substances and polluting materials are stored or used shall be provided. Secondary containment shall be sufficient to store the substance for the maximum anticipated period of time necessary for the recovery of any released substance.

3. Outside storage of hazardous substances and polluting materials shall be prohibited except in product-tight containers which are protected from weather, leakage, accidental damage and vandalism and are stored within a secondary containment system.

4. Out-of-service abandoned tanks shall be emptied and removed in accordance with the State of Michigan Underground Storage Tank Rules.

B. STORM-WATER RUNOFF CONTROL FACILITIES

1. Earth changes and related improvements shall be designed, constructed and maintained to minimize the extent and duration of earth disruption and to protect the natural environment.

2. On-site storm-water runoff control facilities which protect water quality and prevent unwanted flooding shall be required for all sites. Storm-water runoff control facilities may include but are not limited to detention basins, retention ponds, infiltration trenches, infiltration basins, drainage wells, grass swales, grass swales with check dams, filter strips and other facilities.

3. Storm-water control facilities shall be planned and designed to reproduce the pre-development hydrology of the site to the maximum possible extent.

4. Infiltration trenches, perforated pipe and infiltration basins shall be encouraged provided that (a) sediment is removed from storm-water runoff before runoff reaches the infiltration facility and (b) adequate provisions for facility maintenance have been made.

5. Infiltration basins shall be lined with a vegetative cover designed to slow the flow of runoff and to trap pollutants. Sediment traps, catch basins and/or sediment basins shall be provided for the purpose of collecting sediment before storm water reaches the infiltration basin or trench. Infiltration facilities shall be designed to distribute storm-water runoff volume evenly over the floor of the basin or trench and to prevent ponding or standing water.

6. Drainage wells, commonly known as dry wells, may be used as a storm-water control method if the use of storm-water retention or detention basins, either on- or off-site, is not feasible. All drainage wells must provide the following: (1) catch basins, sediment basins, silt traps or vegetative filter strips to remove sediment from storm water flowing to the drainage well, (2) an approved overflow system and (3) adequate provisions for maintenance.

7. Detention basins shall be designed as extended detention basins to detain runoff on the site for 24 hours or more to allow for maximum settling and removal of suspended solids and other pollutants. Vegetation shall be installed and maintained in the basin to help absorb pollutants.

8. When a downstream outlet (open channel or storm sewer) is unacceptable, minimum detention, retention and infiltration basins on the site shall have the storage capacity to hold the increase in runoff volume generated by the earth change. The required volume shall be calculated by comparing the undeveloped condition to the developed condition for a 25-year 24-hour frequency storm event. Provisions for overflow shall be made. In general, this paragraph shall apply to larger open areas where storm sewers do not exist.

9. If a quantity or capacity problem exists with an outlet as may be determined by the City Engineer, the peak rate of discharge from a site shall be as determined by the City Engineer. It should be assumed for design purposes, that such problems exist with almost all storm sewers within the City. However, in general, such runoff rate will normally not be less than the pre-developed rate, and required on-site storage shall not be greater than that required for a 10-year frequency storm event with 24 hour minimum detention. In general, a short hand design method of a 2½" rain over all impervious surfaces may be used. Drainage facilities for quantity purposes shall be designed to pass a 10-year frequency storm event.

10. As a minimum, all drainage control on all multi-family, commercial and industrial sites when developed shall be designed to allow infiltration or to retain in some acceptable manner all small storms or first-flush runoff which shall be the first one-half (½") inch of runoff. The City Engineer, at the written request of the Michigan Department of Environmental Quality, may reduce the minimum infiltration retention requirements if it is determined that the introduction of surface storm-water infiltration into the groundwater would increase and/or exacerbate the existing known pollution at a site.

11. A two-stage design for detention and retention basins shall be used on sites where parking lots and other impervious surfaces exceed five (5) acres in size as well as for other sites identified by the City Engineer or the Michigan Department of Environmental Quality as requiring special protection for water quality purposes. In such cases, a meeting will be set up between the property owner/developer and City Engineer to discuss details of design and requirements.

12. The use of Swirl Concentrator technology or other "new technology" systems in which the removal of a minimum of 80% of pollutants, including grit, oil, hydrocarbons and floating contaminants for on-site storm-water runoff control facilities, is encouraged. Where these "new technology" systems are designed within projects for areas where off-site receiving and conveyance facilities have adequate capacity, the City Engineer may reduce or eliminate on-site retention/detention requirements.

C. STORM-WATER CONVEYANCE FACILITIES AND RECEIVING WATERS

1. Unless otherwise approved, storm-water runoff shall be conveyed through swales, vegetated buffer strips or other approved facilities so as to decrease runoff velocity, to remove pollutants, to allow suspended sediments to settle and to encourage infiltration.

2. When storm sewers are determined to be necessary by the City Engineer, the applicant shall design the drainage system to mitigate any harmful impact on water quality by using appropriate structural devices or other best management methods.

3. Drain spouts from roofs and sump pumps from basements shall be directed to on-site swales, detention basins or other measures designed to slow the flow of storm-water runoff to non-erosive velocities whenever possible.

D. SITE CONSTRUCTION CONTROL

1. All earth changes shall be designed, constructed and maintained in such a manner as to minimize the extent and duration of earth disruption.

2. Soil erosion control facilities shall be designed to remove sediment from storm water before the storm water leaves the site of the earth-change activity.

3. Vegetative stabilization or other soil erosion control measures shall be installed and maintained throughout the development process. Critical areas exposed during construction shall be protected with temporary vegetation, mulching, filter fences or other methods of stabilization.

4. Storm-water runoff control and soil erosion control measures shall be installed before grading, filling or removal of vegetative cover is initiated.

5. Filter fences and other soil erosion control facilities installed at the perimeter of a development site shall be installed at least five (5') feet from the property boundary to allow for on-site maintenance.

6. Fill slope grades on the perimeter of the graded area adjacent to lakes, streams, wetlands and storm-water ponds, or adjoining properties shall not have a slope steeper than a 33 percent rise (3 feet horizontal to 1 foot vertical) unless approved by the City Engineer.

7. Retention and detention basins shall have an emergency overflow system. The overflow system shall be designed to accommodate flow from the 100-year storm event, or as otherwise required by the Michigan Department of Environmental Quality.

8. Side slopes of any storm-water retention or detention basin shall be no greater than 3:1 (horizontal to vertical) so as to prevent soil erosion and allow for basin maintenance.

9. Storm-water basins with depths greater than three feet shall have one or more of the following safety features: (a) Safety ledges at the basin perimeter which are at least eight feet wide for every three feet of vertical height; (b) aquatic vegetation surrounding the basin which discourages wading; or (c) fencing to prevent unauthorized access to the basin.

10. Soil erosion control measures shall be maintained throughout the duration of the earth change including the later stages of development. Maintenance activities include but are not limited to

removal of accumulated sediment, structural repairs, reseeding or replacement of vegetative cover and lawn mowing.

11. Removal of natural vegetation and tree roots within twenty five (25) feet of the ordinary high water mark of any wetland, lake or stream shall be prohibited unless approved for recreational uses. A lake or stream buffer area greater than twenty five (25) feet may be required by the City Engineer if necessary for soil erosion control purposes.

12. Grading of land or other earth changes shall not be permitted in any flood plain unless approved by the Michigan Department of Environmental Quality as well as the City Engineer. Further, all approved grading of land or other earth changes within a flood plain or within the required buffer area of a lake or stream shall not reduce the storage capacity of the flood plain and shall meet the requirements of the City Zoning Ordinance.

E. DESIGN PARAMETERS FOR FACILITY CONSTRUCTION

1. Design parameters for ground-water protection, storm-water management and soil erosion facilities shall follow best management practices as identified by the City Engineer, the Grand Traverse County Soil Conservation Service and/or the Michigan Department of Environmental Quality.

2. The Michigan Department of Environmental Quality "Urban Storm-water Best Management Practices Manual" will be used as a reference along with other manuals such as "Controlling Urban Runoff" by the Metropolitan Washington Council of Governments and the Small Business Guide to Secondary Containment by the Clinton River Watershed Council.

Public Health Code (Excerpt : Act 368 of 1978)
Public Act 507 of 2002

333.12541 Testing and evaluating quality of water at bathing beaches; purpose; posting sign; injunction; definitions.

Sec. 12541.

(1) The local health officer or an authorized representative of the local health department having jurisdiction may test and otherwise evaluate the quality of water at bathing beaches to determine whether the water is safe for bathing purposes. However, the local health officer or authorized representative shall notify the city, village, or township in which the bathing beach is located prior to conducting the test or evaluation.

(2) If a local health officer or an authorized representative of a local health department conducts a test or evaluation of a bathing beach under subsection (1), within 36 hours of conducting the test or evaluation, he or she shall notify the department, the city, village, or township in which the bathing beach is located, and the owner of the bathing beach of the results of the test or evaluation.

(3) The owner of the bathing beach shall post at the main entrance to the bathing beach or other visible location a sign that states whether or not the bathing beach has been tested or evaluated under subsection (1) and, if the bathing beach has been tested, the location of where test results may be reviewed. Open stretches of beach or beaches at road ends that are not advertised or posted as public bathing beaches do not need to have signs posted.

(4) If a local health officer or authorized representative of the local health department conducts a test or evaluation under subsection (1) and, based upon the standards promulgated under section 12544, the health officer or the authorized representative determines that the water is unsafe for bathing, he or she may petition the circuit court of the county in which the bathing beach is located for an injunction ordering the person owning or operating the bathing beach to close the bathing beach for use by bathers or ordering other measures to keep persons from entering on the bathing beach. Upon receipt of a petition under this subsection, the court may grant an injunction if circumstances warrant it.

(5) As used in this section:

(a) “Bathing beach” means a beach or bathing area offered to the public for recreational bathing or swimming. It does not include a public swimming pool as defined in section 12521.

(b) “Department” means the department of environmental quality.

History: 1978, Act 368, Eff. Sept. 30, 1978 ;-- Am. 2002, Act 507, Eff. Mar. 31, 2003
Popular Name: Act 368

APPENDIX G

Stormwater Treatment Maps

City of Traverse City
Department of Public Services

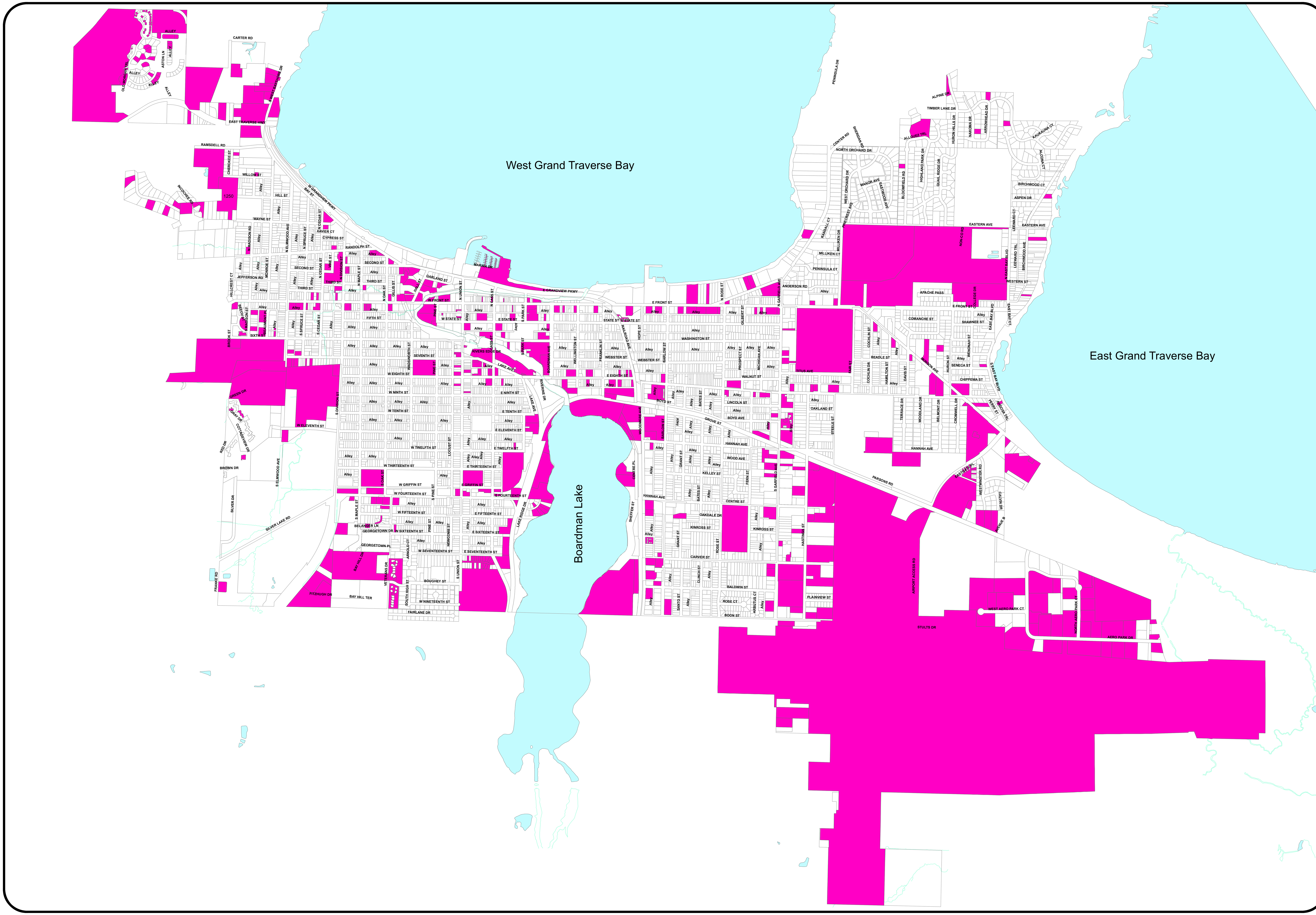
STORMWATER TREATMENT SYSTEMS LOCATION MAP

1 inch = 800 feet

4-19-17
JPT

TC ENGINEERING
City of Traverse City

Stormwater Permit Locations



cblack

This map is based on digital databases from the City of Traverse City.Traverse City cannot accept any responsbility for errors, ommissions or positional accuracy. There are no warranties expressed or implied.

Document Path: X:\TCPROJ\ENGINEER\Maps\StormwaterPermits\StormwaterPermitLocations.mxd

City of Traverse City
Department of Public Services

STREET SWEEPING MAP
ROUTES AND FREQUENCY

1 inch = 700 feet

12-12-16

APPENDIX H

Bibliography, Resources, and References

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Kids Creek Streambank Inventory Worksheet Samples

Channel Modification **CM**

WATERSHED/SUBSHED:	DATE: 10/3/16	ASSESSED BY: ZL BQ
SURVEY REACH ID:	TIME: ___:___ AM/PM	PHOTO ID: (Camera-Pic #) ~~1091~~ 1092
SITE ID: (Condition-#) CM-____	START LAT ___° ___' ___" LONG ___° ___' ___" LMK ____ / END LAT ___° ___' ___" LONG ___° ___' ___" LMK ____	GPS: (Unit ID) 129 – 130

TYPE: ☐ Channelization ☑ Bank armoring ☐ concrete channel ☐ Floodplain encroachment ☑ Other FENCE

MATERIAL:			DIMENSIONS:
☐ Concrete ☐ Gabion	Does channel have perennial flow?	☑ Yes ☐ No	Height 2 (ft)
☐ Rip Rap ☐ Earthen	Is there evidence of sediment deposition?	☐ Yes ☑ No	Bottom Width ____ (ft)
☐ Metal	Is vegetation growing in channel?	☐ Yes ☐ No	Top Width: ____ (ft)
☐ Other: STONE	Is channel connected to floodplain?	☐ Yes ☐ No	Length: ____ (ft)

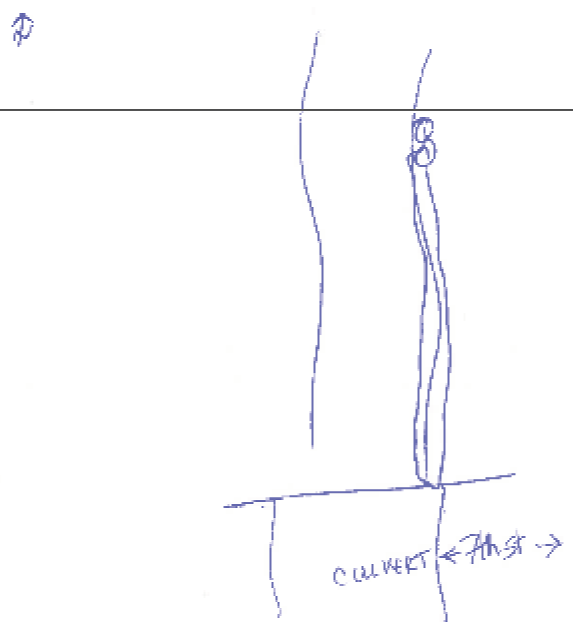
BASE FLOW CHANNEL
Depth of flow ________ (in)
Defined low flow channel? ☐ Yes ☐ No
% of channel bottom ______ %

ADJACENT STREAM CORRIDOR
Available width LT ______ (ft) RT ______ (ft)
Utilities Present? ☐ Yes ☐ No
Fill in floodplain? ☐ Yes ☐ No

POTENTIAL RESTORATION CANDIDATE ☐ Structural repair ☐ Base flow channel creation ☐ Natural channel design ☐ Can't tell ☐ no ☐ De-channelization ☐ Fish barrier removal ☐ Bioengineering

CHANNELIZATION SEVERITY: (Circle #)	A long section of concrete stream (>500') channel where water is very shallow (<1" deep) with no natural sediments present in the channel		A moderate length (> 200'), but channel stabilized and beginning to function as a natural stream channel. Vegetated bars may have formed in channel.	An earthen channel less than 100 ft with good water depth, a natural sediment bottom, and size and shape similar to the unchannelized stream reaches above and below impacted area.	
	5	4	3	2	1

NOTES:



Severe Bank Erosion **ER**

WATERSHED/SUBSHED:		DATE: 11 / 1 / 16	ASSESSED BY: ZL BG
SURVEY REACH:	TIME: ___:___ AM/PM	PHOTO ID (CAMERA-PIC #): PB010029-034	
SITE ID: (Condition-#) ER-____	START LAT ___° ___' ___" LONG ___° ___' ___" LMK ____ / END LAT ___° ___' ___" LONG ___° ___' ___" LMK ____		GPS: (Unit ID) 156

PROCESS: ☐ Currently unknown
- ☒ Downcutting
- ☒ Widening
- ☐ Headcutting
- ☐ Aggrading
- ☐ Sed. deposition
- ☐ Bed scour
- ☒ Bank failure
- ☐ Bank scour
- ☒ Slope failure
- ☐ Channelized

BANK OF CONCERN: ☐ LT ☒ RT ☐ Both *(looking downstream)*

LOCATION: ☒ Meander bend ☐ Straight section ☐ Steep slope/valley wall ☐ Other:

DIMENSIONS:

Length (Est/GPS)	LT ___ ft	and/or RT ___ ft	Bottom width	___ ft
Bank Ht	LT ___ ft	and/or RT 2.0 ft	Top width	___ ft
Bank Angle	LT ___°	and/or RT VERT°	Wetted Width	___ ft

LAND OWNERSHIP: ☒ Private ☐ Public ☐ Unknown

LAND COVER: ☒ Forest ☐ Field/Ag ☒ Developed:

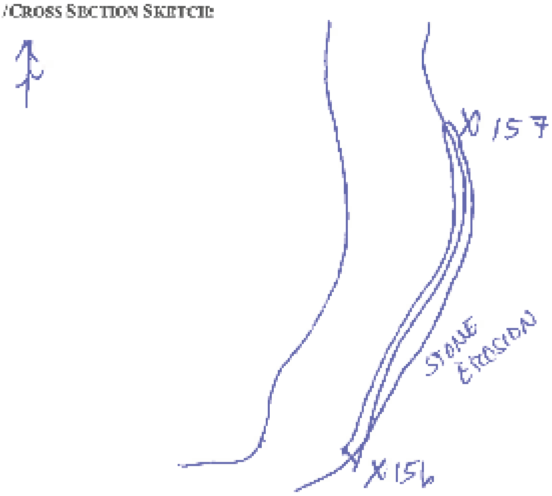
POTENTIAL RESTORATION CANDIDATE: ☐ Grade control ☒ Bank stabilization ☐ No ☐ Other:

THREAT TO PROPERTY/INFRASTRUCTURE: ☐ No ☐ Yes (Describe):

EXISTING RIPARIAN WIDTH: ☒ <25 ft ☐ 25 - 50 ft ☐ 50-75ft ☐ 75-100ft ☐ >100ft

EROSION SEVERITY *(circle #)* Channelized→☐ 1	Active downcutting; tall banks on both sides of the stream eroding at a fast rate; erosion contributing significant amount of sediment to stream; obvious threat to property or infrastructure. (5 4)	Past downcutting evident, active stream widening, banks actively eroding at a moderate rate; no threat to property or infrastructure (3)	Grade and width stable; Isolated areas of bank failure/erosion; likely caused by a pipe outfall, local scour, impaired riparian vegetation or adjacent use. (2 1)
ACCESS:	Good access: Open area in public ownership, sufficient room to stockpile materials, easy stream channel access for heavy equipment using existing roads or trails. (5 4)	Fair access. Forested or developed area adjacent to stream. Access requires tree removal or impact to landscaped areas, Stockpile areas small or distant from stream. (3)	Difficult access. Must cross wetland, steep slope or other sensitive areas to access stream. Minimal stockpile areas available and/or located a great distance from stream section. Specialized heavy equipment required. (2 1)

NOTES/CROSS SECTION SKETCH:



REPORTED TO AUTHORITIES ☐ Yes ☐ No

Impacted Buffer **IB**

WATERSHED/SUBSHED: | **DATE:** 11 / 1 / 16 | **ASSESSED BY:** ZC BL

SURVEY REACH: | TIME: ___:___ AM/PM | **PHOTO ID:** (*Camera-Pic #*) Paddock# 103

SITE ID: (*Condition-#*) IB-____ | *START* LAT ___° ___' ___" LONG ___° ___' ___" LMK ____ | **GPS:** (*Unit ID*) 179,180,182
END LAT ___° ___' ___" LONG ___° ___' ___" LMK ____

IMPACTED BANK: ☒ LT ☒ RT ☒ Both

REASON INADEQUATE: ☒ Lack of vegetation ☒ Too narrow ☐ Widespread invasive plants ☐ Recently planted ☐ Other:

LAND USE: (*Facing downstream*)

	Private	Institutional	Golf Course	Park	Other Public
LT Bank	☒	☐	☐	☐	☐:
RT Bank	☒	☐	☐	☐	☐:

DOMINANT LAND COVER:

	Paved	Bare ground	Turf/lawn	Tall grass	Shrub/scrub	Trees	Other
LT Bank	☐	☐	☒	☐	☐	☐	☐:
RT Bank	☐	☐	☒	☐	☐	☐	☐

INVASIVE PLANTS: ☒ None ☐ Rare ☐ Partial coverage ☐ Extensive coverage ☐ unknown

STREAM SHADE PROVIDED? ☐ None ☒ Partial ☐ Full | **WETLANDS PRESENT?** ☒ No ☐ Yes ☐ Unknown

POTENTIAL RESTORATION CANDIDATE ☐ Active reforestation ☒ Greenway design ☐ Natural regeneration ☐ Invasives removal ☐ no ☐ Other:

RESTORABLE AREA

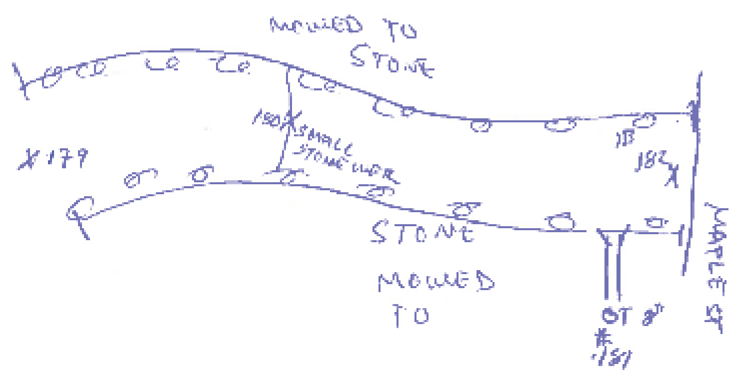
	LT	RT
Length (ft):		
Width (ft):		

REFORESTATION POTENTIAL: (*Circle #*)

5	4	3	2	1
Impacted area on public land where the riparian area does not appear to be used for any specific purpose; plenty of area available for planting		Impacted area on either public or private land that is presently used for a specific purpose; available area for planting adequate		Impacted area on private land where road, building encroachment or other feature significantly limits available area for planting

POTENTIAL CONFLICTS WITH REFORESTATION ☐ Widespread invasive plants ☐ Potential contamination ☐ Lack of sun ☐ Poor/unsafe access to site ☐ Existing impervious cover ☐ Severe animal impacts (deer, beaver) ☐ Other:

NOTES:



Storm Water Outfalls **OT**

WATERSHED/SUBSHED:		**DATE:** 10/28/16	**ASSESSED BY:** ZL BG
SURVEY REACH ID:	**TIME:** ___:___ AM/PM	**PHOTO ID:** (*Camera-Pic #*) 1096 # 1094	
SITE ID (*Condition #*): OT-____	**LAT** ___° ___' ___" **LONG** ___° ___' ___"	**LMK** ____	**GPS:** (*Unit ID*) 64

BANK: ☐ LT ☒ RT ☐ Head

FLOW: ☐ None ☐ Trickle ☐ Moderate ☐ Substantial ☐ Other: SUBMERGED

TYPE: ☐ Closed pipe — **MATERIAL:** ☒ Concrete ☐ Metal ☐ PVC/Plastic ☐ Brick ☐ Other: — **SHAPE:** ☐ Single ☒ Circular ☐ Double ☐ Elliptical ☐ Triple ☐ Other: — **DIMENSIONS:** Diameter: 8 (in) — **SUBMERGED:** ☐ No ☐ Partially ☒ Fully

TYPE: ☐ Open channel — ☒ Concrete ☐ Earthen ☐ Other: — ☐ Trapezoid ☐ Parabolic ☐ Other: — Depth: 4 (in) Width (Top): ____ (in) (Bottom): ____ (in) — NOT APPLICABLE

CONDITION: ☐ None ☐ Chip/Cracked ☐ Peeling Paint ☐ Corrosion ☒ Other: OLD

ODOR: ☒ No ☐ Gas ☐ Sewage ☐ Rancid/Sour ☐ Sulfide ☐ Other:

DEPOSITS/STAINS: ☐ None ☐ Oily ☐ Flow Line ☐ Paint ☐ Other:

VEGGIE DENSITY: ☒ None ☐ Normal ☐ Inhibited ☐ Excessive ☐ Other:

PIPE BENTHIC GROWTH: ☒ None ☐ Brown ☐ Orange ☐ Green ☐ Other:

POOL QUALITY: ☒ No pool ☐ Good ☐ Odors ☐ Colors ☐ Oils ☐ Suds ☐ Algae ☐ Floatables ☐ Other:

FOR FLOWING ONLY		
	COLOR:	☐ Clear ☐ Brown ☐ Grey ☐ Yellow ☐ Green ☐ Orange ☐ Red ☐ Other:
	TURBIDITY:	☐ None ☐ Slight Cloudiness ☐ Cloudy ☐ Opaque
	FLOATABLES:	☐ None ☐ Sewage (toilet paper, etc.) ☐ Petroleum (oil sheen) ☐ Other:
OTHER CONCERNS:		☐ Excess Trash (paper/plastic bags) ☐ Dumping (bulk) ☐ Excessive Sedimentation ☐ Needs Regular Maintenance ☐ Bank Erosion ☐ Other: NEEDS RESTORATION OR REMOVAL

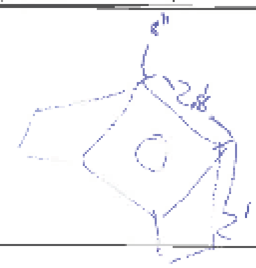
POTENTIAL RESTORATION CANDIDATE ☐ Discharge investigation ☐ Stream daylighting ☐ Local stream repair/outfall stabilization ☐ no ☐ Storm water retrofit ☐ Other:

If yes for daylighting:
Length of vegetative cover from outfall: ________ ft Type of existing vegetation: ______________ Slope: ____ ° ' "

If yes for stormwater:
Is stormwater currently controlled? ☐ Yes ☐ No ☐ Not investigated
Land Use description: ____________
Area available:

OUTFALL SEVERITY: (*circle #*)	Heavy discharge with a distinct color and/or a strong smell. The amount of discharge is significant compared to the amount of normal flow in receiving stream; discharge appears to be having a significant impact downstream.	Small discharge, flow mostly clear and odorless. If the discharge has a color and/or odor, the amount of discharge is very small compared to the stream's base flow and any impact appears to be minor / localized.	Outfall does not have dry weather discharge, staining, or appearance of causing any erosion problems.
	5 4	3 2	1

SKETCH/NOTES:



PHOTOS: PA280013 — 16

REPORTED TO AUTHORITIES: ☐ YES ☐ NO

Reach Level Assessment **RCH**

SURVEY REACH ID: ______	WTRSHD/SUBSHED:	DATE: 10/26/16	ASSESSED BY: ZC BG
START TIME: ___:___ AM/PM LMK: ______ LAT ___° ___' ___" LONG ___° ___' ___" DESCRIPTION:	END TIME: ___:___ AM/PM LMK: ______ LAT ___° ___' ___" LONG ___° ___' ___" DESCRIPTION: 1070 - 1068		GPS ID: 14

RAIN IN LAST 24 HOURS ☐ Heavy rain ☐ Steady rain ☐ None ☑ Intermittent ☐ Trace

PRESENT CONDITIONS ☐ Heavy rain ☑ Steady rain ☐ Intermittent ☐ Clear ☐ Trace ☐ Overcast ☐ Partly cloudy

SURROUNDING LAND USE: ☐ Industrial ☐ Commercial ☐ Urban/Residential ☐ Suburban/Res ☐ Forested ☐ Institutional ☐ Golf course ☒ Park ☐ Crop ☐ Pasture ☐ Other:

AVERAGE CONDITIONS *(check applicable)*

BASE FLOW AS% CHANNEL WIDTH ☐ 0-25% ☐ 25-50 % ☐ 50%-75% ☐ 75-100%

DOMINANT SUBSTRATE ☑ Silt/clay (fine or slick) ☑ Sand (gritty) ☐ Gravel (0.1-2.5") ☐ Cobble (2.5 - 10") ☐ Boulder (>10") ☐ Bed rock

WATER CLARITY ☑ Clear ☐ Turbid *(suspended matter)* ☐ Stained *(clear, naturally colored)* ☐ Opaque *(milky)* ☐ Other *(chemicals, dyes)*

AQUATIC PLANTS IN STREAM Attached: ☐ none ☒ some ☐ lots Floating: ☐ none ☐ some ☐ lots

WILDLIFE IN OR AROUND STREAM (Evidence of) ☑ Fish ☐ Beaver ☑ Deer ☐ Snails ☑ Other: BIRDS

STREAM SHADING (water surface) ☐ Mostly shaded (≥75% coverage) ☒ Halfway (≥50%) ☐ Partially shaded (≥25%) ☐ Unshaded (< 25%)

CHANNEL DYNAMICS ☐ Unknown ☐ Downcutting ☐ Widening ☐ Headcutting ☐ Aggrading ☒ Sed. deposition ☐ Bed scour ☐ Bank failure ☐ Bank scour ☐ Slope failure ☐ Channelized

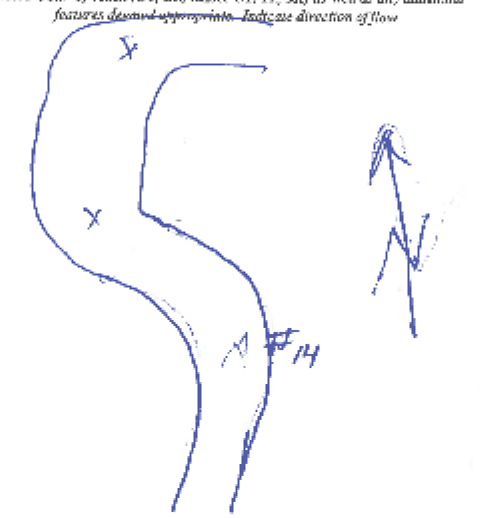
CHANNEL DIMENSIONS *(Facing downstream)* Height: LT bank 2.5 (ft) RT bank 2.5 (ft) Width: Bottom ____ (ft) Top 13 (ft)

REACH ACCESSIBILITY

Good: Open area in public ownership, sufficient room to stockpile materials, easy stream channel access for heavy equipment using existing roads or trails.	Fair: Forested or developed area adjacent to stream. Access requires tree removal or impact to landscaped areas. Stockpile areas small or distant from stream	Difficult: Must cross wetland, steep slope, or sensitive areas to get to stream. Few areas to stockpile available and/or located a great distance from stream. Specialized heavy equipment required.
5 4	3 2	1

REACH SKETCH AND SITE IMPACT TRACKING

Sample planar sketch of survey reach. Track locations and IDs for all site impacts within the survey reach (OT, ER, IB,SC, UT, TR, MI) as well as any additional features deemed appropriate. Indicate direction of flow



PHOTOS: PA 260042 - PA 260044

NOTES: *(biggest problem you see in survey reach)*

REPORTED TO AUTHORITIES ☐ Yes ☐ No

Stream Crossing **SC**

WATERSHED/SUBSHED:		DATE: 10 / 26 / 16	ASSESSED BY: ZC BG
SURVEY REACH ID:	TIME: 3 : 00 AM/PM	PHOTO ID: (Camera-Pic #) /#	
SITE ID: (Condition-#) SC-____	LAT ___° ___' ___" LONG ___° ___' ___"	LMK____	GPS (Unit ID) 20

TYPE: ☐ Road Crossing ☐ Railroad Crossing ☐ Manmade Dam ☐ Beaver Dam ☐ Geological Formation ☐ Other:

FOR ROAD/ RAILROAD CROSSINGS ONLY

SHAPE	# BARRELS:	MATERIAL:	ALIGNMENT:	DIMENSIONS: (if variable, sketch)
☒ Arch ☐ Bottomless ☐ Box ☐ Elliptical ☐ Circular ☐ Other:	☒ Single ☐ Double ☐ Triple ☐ Other:	☒ Concrete ☐ Metal ☐ Other:	☒ Flow-aligned ☐ Not flow-aligned ☐ Do not know	Barrel diameter: 11 (ft) Height: 5 (ft)

CONDITION: (Evidence of…)	CULVERT SLOPE:	
☐ Cracking/chipping/corrosion ☐ Downstream scour hole ☒ Sediment deposition ☐ Failing embankment ☐ Other (describe):	☐ Flat ☒ Slight (2° – 5°) ☐ Obvious (>5°)	Culvert length: ____(ft) Width: ____(ft) Roadway elevation: ____(ft)

POTENTIAL RESTORATION CANDIDATE ☐ Fish barrier removal ☐ Culvert repair/replacement ☐ Upstream storage retrofit
☐ no ☐ Local stream repair ☐ Other:

IS SC ACTING AS GRADE CONTROL ☒ No ☐ Yes ☐ Unknown

If yes for fish barrier

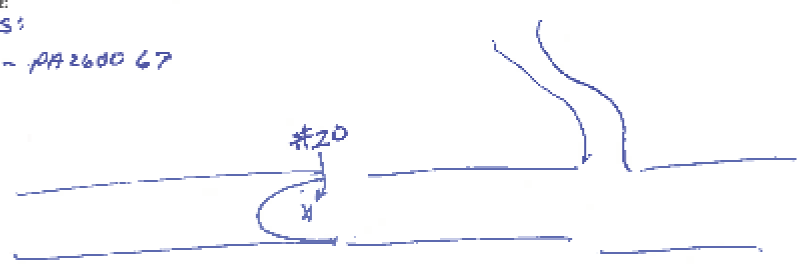
EXTENT OF PHYSICAL BLOCKAGE
☐ Total ☐ Partial
☐ Temporary ☐ Unknown

CAUSE:
☐ Drop too high Water Drop: ____ (in)
☐ Flow too shallow Water Depth: ____ (in)
☐ Other:

BLOCKAGE SEVERITY: (circle #)

A structure such as a dam or road culvert on a 3rd order or greater stream blocking the upstream movement of anadromous fish, no fish passage device present.	A total fish blockage on a tributary that would isolate a significant reach of stream, or partial blockage that may interfere with the migration of anadromous fish.	A temporary barrier such as a beaver dam or blockage at the very head of a stream with very little viable fish habitat above it; natural barriers such as waterfalls.
5 4	3	2 1

NOTES/SKETCH:
PHOTOS:
PA260061 – PA260067



REPORTED TO AUTHORITIES ☐ YES ☐ NO

Trash and Debris **TR**

WATERSHED/SUBSHED:		DATE: 11 / 2 / 16	ASSESSED BY: ZC JY
SURVEY REACH ID:	TIME: ___:___ AM/PM	PHOTO ID: (Camera-Pic #) #	
SITE ID: (Condition-#) TR-___	LAT ___° ___' ___" LONG ___° ___' ___" LMK ___		GPS: (Unit ID) 207

TYPE:	MATERIAL:	SOURCE:	LOCATION:	LAND OWNERSHIP:
☐ Industrial ☐ Commercial ☐ Residential	☐ Plastic ☐ Paper ☐ Metal ☐ Tires ☐ Construction ☐ Medical ☐ Appliances ☐ Yard Waste ☐ Automotive ☐ Other:	☒ Unknown ☐ Flooding ☐ Illegal dump ☐ Local outfall	☒ Stream ☐ Riparian Area ☐ Lt bank ☒ Rt bank	☐ Public ☒ Unknown ☐ Private AMOUNT (# Pickup truck loads):

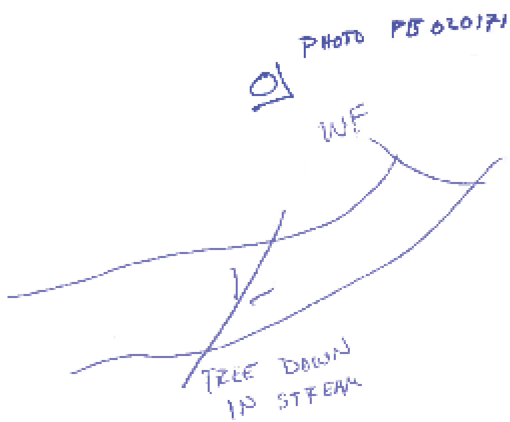
POTENTIAL RESTORATION CANDIDATE ☒ Stream cleanup ☐ Stream adoption segment ☒ Removal/prevention of dumping
☐ no ☐ Other:

If yes for trash or debris removal	EQUIPMENT NEEDED: ☒ Heavy equipment ☐ Trash bags ☐ Unknown	DUMPSTER WITHIN 100 FT: ☐ Yes ☐ No ☐ Unknown
	WHO CAN DO IT: ☒ Volunteers ☒ Local Gov ☐ Hazmat Team ☐ Other	

CLEAN-UP POTENTIAL: (*Circle #*)	A small amount of trash (i.e., less than two pickup truck loads) located inside a park with easy access	A large amount of trash, or bulk items, in a small area with easy access. Trash may have been dumped over a long period of time but it could be cleaned up in a few days, possibly with a small backhoe.		A large amount of trash or debris scattered over a large area, where access is very difficult. Or presence of drums or indications of hazardous materials	
	5	4	3	2	1

NOTES: PHOTOS :
P8020165-167

REPORTED TO AUTHORITIES ☐ YES ☐ NO



Utility Impacts **UT**

WATERSHED/SUBSHED:	DATE: 10/27/16	ASSESSED BY: ZC RG
SURVEY REACH ID:	TIME: 10:17 AM/PM	PHOTO ID: (Camera-Pic #) 10/4 - 1021 ## 25
SITE ID: (Condition-#) UT-_____	LAT ___° ___' ___" LONG ___° ___' ___" LMK: _____	GPS: (Unit ID) 21

TYPE: ☐ Leaking sewer ☒ Exposed pipe ☐ Exposed manhole ☐ Other:

MATERIAL: ☐ Concrete ☐ Corrugated metal ☒ Smooth metal ☐ PVC ☐ Other:

LOCATION: ☐ Floodplain ☐ Stream bank ☐ Above stream ☒ Stream bottom ☐ Other:

POTENTIAL FISH BARRIER: ☐ Yes ☒ No

PIPE DIMENSIONS: Diameter: 3 in Length exposed: ALL 15'

CONDITION: ☐ Joint failure ☐ Pipe corrosion/cracking ☐ Protective covering broken ☐ Manhole cover absent ☐ Other:

EVIDENCE OF DISCHARGE		
	COLOR	☒ None ☐ Clear ☐ Dark Brown ☐ Lt Brown ☐ Yellowish ☐ Greenish ☐ Other:
	ODOR	☒ None ☐ Sewage ☐ Oily ☐ Sulfide ☐ Chlorine ☐ Other:
	DEPOSITS	☒ None ☐ Tampons/Toilet Paper ☐ Lime ☐ Surface oils ☐ Stains ☐ Other:

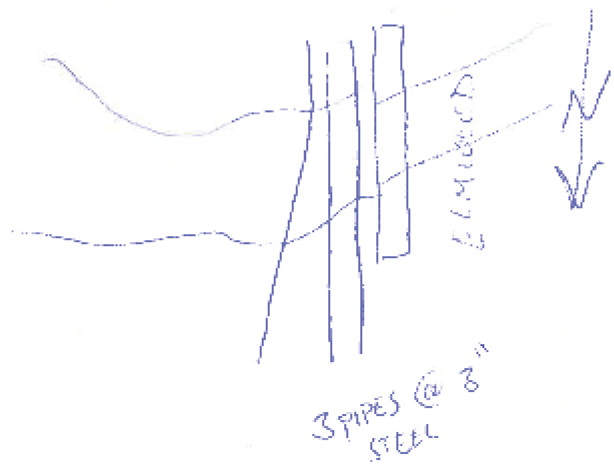
POTENTIAL RESTORATION CANDIDATE ☐ Structural repairs ☒ Pipe testing ☐ Citizen hotlines ☐ Dry weather sampling ☐ no ☐ Fish barrier removal ☐ Other: DETERMINE WHO OWNS

If yes to fish barrier, Water Drop: _______ (in)

UTILITY IMPACT SEVERITY: (Circle #)				
Section of pipe undermined by erosion and could collapse in the near future; a pipe running across the bed or suspended above the stream; a long section along the edge of the stream where nearly the entire side of the pipe is exposed, or a manhole stack that is located in the center of the stream channel and there is evidence of stack failure.		A moderately long section of pipe is partially exposed but there is no immediate threat that the pipe will be undermined and break in the immediate future. The primary concern is that the pipe may be punctured by large debris during a large storm event.		Small section of exposed pipe, stream bank near the pipe is stable; the pipe is across the bottom of the stream but only a small portion of the top of the pipe exposed; the pipe is exposed but is reinforced with concrete and it is not causing a blockage to upstream fish movement; a manhole stack that is at the edge of the stream and does not extend very far out into the active stream channel.
Leaking = ☐ 5	5	4 (circled)	3	2 1

NOTES: PHOTOS PA270017 – PA270019

REPORTED TO LOCAL AUTHORITIES ☐ Yes ☐ No



Pine Street 5-Year Return Interval

Designations	Identification Numbers (Manhole / Pipe)	SWMM Junction / Conduit	MH Elevations Rim (Estimate)	MH Elevations Invert	Diameter (inches)	Cuml Dist / Length (feet)	Station	Slope Pipe (ft/ft) (1)	Slope Land (ft/ft) (1)	Area (sq feet) (2)	Area (acres)	"Width" (feet) (3)	Proportional Land Use per Subcatchment (acres) (4) Pavement	Residential	Forested	Tc (min) (6)	Rational C (Rossmiller) 2007 CN (10)	Rational C (Type A soil) (11)
													0.25	0.22	0.53			
14th Street	33002	J14	613.4	610.40		3881.77	38 + 81.77											
A14	2410	C14-G			8	178.59		0.0034	0.0011	12413	0.28	400	0.07	0.06	0.15	42.18	0.25	0.22
Griffin	33003	JG	612.7	609.80		3703.18	37 + 03.18											
	2409	CG-13			10	208.99		0.0033								1.38		
13.3 Alley	33004	J13.3	613.0	609.10		3494.19	34 + 94.19											
A13.3	2406	C13.3-13			10	219.35		0.0037	0.0011	159023	3.65	500	0.91	0.81	1.94	1.44	0.25	0.22
13th Street	33005	J13	613.1	608.29		3274.84	32 + 74.84											
A13	2403	C13-12.5			12	232.23		0.0034	0.0011	123982	2.85	310	0.71	0.63	1.51	1.53	0.25	0.22
12.5 Alley	33006	J12.5	612.9	607.50		3042.61	30 + 42.61											
	2402	C12.5-12			12	203.20		0.0032								1.34		
12th Street	33007	J12	613.29	606.84		2839.41	28 + 39.41											
A12	700	C12-11.5			18	227.22		0.0018	0.0011	379085	8.70	870	2.17	1.92	4.62	1.50	0.25	0.22
11.5 Alley	33008	J11.5	612.68	606.43		2612.19	26 + 12.19											
	694	C11.5-11S			18	157.25		0.0021								1.04		
11th Street S side	33009	J11S	612.13	606.10		2454.94	24 + 54.94											
A11	693	C11S-11N			24	79.76		0.0023	0.0011	198901	4.57	730	1.14	1.01	2.42	0.53	0.25	0.22
11th Street N side	33010	J11N	611.88	605.92		2375.18	23 + 75.18											
	692	C11N-10.5			24	185.62		0.0017								1.22		
10.5 Alley	33011	J10.5	612.18	605.60		2189.56	21 + 89.56											
	691	C10.5-10			24	198.91		0.0014								1.31		
10th Street	33012	J10	611.6	605.33		1990.65	19 + 90.65											
A10	683	C10-9.5			30	226.98		0.0015	0.0011	277511	6.37	730	1.59	1.41	3.38	1.50	0.25	0.22
9.5 Alley	33013	J9.5	611.23	605.00		1763.67	17 + 63.67											
	682	C9.5-9			30	185.77		0.0017								1.22		
9th Street	33014	J9	611.0	604.68		1577.90	15 + 77.90											
A9	1412	C9-8.5			30	243.05		0.0015	0.0011	154307	3.54	570	0.88	0.78	1.88	1.60	0.25	0.22
8.5 Alley	33015	J8.5	610.85	604.32		1334.85	13 + 34.85											
A8.5	1371	C8.5-8			30	202.68		0.0018	0.0011	92574	2.13	345	0.53	0.47	1.13	1.34	0.25	0.22
8th Street	33016	J8	610.76	603.96		1132.17	11 + 32.17											
A8	1370	C8-7			21	430.53		0.0026	0.0011	131717	3.02	450	0.75	0.67	1.60	2.84	0.25	0.22
7th Street	33017	J7	610.2	602.83		701.64	07 + 01.64											
A7	1303	C7-6.5			21	213.89		0.0033	0.0011	222177	5.10	640	1.27	1.13	2.70	1.41	0.25	0.22
6.5 Alley	33018	J6.5	609.40	602.12		487.75	04 + 87.75											
A6.5	1298	C6.5-6S			21	212.97		0.0061	0.0011	208426	4.78	680	1.19	1.06	2.54	1.40	0.25	0.22
6th Street S side	33019	J6S	609.48	600.83		274.78	02 + 74.78											
A6	1297	C6S-6N			18	61.26		0.0504	0.0011	29937	0.69	120	0.17	0.15	0.36	0.40	0.25	0.22
6th Street N side	33020	J6N	613.62	597.75		213.52	02 + 13.52											
		C6N-A1			24	53.52		0.0989								0.35		
Upstream Swirl MH	33024	JA1	600.00	592.45		160.00	01 + 60.00											
Bypass pipe	1296	CA1-A2			24	15.00		0.5033		--		--	--	--	--	--		
Downstream Swirl MH	33025	JA2	598.50	584.90		145.00	01 + 45.00											
Outfall pipe	4726	Coutlet			24	145.00		0.0269		--		--	--	--	--	--		
Boardman Outfall	-99999	Out1		581.00		0.00	00 + 00.00											

Free Outfall (33) Elevation: 581.0 | Total Length = 3882 ft | Ave Slope = 0.0046 (W/O drop from 6th St) | Total Area = 1990053 sf 45.69 ac; 2007 Area = 45.69 ac | 11.38 / 11.38 | 10.08 / 10.08 | 24.23 / 24.23 | Tc 66 min

Land Use Designations — Curve Numbers: Pavement 98, Residential 75, Forested 55; Area Proportions 0.25, 0.22, 0.53.

Tc Input/IDF Data — $T_{overland}$ = 41 min; $V_{pipe,ave}$ = 2.5 fps; (8) RI = 5 yr; (8) I5 = 1.34 in/hr

Peak Flow Rate (cfs) (7)

Row	[A] Rossmiller Rational Method, No Ia component (12), 2007 CN	[B] Type A soil	[C] MDEQ/SCS Calculated, Ia const=0.05	[D] Calculated, Ia const=0.2	[E1] Tabular (13)	[E2]	[F] (18) Single Sub Area, 55.0, 47% IMP	[G] (19) EPA SWMM Curve Number 2007, 55.0, 47% IMP	[H] (20) 70.1, 0% IMP	[I] Horton, Modified City Model, Infiltration (cfs)	[J] (21)	[K] (22) Type II	[L] (23) Green-Ampt City	[M] (24) OHM	[N] (25) OHM (scaled)
A14	0.1	0.1	0.1	0.1	0.1	0.1	--	0.2	0.1	0.6	0.6	0.9			
A13.3	1.3	1.1	1.4	0.9	1.4	0.8	--	1.9	0.3	1.9	1.9	1.2			
A13	2.2	2.0	2.5	1.5	2.4	1.3	--	3.2	0.4	2.6	2.6	3.3			
A12	5.1	4.5	5.6	3.4	5.5	3.0	--	5.5	1.0	5.5	5.5	8.5			
J11S													9.2	9.2	9.2
A11	6.6	5.8	7.2	4.4	7.1	3.9	--	7.1	1.2	7.0	7.0	11.9	17.9	30.36	23.79 (25)
A10	8.7	7.6	9.5	5.8	9.4	5.2	--	8.8	1.3	8.9	8.9	13.7			
J9													10.5	14.6	14.6
A9	9.9	8.7	10.8	6.6	10.7	5.9	--	10.3	1.4	10.2	10.2	11.4			
A8.5	10.6	9.3	11.6	7.1	11.4	6.3	--	11.5	1.5	12.0	12.0	12.0	11.8	21.16	15.71 (25)
A8	11.6	10.2	12.7	7.7	12.5	6.9	--	12.8	1.5	12.2	12.2	13.9			
A7	13.3	11.6	14.5	8.9	14.3	7.9	--	14.9	1.6	14.1	14.1	15.2			
A6.5 (J6.5)	14.9	13.0	16.3	9.9	16.0	8.8	--	17.1	1.7	15.8	15.8	19.2	22.1	27.2	27.2
A6	15.1	13.2	16.5	10.1	16.1	8.9	22.0	17.4	1.7	16.1	16.1	19.9	11.5	21.21	15.50 (25)
Total	15.1	13.2	16.5	10.1	16.1	8.9	22.0	17.4 / 20.4	1.7	16.1 / 17.1	16.1 / 17.1	19.9 / 24.6	22.1 / 36.9	27.2 / 70.4	27.2 / 50.4 (18)

OHM Multiplier: 0.459 (tabular ave/XP peak flow)

Total Subcatchment Peak Runoff: 40.3 | 41.5 | 72.7 | 88.0

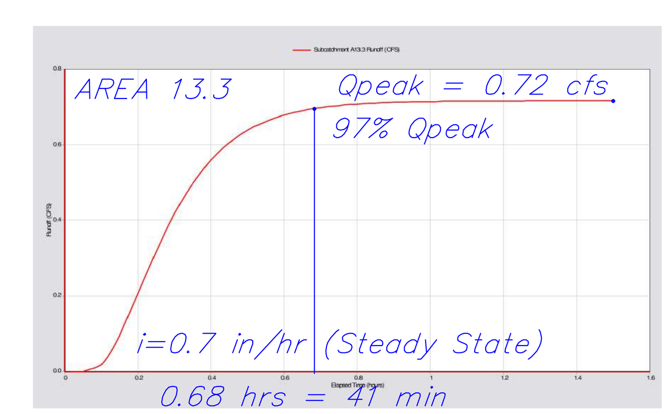
NOTE: SEE SHEET 2 OF 3 FOR 2- AND 10-YEAR ANALYSES AND NOTES

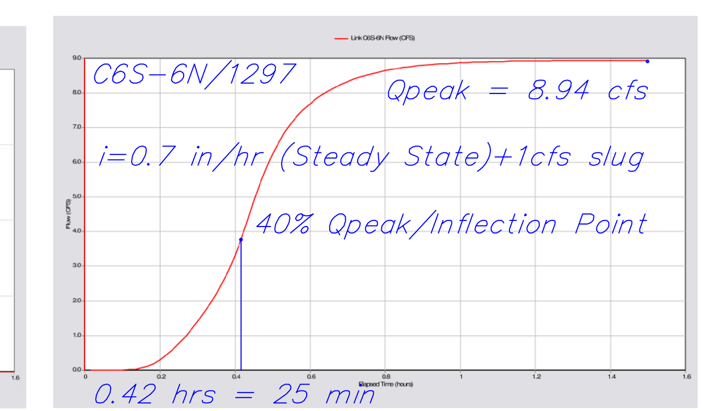
5-Year Infiltration/Rainfall/Runoff Data						SCS Method: Surface Runoff (SRO) Calculated* (15) Ia Constant		SCS Method: Unit SRO (q_u) Tabular Table 7.2	Table 7-3**	MDEQ Unit Peak Hydrograph Calculated (17)
Description	2007	Rossmiller	24-hr Rainfall			0.05	0.2			
Soil type:	B	A	2 yr	P_2 =	2.09 in	--	--	0.26 in	0.64 cfs/(in-ac)	0.39 cfs/(in-ac)
Curve No.	70.1 (5)	66.7 (5)	5 yr	P_5 =	2.7 in	0.917	0.559	0.56 in	0.64 cfs/(in-ac)	--
Storage	4.26 in	4.99 in	10 yr	P_{10} =	3.21 in	--	--	0.85 in	0.64 cfs/(in-ac)	--
				Ia =		0.213 in	0.852 in	(16)		

*Per 2007 CN

** 2007 average slopes: pipe 0.78%; watershed 0.11%. Table 7-3 value for 0.11% slope: 0.35 cfs/(in-ac)

PINE STREET HYDROLOGY AND HYDRAULICS
5-YR RETURN PERIOD HAND CALCS AND MODELING RESULTS

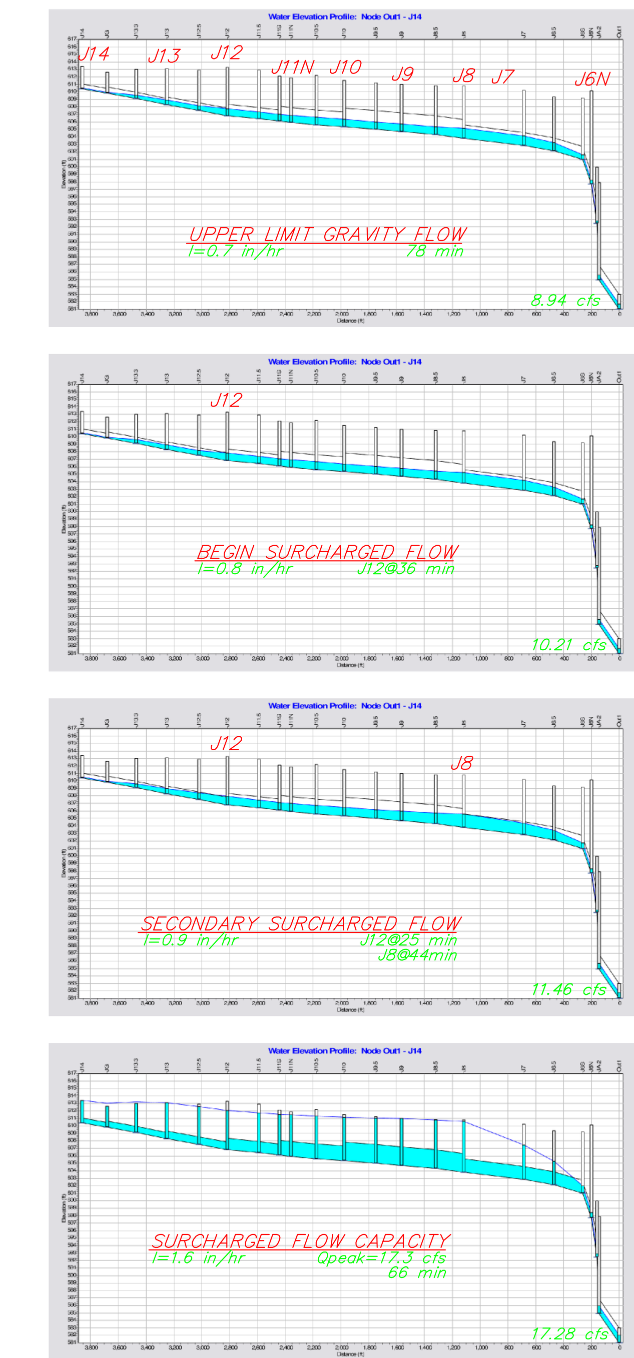




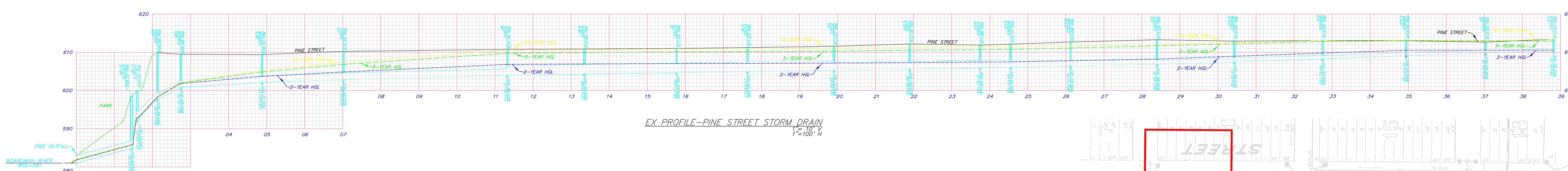
2-YEAR INTENSITY 1.07 IN/HR
5-YEAR INTENSITY 1.34 IN/HR
10-YEAR INTENSITY 1.59 IN/HR

TIME OF CONCENTRATION
Tc=66 MIN OVERLAND/PIPE FLOW

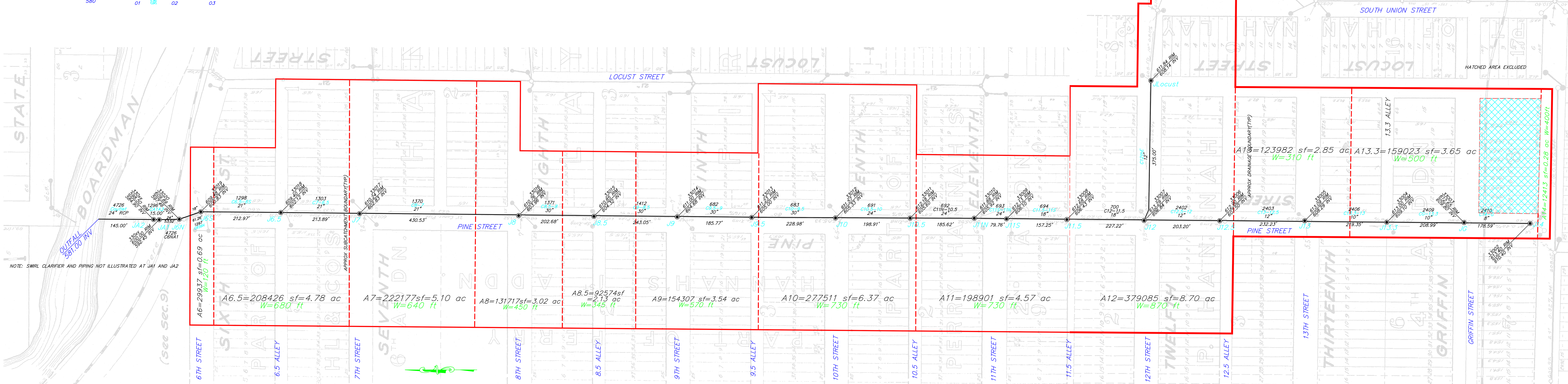
STORM DRAIN PERFORMANCE
PINE STREET NET RUNOFF



NOTE: THE ABOVE ANALYSES REFLECT A CONSTANT RAINFALL INTENSITY WITH THE BEGINNING OF OCCURRENCES AT NOTED TIMES



EX PROFILE–PINE STREET STORM DRAIN
1"=10' V
1"=100' H



NOTE: SWIRL CLARIFIER AND PIPING NOT ILLUSTRATED AT JA1 AND JA2

EX STORM DRAIN AND SUBCATCHMENTS–PINE STREET
1"=100'

PINE STREET DRAINAGE AREA HYDROLOGY AND HYDRAULICS
EX STORM DRAIN AND SUBCATCHMENTS, 5-YEAR ANALYSIS,
TIME OF CONCENTRATION, AND STORM DRAIN PERFORMANCE
TRAVERSE CITY, MICHIGAN

Prince-Lund Engineering, PLC
P.O. Box 1265, Traverse City, Michigan 49685
(888) 418-2695

REVISIONS | DATE | BY | DESCRIPTION

DRAWN BY: MAL
SCALE: AS NOTED
DATE: 03/23/17
PROJECT ID: 1614-OHM
DRAWING: Hydrology and Hydraulics Pine St Drainage Area
SHEET No: 1 of 3

EPA SWMM INPUT

ROUTING — DYNAMIC WAVE
INFILTRATION — CURVE NUMBER
DURATION — 66 MIN
TIME STEPS
REPORTING — 1 MIN
DRY WEATHER — 1 MIN
WET WEATHER — 1 SEC
ROUTING MODEL — DYNAMIC WAVE
RAIN SERIES
TIME — 1.5 HR; 66 MIN; 24 HR
INTERVAL — 1 MIN; 0.1 HR; 0.25 HR
TYPE — 2-, 5-, 10-YEAR; TYPE II
RAIN GAUGE
FORMAT — VOLUME; CUMULATIVE/INCHES
SOURCE TYPE — TIME SERIES
SUBCATCHMENT
AREA — VARIES, 45.7 AC TOTAL
WIDTH — VARIES, FEET
GROUND SLOPE — 0.11%
IMPERVIOUSNESS — 0%, 47%
N impervious — 0.014
N pervious — 0.16%, 0.30
D impervious — 0.05
D pervious — 0.1, 0.2
% impervious — 0%, 10%
PARTIAL ROUTING — 41% IMPERV OVER PERV; 100% PERV TO OUTLET
BASELINE DATA
OBSERVATION POINT — 6TH ST/C6S-6N
Tc — 66 MIN
CURVE NUMBER
NUMBER — 55.0, 70.1
DRY TIME — 1.4
MODIFIED GREEN-AMPT
K saturated — .5
SUCTION HEAD — 1.909*
DEF initial — 0.34
*MATHEMATICALLY RELATED=3.237*Ks^(-0.328)
HORTON
f maximum — 20**
f minimum — 5**
T drying — 1.40***
K decay — 6
**National Resources Conservation Service (4)
***BY DEFINITION; T drying=3.125*(f min)^0.5

Pine Street 2-Year Return Interval

Land Use Designations — Curve Numbers: Pavement 98, Residential 75, Forested 55; Area Proportions: 0.25, 0.22, 0.53

Tc Input/IDF Data: $T_{overland}$ = 41 min; $V_{pipe, ave}$ = 2.5 fps; (8) RI = 2 yr; (8) I2 = 1.07 in/hr

Designations	Identification Numbers Manhole / Pipe	SWMM Junction / Conduit	MH Elevations Rim (Estimate)	MH Elevations Invert	Diameter (inches)	Cuml Dist / Length (feet)	Station	Slope Pipe (ft/ft) (1)	Slope Land (ft/ft) (1)
14th Street	33002	J14	613.4	610.40		3881.77	38 + 81.77		
A14	2410	C14-G			8	178.59		0.0034	0.0011
Griffin	33003	JG	612.7	609.80		3703.18	37 + 03.18		
	2409	CG-13			10	208.99		0.0033	
13.3 Alley	33004	J13.3	613.0	609.10		3494.19	34 + 94.19		
A13.3	2406	C13.3-13			10	219.35		0.0037	0.0011
13th Street	33005	J13	613.1	608.29		3274.84	32 + 74.84		
A13	2403	C13-12.5			12	232.23		0.0034	0.0011
12.5 Alley	33006	J12.5	612.9	607.50		3042.61	30 + 42.61		
	2402	C12.5-12			12	203.20		0.0032	
12th Street	33007	J12	613.29	606.84		2839.41	28 + 39.41		
A12	700	C12-11.5			18	227.22		0.0018	0.0011
11.5 Alley	33008	J11.5	612.68	606.43		2612.19	26 + 12.19		
	694	C11.5-11S			18	157.25		0.0021	
11th Street S side	33009	J11S	612.13	606.10		2454.94	24 + 54.94		
A11	693	C11S-11N			24	79.76		0.0023	0.0011
11th Street N side	33010	J11N	611.88	605.92		2375.18	23 + 75.18		
	692	C11N-10.5			24	185.62		0.0017	
10.5 Alley	33011	J10.5	612.18	605.60		2189.56	21 + 89.56		
	691	C10.5-10			24	198.91		0.0014	
10th Street	33012	J10	611.6	605.33		1990.65	19 + 90.65		
A10	683	C10-9.5			30	226.98		0.0015	0.0011
9.5 Alley	33013	J9.5	611.23	605.00		1763.67	17 + 63.67		
	682	C9.5-9			30	185.77		0.0017	
9th Street	33014	J9	611.0	604.68		1577.90	15 + 77.90		
A9	1412	C9-8.5			30	243.05		0.0015	0.0011
8.5 Alley	33015	J8.5	610.85	604.32		1334.85	13 + 34.85		
A8.5	1371	C8.5-8			30	202.68		0.0018	0.0011
8th Street	33016	J8	610.76	603.96		1132.17	11 + 32.17		
A8	1370	C8-7			21	430.53		0.0026	0.0011
7th Street	33017	J7	610.2	602.83		701.64	07 + 01.64		
A7	1303	C7-6.5			21	213.89		0.0033	0.0011
6.5 Alley	33018	J6.5	609.40	602.12		487.75	04 + 87.75		
A6.5	1298	C6.5-6S			21	212.97		0.0061	0.0011
6th Street S side	33019	J6S	609.48	600.83		274.78	02 + 74.78		
A6	1297	C6S-6N			18	61.26		0.0504	0.0011
6th Street N side	33020	J6N	613.62	597.75		213.52	02 + 13.52		
		C6N-A1			24	53.52		0.0989	
Upstream Swirl MH	33024	JA1	600.00	592.45		160.00	01 + 60.00		
Bypass pipe	1296	CA1-A2			24	15.00		0.5033	
Downstream Swirl MH	33025	JA2	598.50	584.90		145.00	01 + 45.00		
Outfall pipe	4726	Coutlet			24	145.00		0.0269	
Boardman Outfall	-99999	Out1		581.00		0.00	00 + 00.00		
	Free Outfall (33) Elevation: 581.0				Total Length= 3882 ft			Ave Slope = 0.0046 (W/O drop from 6th St)	

Designations	Area (sq feet) (2)	Area (acres)	'Width' (feet) (3)	Pavement (acres) (4)	Residential (acres) (4)	Forested (acres) (4)	Tc (min) (6)	Rational C 2007 CN (10)	Rational C (Type A soil) (11)	Rossmiller Rational Method (No Ia component (12)) 2007 CN	Rossmiller Type A soil	MDEQ/SCS Calculated Ia const=0.05 (9)	MDEQ/SCS Calculated Ia const=0.2 (9)	MDEQ/SCS Tabular (13)	EPA SWMM Curve Number 2007 Single Sub Area (18) 55.0 47% IMP	Modified City Model 55.0 47%IMP	(20) 70.1 0%IMP	Horton loss-bypass (cfs)	Green-Ampt	Green-Ampt Type II	XP SWMM Model City (a)	XP SWMM Model OHM Type II (b)
A14	12413	0.28	400	0.07	0.06	0.15	42.19	0.23	0.20	0.1	0.1	0.1	0.0	0.0	--	0.6	0.0	9.0	0.1	0.6		
(CG-13)							1.39													(23) 11:58-12:17		
A13.3	159023	3.65	500	0.91	0.81	1.94	1.46	0.23	0.20	1.0	0.9	0.9	0.4	0.7	--	1.6	0.1	1.2	1.2	0.4 to 1.2 (22) 1.6		
A13	123982	2.85	310	0.71	0.63	1.51	1.55	0.23	0.20	1.7	1.5	1.5	0.7	1.1	--	2.6	0.1	2.0	2.0	0.5 to 1.6 (22) 2.2		
(C12.5-12)							1.35													11:58-12:17		
A12	379085	8.70	870	2.17	1.92	4.62	1.51	0.23	0.20	3.8	3.4	3.5	1.7	2.6	--	5.4	0.2	4.6	4.6	8.6		
(C11.5-11S)							1.05														12:00-12:07 0.7 to 3.7 9.5	11:50-12:04 1.5 to 15.5 9.2
A11	198901	4.57	730	1.14	1.01	2.42	0.53	0.23	0.20	5.0	4.3	4.5	2.2	3.3	--	7.1	0.3	6.0	6.0	11.6		
(C11N-10.5)							1.24															
(C10.5-10)							1.33															
A10	277511	6.37	730	1.59	1.41	3.38	1.51	0.23	0.20	6.5	5.7	6.0	2.9	4.4	--	8.9	0.3	7.8	7.8	(21) 11:57-12:03 9.1 to 13.4		
(C9.5-9)							1.24													12:01-12:07 1.3 to 3.5	12:00-12:08 1.6 to 5.8 11.0	11:52-12:03 0.3 to 11.9 14.6
A9	154307	3.54	570	0.88	0.78	1.88	1.62	0.23	0.20	7.4	6.5	6.8	3.3	5.0	--	10.4	0.3	8.8	8.8	10.7		
A8.5	92574	2.13	345	0.53	0.47	1.13	1.35	0.23	0.20	7.9	7.0	7.2	3.5	5.3	--	11.1	0.3	9.5	9.5	13.7		
A8	131717	3.02	450	0.75	0.67	1.60	2.87	0.23	0.20	8.7	7.6	7.9	3.8	5.8	--	12.1	0.3	10.2	10.2	14.5		
A7	222177	5.10	640	1.27	1.13	2.70	1.43	0.23	0.20	10.0	8.7	9.1	4.4	6.7	--	13.8	0.3	11.6	11.6	16.2		11:52-12:01 0.6 to 4.7
A6.5	208426	4.78	680	1.19	1.06	2.54	1.42	0.23	0.20	11.1	9.7	10.1	4.9	7.5	--	15.0	0.3	13.0	13.0	19.1	19.6	27.2
A6	29937	0.69	120	0.17	0.15	0.36	0.41	0.23	0.20	11.3	9.9	10.3	5.0	7.6	16.0	15.3	0.3	13.3	13.3	19.5		
(C6N-A1)							0.36															
(CA1-A2)	--		--	--	--	--	--															
(Coutlet)	--		--	--	--	--	--															
Total Area =	1990053 sf	45.69 ac		11.38	10.08	24.23	Tc 66 min			11.3	9.9	10.3	5.0	7.6	16.0	15.3	0.3	13.3	13.3	6.9 / 19.5 / 26.5	8.4 / 19.6 / 27.9	27.9 / 27.2 / 55.1 (19)
2007 Area =		45.69 ac		11.38	10.08	24.23																

2-Year Infiltration/Rainfall/Runoff Data

Description	2007		Rossmiller		24-hr Rainfall			SCS Method Surface Runoff (SRO) Calculated* (15) Ia Constant 0.05	0.2	SCS Method Unit SRO (q_u) Tabular Table 7.2	Table 7-3**	MDEQ Unit Peak Hydrograph Calculated (17)	
Soil type:	B		A					0.05	0.2				
					2 yr	P_2 =	2.09 in	0.574	0.279	0.26 in	0.64 cfs/(in-ac)	0.39	cfs/(in-ac)
Curve No.	70.1	(5)	66.7	(5)	5 yr	P_5 =	2.7 in	--	--	0.56 in	0.64 cfs/(in-ac)	--	
Storage	4.26	in	4.99	in	10 yr	P_{10} =	3.21 in	--	--	0.85 in	0.64 cfs/(in-ac)	--	
							Ia =	0.213 in	0.852 in	(16)			

*Per 2007 CN

**2007 average slopes: pipe 0.78%; watershed 0.1%

NOTES

(1) The drainage area is extremely flat, with high and low points along the alignment. The 2007 average slope of 0.0011 (L=3700 ft/dE=4.07 ft) was used as part of the input for calculations herein.
(2) City storm drain maps were reviewed and the overall drainage boundary estimated based on inlet locations; area was narrowed slightly 30 ft (+/-) to nearly match 2007 total area
(3) "Width" calculated or estimated based on EPA Storm Water Management Model (SWMM) Reference Manual Volume 1, Chapter 3
(4) Portions of the subarea, in acres; classified impervious, residential, and forested per the 2007 Stormwater Management Report
(5) Average curve number per 2007 model | curve number based on impervious area per Rossmiller CN equation using TYPE A soil constant (39); Note: using Type B constant (61), resulting CN is 70.2 or approx equal to 2007 CN
(6) Once the drainage areas and storm drain piping were finalized, first ran a simulation with only the upper subcatchment (A13.3) draining plus a somewhat impervious area, providing a "slug" of water traveling along the pipe in order to determine a time of equilibrium of 41 minutes; then took a general look assuming 600 ft@1 fps in A13.3 and 2.6 fps in the pipe for a total of 35 minutes, which does not account for the time to fill Initial Abstractions, so Tc something greater; finally, analyzed A13.3 subcatchment using the 0.97Qp to determine an equalization time of 37 minutes, to which the 25 minute travel time was added to establish a Tc of 60 minutes.
(7) Peak Flow Rate(cfs) = Unit SRO (qu) <see (16) below> mult by SRO < (P-Ia)^2 / (P-Ia+S) in inches> mult by Area in square miles See (15) below for S and Ia Note: USDA T55 Appendix f has refined qu based on Tc (not used)
(8) Chosen return period and corresponding average intensity for a duration equal to the Tc calculated in (7); average intensity is calculated using equation (Boucher, Costa County, CA, 2010) fit to NOAA DDF curves developed for rainfall data at Cherry Capital Airport (see IDF equations tab)
(9) The SCS/MDEQ methods typically underestimate peak runoff rates for total surface runoff (SRO) less than 1/2 in
(10) Rational method C constant calculated using Rossmiller's equation which is dependent on several variables such as curve number (2007 Study,Type B soil), return interval, average land surface slope, rainfall intensity, and percent impervious
(11) Rational method C constant calculated using Rossmiller's equation which is dependent on several variables such as curve number (Rossmiller Type A soil), return interval, average land surface slope, rainfall intensity, and percent impervious
(12) Both C coefficients were calculated Rossmiller's equation to convert from CN, however the 2007 is based on a Type B soil while the other is based on a Type A soil per NRCS Web Soil Survey, maps and descriptions
(13) These replicate the 2007 Stormwater Management Report calculations using the tabular SCS curve method based on areas and land uses assumed/measured therein; the 5-year return interval (only) includes the land slope Qpeak for comparison purposes; see MDEQ Soil Erosion and Sedimentation Control Training Manual, Chapter 7
(14) It is worth noting how rational method numbers and SCS/MDEQ numbers are close to one another; although both are based on the same return period, one is entirely derived from projected local/historical intensities of the calculated rainfall duration (Tc), while the other is based on a peak runoff relationships derived from a 24-hour duration rainfall based on certain statistical correlations
(15) Total SRO in inches; based on 24-hour rainfall, curve number, and initial abstraction; TR-55 runoff equation, Appendix F; see Chapter 7 "Computing Flood Discharges for Small Ungauged Watersheds", Mich DNR, June 2010 for following equ: SRO= ((P-Ia)^2)/(S+P-Ia) where: S=storage in inches=((1000/CN)-10); CN=curve number; P= 24-hr rainfall in inches for a given return period; Ia=initial abstraction=(constant)*S; constant=0.2 normally, but 0.05 is proposed in certain instances (Table 7-2 equivalent; MDEQ Soil Erosion and Sedimentation Control Training Manual, Chapter 7; see SCS Curve Method tab)
(16) Per definition, however for tabular calcs do not account for this, only the equation approach and numbers are very sensitive to changes; 0.05 has been proposed to replace the current 0.2 constant; see (6) and SCS Curve No. Method tab
(17) MDEQ Stormwater Management Guidebook, Chapter 7, Unit Hydrograph Peak, Equation 21: qu (unit surface runoff)= 270.9*(Tc)^-0.81) in cfs/(sq mi-in) (Table 7-3 equivalent; MDEQ Soil Erosion and Sedimentation Control Training Manual, Chapter 7) mult by area in square miles where=> S= (1000/CN) - 10 Note: USDA T55 Appendix f has refined qu= based on Tc (not used)
(18) An initial estimate of peak flow modeling the entire drainage area as one, using a "width" of 7760 ft (2xpipe length) and the average slope of 0.0011
(19) Model was run with all existing pipes oversized to 42 inches so system flows entirely as an open channel with no losses occurring upstream; runoff quantities are identical for both ex piping and oversized piping simulations
(20) SWMM infiltration methodology does not support curve numbers weighted with impervious areas as these results illustrate; instead, use the percent impervious and appropriate routing in conjunction with a representative pervious CN (55)
(21) Although flooding noted within the model output, a review of reported "flooding" is actually oscillations of the HGL and does not appear to reflect actual ponded conditions
(22) Documented "flooding" includes reverse flow conditions during simulation
(23) This simulation reflects the 3-subcatchment model configuration with inputs (slopes, routing, etc.) reflecting those developed for the City model with a standard Type II rainfall distribution with 0.1 hr time-step increments (P2=2.09; P5=2.70 in); maximum subcatchment runoff as developed on MODEL EQUIVALENCE CONFIRMATION AND STEPPED INPUT CHANGE ANALYSIS, bottom left, Column (7)
(24) This simulation reflects the 3-subcatchment model configuration with inputs (slopes, routing, etc.) reflecting those developed for the OHM model including their 15-minute, Type II rainfall distribution (OHM P2=2.27; P5=2.76 in); maximum sub-catchment runoff as developed on MODEL EQUIVALENCE CONFIRMATION AND STEPPED INPUT CHANGE ANALYSIS, bottom left, Column (1)
(25) Peak subcatchment surface runoff generated by EPA SWMM
(a) Locust Street lateral capacity limits inflows from Subcatchment A12b; creates following losses: Type II 0.1 to 3.6 cfs from 11:57 to 12:21 (24 min) w/reverse flow in pipe (up to 1.9 cfs from 11:58 to 12:19 (21 min); Green-Ampt I5 · 0.12(+/-) cfs from 00:38 to 01:07 (29 min); Horton · 0.12(+/-) cfs from 00:38 to 01:07 (29 min); CN 55.0 · 0.2 to 2.0 cfs from 00:37 to 01:08 (41 min) w/reverse flow in pipe from 00:50 to 01:08
(b) Locust Street lateral capacity limits inflows from Subcatchment A12b; creates following losses: Green-Ampt I10 · 0.5 to 1.7 cfs from 00:28 to 01:08 (40 min) w/reverse flow in pipe from 00:29 to 01:07; Horton · 0.5 to 1.7 cfs from 00:28 to 01:08 (40 min) w/reverse flow in pipe from 00:29 to 01:07; CN 55.0 · 0.1 to 2.8 cfs from 00:28 to 01:18 (50 min) w/reverse flow in pipe from 00:29 to 01:16

PINE STREET HYDROLOGY AND HYDRAULICS

2-YR RETURN PERIOD — HAND CALCS AND MODELING RESULTS
10-YR RETURN PERIOD

10-Year Infiltration/Rainfall/Runoff Data

Description	2007		Rossmiller		24-hr Rainfall			SCS Method Surface Runoff (SRO) Calculated* (15) Ia Constant 0.05	0.2	SCS Method Unit SRO (q_u) Tabular Table 7.2	Table 7-3**	MDEQ Unit Peak Hydrograph Calculated (17)	
Soil type:	B		A					0.05	0.2				
					2 yr	P_2 =	2.09 in	--	--	0.26 in	0.64 cfs/(in-ac)	0.39	cfs/(in-ac)
Curve No.	70.1	(5)	66.7	(5)	5 yr	P_5 =	2.7 in	--	--	0.56 in	0.64 cfs/(in-ac)	--	
Storage	4.26	in	4.99	in	10 yr	P_{10} =	3.21 in	1.238	0.840	0.85 in	0.64 cfs/(in-ac)	--	
							Ia =	0.213 in	0.852 in	(16)			

*Per 2007 CN

**2007 average slopes: pipe 0.78%; watershed 0.1%

Pine Street 10-Year Return Interval

Land Use Designations — Curve Numbers: Pavement 98, Residential 75, Forested 55; Area Proportions: 0.25, 0.22, 0.53

Tc Input/IDF Data: $T_{overland}$ = 41 min; $V_{pipe, ave}$ = 2.5 fps; (8) RI = 10 yr; (8) I10 = 1.59 in/hr

Designations	Identification Numbers Manhole / Pipe	SWMM Junction / Conduit	MH Elevations Rim (Estimate)	MH Elevations Invert	Diameter (inches)	Cuml Dist / Length (feet)	Station	Slope Pipe (ft/ft) (1)	Slope Land (ft/ft) (1)
14th Street	33002	J14	613.4	610.40		3881.77	38 + 81.77		
A14	2410	C14-G			8	178.59		0.0034	0.0011
Griffin	33003	JG	612.7	609.80		3703.18	37 + 03.18		
	2409	CG-13			10	208.99		0.0033	
13.3 Alley	33004	J13.3	613.0	609.10		3494.19	34 + 94.19		
A13.3	2406	C13.3-13			10	219.35		0.0037	0.0011
13th Street	33005	J13	613.1	608.29		3274.84	32 + 74.84		
A13	2403	C13-12.5			12	232.23		0.0034	0.0011
12.5 Alley	33006	J12.5	612.9	607.50		3042.61	30 + 42.61		
	2402	C12.5-12			12	203.20		0.0032	
12th Street	33007	J12	613.29	606.84		2839.41	28 + 39.41		
A12	700	C12-11.5			18	227.22		0.0018	0.0011
11.5 Alley	33008	J11.5	612.68	606.43		2612.19	26 + 12.19		
	694	C11.5-11S			18	157.25		0.0021	
11th Street S side	33009	J11S	612.13	606.10		2454.94	24 + 54.94		
A11	693	C11S-11N			24	79.76		0.0023	0.0011
11th Street N side	33010	J11N	611.88	605.92		2375.18	23 + 75.18		
	692	C11N-10.5			24	185.62		0.0017	
10.5 Alley	33011	J10.5	612.18	605.60		2189.56	21 + 89.56		
	691	C10.5-10			24	198.91		0.0014	
10th Street	33012	J10	611.6	605.33		1990.65	19 + 90.65		
A10	683	C10-9.5			30	226.98		0.0015	0.0011
9.5 Alley	33013	J9.5	611.23	605.00		1763.67	17 + 63.67		
	682	C9.5-9			30	185.77		0.0017	
9th Street	33014	J9	611.0	604.68		1577.90	15 + 77.90		
A9	1412	C9-8.5			30	243.05		0.0015	0.0011
8.5 Alley	33015	J8.5	610.85	604.32		1334.85	13 + 34.85		
A8.5	1371	C8.5-8			30	202.68		0.0018	0.0011
8th Street	33016	J8	610.76	603.96		1132.17	11 + 32.17		
A8	1370	C8-7			21	430.53		0.0026	0.0011
7th Street	33017	J7	610.2	602.83		701.64	07 + 01.64		
A7	1303	C7-6.5			21	213.89		0.0033	0.0011
6.5 Alley	33018	J6.5	609.40	602.12		487.75	04 + 87.75		
A6.5	1298	C6.5-6S			21	212.97		0.0061	0.0011
6th Street S side	33019	J6S	609.48	600.83		274.78	02 + 74.78		
A6	1297	C6S-6N			18	61.26		0.0504	0.0011
6th Street N side	33020	J6N	613.62	597.75		213.52	02 + 13.52		
		C6N-A1			24	53.52		0.0989	
Upstream Swirl MH	33024	JA1	600.00	592.45		160.00	01 + 60.00		
Bypass pipe	1296	CA1-A2			24	15.00		0.5033	
Downstream Swirl MH	33025	JA2	598.50	584.90		145.00	01 + 45.00		
Outfall pipe	4726	Coutlet			24	145.00		0.0269	
Boardman Outfall	-99999	Out1		581.00		0.00	00 + 00.00		
	Free Outfall (33) Elevation: 581.0				Total Length= 3882 ft			Ave Slope = 0.0046 (W/O drop from 6th St)	

Designations	Area (sq feet) (2)	Area (acres)	'Width' (feet) (3)	Pavement (acres) (4)	Residential (acres) (4)	Forested (acres) (4)	Tc (min) (6)	Rational C 2007 CN (10)	Rational C (Type A soil) (11)	Rossmiller Rational Method (No Ia component (12)) 2007 CN	Rossmiller Type A soil	MDEQ/SCS Calculated Ia const=0.05 (9)	MDEQ/SCS Calculated Ia const=0.2 (9)	MDEQ/SCS Tabular (13)	EPA SWMM Curve Number 2007 Single Sub Area (18) 55.0 47% IMP	Modified City Model 55.0 47%IMP	(20) 70.1 0%IMP	Green-Ampt	Horton loss-bypass (cfs)
A14	12413	0.28	400	0.07	0.06	0.15	42.18	0.26	0.23	0.1	0.1	0.1	0.1	0.2	--	(21) 0.3	0.2	(21) 0.6	(21) 0.6
(CG-13)							1.38									0.1 to 1.2 (22) 00:21-01:25 0.1 to 1.0	(22)	0.2 to 1.2 00:21-01:17 0.9	0.2 to 1.2 00:21-01:17 0.9
A13.3	159023	3.65	500	0.91	0.81	1.94	1.44	0.26	0.23	1.6	1.4	1.9	1.3	2.1	--	2.4	0.6	1.8	1.8
A13	123982	2.85	310	0.71	0.63	1.51	1.53	0.26	0.23	2.8	2.4	3.3	2.2	3.7	--	0.1 to 0.8 4.0	0.8	0.1 to 0.2 2.3	0.1 to 0.2 2.3
(C12.5-12)							1.34									00:45-01:09		01:00-01:07	01:00-01:07
A12	379085	8.70	870	2.17	1.92	4.62	1.50	0.26	0.23	6.4	5.6	7.6	5.1	8.4	--	(b) 6.3	2.0	(b) 6.3	(b) 6.3
(C11.5-11S)							1.04												
A11	198901	4.57	730	1.14	1.01	2.42	0.53	0.26	0.23	8.2	7.2	9.8	6.6	10.9	--	6.8	2.4	8.2	8.2
(C11N-10.5)							1.22												
(C10.5-10)							1.31												
A10	277511	6.37	730	1.59	1.41	3.38	1.50	0.26	0.23	10.8	9.5	12.9	8.7	14.4	--	10.3	2.9	9.8	9.8
(C9.5-9)							1.22									00:56-01:07 0.2 to 0.9			
A9	154307	3.54	570	0.88	0.78	1.88	1.60	0.26	0.23	12.3	10.8	14.6	9.9	16.3	--	10.4	3.1	10.4	10.4
A8.5	92574	2.13	345	0.53	0.47	1.13	1.34	0.26	0.23	13.2	11.6	15.7	10.6	17.5	--	0.2 to 0.8 11.3	3.3	11.3	11.3
A8	131717	3.02	450	0.75	0.67	1.60	2.84	0.26	0.23	14.4	12.7	17.1	11.6	19.1	--	0.3 to 0.8 12.6	3.5	12.6	12.6
A7	222177	5.10	640	1.27	1.13	2.70	1.41	0.26	0.23	16.5	14.5	19.6	13.3	21.9	--	15.1	3.8	14.9	14.9
A6.5	208426	4.78	680	1.19	1.06	2.54	1.40	0.26	0.23	18.5	16.2	22.0	14.9	24.5	--	17.9	4.1	16.9	16.9
A6	29937	0.69	120	0.17	0.15	0.36	0.40	0.26	0.23	18.8	16.5	22.3	15.1	24.9	28.1	18.3	4.1	17.2	17.2
(C6N-A1)							0.35												
(CA1-A2)	--		--	--	--	--	--												
(Coutlet)	--		--	--	--	--	--												
Total Area =	1990053 sf	45.69 ac		11.38	10.08	24.23	Tc 66 min			18.8	16.5	22.3	15.1	24.9	28.1	7.6 / 18.3 / 25.9	4.1	3.1 / 17.2 / 20.3	3.1 / 17.2 / 20.3 (19)
2007 Area =		45.69 ac		11.38	10.08	24.23													

REVISIONS — DATE — BY — DESCRIPTION

PINE STREET DRAINAGE AREA HYDROLOGY AND HYDRAULICS

2-YEAR AND 10-YEAR ANALYSES, NOTES, AND GENERAL INFORMATION
TRAVERSE CITY, MICHIGAN

Prince-Lund Engineering, PLLC
P.O. Box 1205, Traverse City, Michigan 49685
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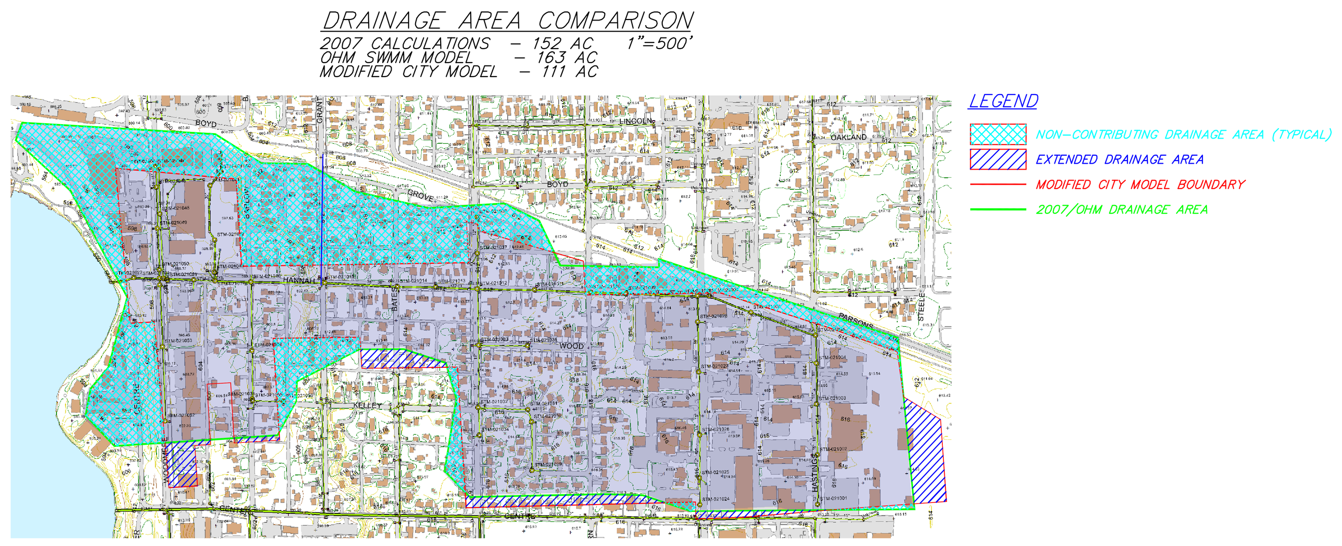
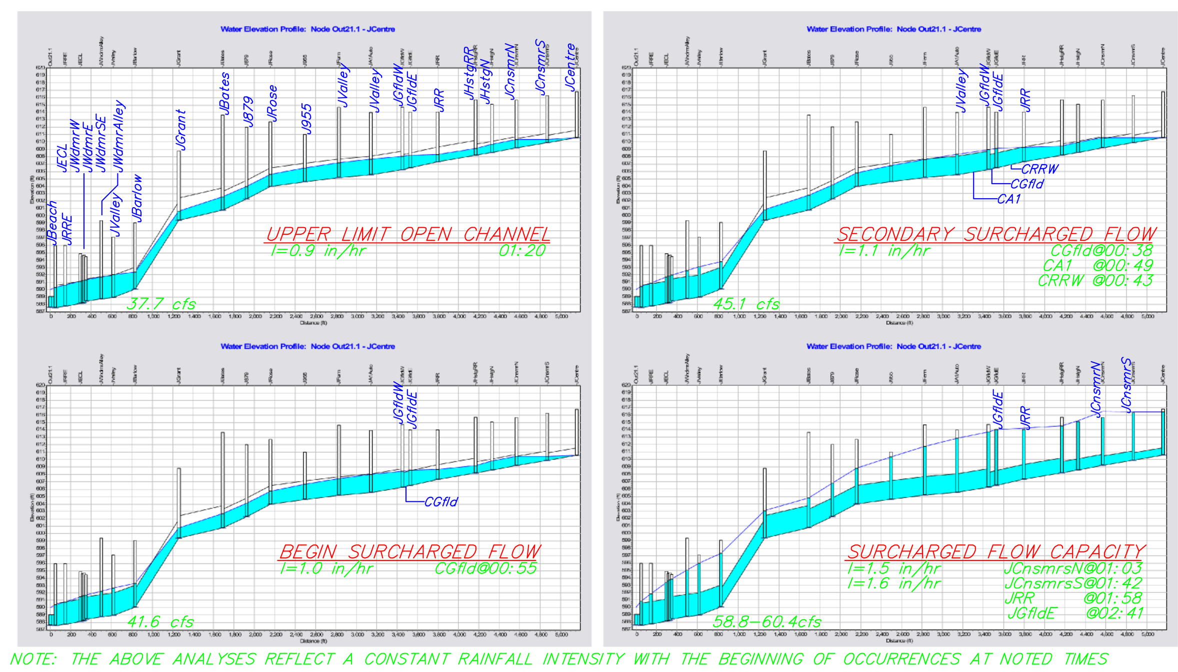
DRAWN BY: MAL
SCALE: AS NOTED
DATE: 03/23/17
PROJECT ID: 1614-OHM
DRAWING: Hydrology and Hydraulics Pine St Drainage Area
SHEET No. 2 of 3





STORM DRAIN PERFORMANCE
HANNA AVENUE NET RUNOFF

Hanna Avenue 5-Year Return Interval

Designations	Identification Numbers (Manhole / Pipe)	SWMM Junction / Conduit	MH Elevations Rim (Estimate)	MH Elevations Invert	Diameter (inches)	Cuml Dist / Length (feet)	Slope Pipe (ft/ft) (1)	Slope Land (ft/ft) (1)	Area (sq feet) (2)	Area (acres)	"Width" (feet) (3)	Pavement 98 (0.3231)	Residential 75 (0.17)	Forested 55 (0.51)	Tc (min) (6)	Rational C 2007 CN (10)	Rational C (Type A soil) (11)	[A] 2007 CN	[B] Type A soil	[C]	[D]	[E1]	[E2]
																72.2	67.9						
S Hastings Street at Centre Street	21001	JCenter	616.82	610.59		5149.98																	
Southerly SD reach on Hastings St	2683	CHstgS			12	290.01	0.0025								31.86								
S End Consumers Power Bldg	21002	JCnsmrS	616.27	609.87		4859.97																	
AHstg	2680	CConsumer			15	297.56	0.0024	0.001	588945	13.52	1010	4.37	2.25	6.90	1.91	0.27	0.23	5.0	4.2	5.4	3.5	4.1	3.5
S End Consumers Power Bldg	21003	JCnsmrN	615.69	609.17		4562.41																	
	3144	CHstgN			18	238.75	0.0024								1.53								
N Hastings Street	21004	JHstg N	615.07	608.59		4323.66																	
	3143	CHstgRR			18	162.48	0.0023								1.04								
Hastings S/O Railroad	21005	JHstgRR	615.71	608.21		4161.18																	
	2012.1	CRRE			24	374.51	0.0023								2.40								
Railroad Easement	21006	JRR	610.0	607.33		3786.67																	
AGfldE	2012.2	CRRW			24	266.37	0.0032	0.001	508653	11.68	1060	3.77	1.94	5.96	1.71	0.27	0.23	9.3	7.9	10.1	6.6	7.7	6.6
Hannah at Garfield-East	21007	JGfldE	614.0	606.49		3520.30																	
	2012.3	CGfld			24	82	0.0028								0.53								
S Garfield S/of Hanna	21027	JGfldS	614.0	608.80				0.0018	723893	16.62	1430	5.37	2.76	8.49		0.27	0.23	15.5	13.2	16.8	11.0	12.8	10.9
AGfldS		CGfldS			18	400	0.0028																
				607.66																			
Hannah at Garfield-West	21008	JGfldW	614.73	606.26		3438.30																	
AA1Auto	2012.4	CA1			30	311	0.0023	0.0034	142358	3.27	300	1.06	0.54	1.67	1.99	0.28	0.24	16.8	14.3	18.1	11.8	13.8	11.7
Hannah at A1 Auto	21009	JA1Auto	613.94	605.53		3127.30																	
AFern	2012.5	CFernE			30	311	0.0012	0.0024	164430	3.77	960	1.22	0.63	1.93	1.99	0.27	0.23	18.2	15.5	19.7	12.8	14.9	12.7
Hannah at Fern	21010	JFern	614.67	605.17		2816.30																	
	2013.1	CFernW			30	333	0.0017								2.13								
955 Hanna/Tan House	21011	J955	612.9	604.59		2483.30																	
ARoseE	2013.2	CRoseE			30	333	0.0019	0.0038	377226	8.66	1540	2.80	1.44	4.42	2.13	0.28	0.24	21.5	18.3	23.2	15.1	17.6	15.0
Rose St @ Kelley St S/of Hanna	21032	JKelley	615.0	610.40																			
AKelley		CRoseS			12	366	0.0071	0.002	409396	9.40	1680	3.04	1.56	4.80		0.27	0.23	3.5	3.0	3.8	2.5	2.9	2.4
Rose St @ Wood St S/of Hanna	21033	JWood	614.1	607.79																			
AWood		CRose			12	320	0.0071	0.002	244335	5.61	1160	1.81	0.93	2.86		0.27	0.23	5.6	1.8	6.0	1.5	1.7	1.5
				605.51																			
Hannah at Rose	21012	JRose	612.70	603.97		2150.30																	
	1886.1	CRoseW			30	233	0.0073								1.49								
879 Hanna/Lavender House	21013	J879	612.0	602.26		1917.30																	
ABatesE	1886.2	CBatesE			30	233	0.0064	0.0026	245861	5.64	950	1.82	0.94	2.88	1.49	0.28	0.24	32.9	23.1	35.3	20.5	23.9	20.3
Hannah at Bates	21014	JBates	613.64	600.77		1684.30																	
AGrantE	1887.1	CBatesW			36	429	0.0032	0.0089	187304	4.30	760	1.39	0.71	2.20	2.75	0.29	0.25	34.6	24.6	37.0	21.6	25.2	21.4
Hannah at Grant	21015	JGrant	608.8	599.41		1255.30																	
ABarlowE	1887.2	CGrantW			30	429	0.0218	0.018	336972	7.74	1670	2.50	1.29	3.95	2.75	0.30	0.26	37.7	27.3	40.1	23.7	27.6	23.5
Hannah at Barlow	21016	JBarlow	599.1	590.06		826.30																	
AWdmrNE	1887.3	CValleyE			36	207.60	0.0053	0.0028	299946	6.89	1520	2.22	1.14	3.52	1.33	0.28	0.24	40.3	29.6	42.9	25.5	29.7	25.2
Hannah at Valley	21017	JValley	597.11	588.97		618.70																	
AWdmrSE	1670	CValleyW			36	122.03	0.0017	0.0104	79080	1.82	400	0.59	0.30	0.93	0.78	0.29	0.25	41.1	30.2	43.6	26.0	30.2	25.7
Hannah at Wdmr Alley	21018	JWdmrAlley	599.40	588.76		496.67																	
	1475.1	CAlleyW			36	149.79	0.0020								0.96								
Hanna/Woodmere SE Corner	210??	JWdmrSE	594.5	588.46		346.88																	
AWdmrSW	1475.2	CAngle			36	22	0.0100	0.0063	263716	6.05	840	1.96	1.01	3.09	0.14	0.28	0.24	43.4	32.2	46.0	27.5	32.1	27.3
East of E'ly twin Manholes	21019	JWdmrE	594.65	588.24		324.88																	
AWdmrNW	1317	CShorty			36	7.38	0.0054	0.0045	242450	5.57	800	1.80	0.93	2.84	0.05	0.28	0.24	45.6	34.1	48.3	29.0	33.8	28.7
West of E'ly twin Manholes	21020	JWdmrW	594.63	588.20		317.50																	
	3336	CWdmrE			36	22.88	0.0035								0.15								
Woodmere Eside C/L	21021	JECL	594.86	588.12		294.62																	
	3337	CWdmrW			36	149.66	0.0023								0.96								
Hanna Eside RR Tracks	21022	JRRE	596.00	587.78		144.96																	
	1479	CBeach			36	94.96	0.0023								0.61								
Beachfront Manhole	21023	JBeach	596.00	587.56		50.00																	
Boardman Lake Outlets (2)	1480	C21			30	50.00									0.32								
	Out-21	Out21		587.00		Each																	
	1481	C21.1			18																		
	Out-21.1	Out21.1		587.60																			
	Submerged Outfall (21) Elevation:			590.0					Total Area 4814565 sf	110.53 ac		35.71	18.38	56.44	Tc 63 min								
	Ave Slope =		0.0045						2007 Area	151.80 ac		49.05	25.24	77.52				45.6	34.1	48.3	29.0	33.8	28.7
															Area Conversion:		1.373	62.6	46.8	66.3	39.8	46.4	39.5 (27)

Land Use Designations: Curve Numbers — Pavement 98, Residential 75, Forested 55; Area Proportions 0.3231, 0.17, 0.51; Proportional Land Use per Subcatchment (acres) (4).

Tc Input/IDF Data: $T_{overland}$ = 30 min; $V_{pipe, ave}$ = 2.6 fps; (7) RI = 5 yr; (7) I_5 = 1.38 in/hr

Hand Calculations (14): Rossmiller Rational Method, No Ia component (12) — [A] 2007 CN, [B] Type A soil; MDEQ/SCS (8) (9) — Calculated, Ia const=0.05 [C]; Tabular (13), Ia const=0.2 [D], [E1], [E2]

Peak Flow Rate (cfs) — EPA SWMM Software: Curve Number 2007 — [F] (18) Single Sub Area 55.0; Modified City Model, Duration/Frequency Intensities — [G] (21) 55.0, [H] (21) 72.2, Horton [I] (21) loss-bypass (cfs), Green-Ampt [J] (21); Type II — [K] (21), City Model [L] (22), [M] (23); OHM TypeII — OHM [N] (24); XP SWMM — OHMRouted

Pipe/Junction Identification	[F]	[G]	[H]	[I]	[J]	[K]	[L]	[M]	[N]		XP SWMM OHMRouted	
						12:06-12:17						
JCnsmrS						0.2 to 1.3						
						11:57-12:10						
JCnsmrN						0.2 to 7.4						
CHstgN		7.1	0.6	7.1	7.1	10.8						
JHstg N						0.2 to 1.7	11:53-12:10	11:46-12:02	11:44-12:03		11:46-12:05	
						12:02-12:18	0.2 to 16.7	4.6 to 31.40	0.4 to 43.9		0.2 to 34.1	
JHstgRR21005							31.78	52.3	68.80	11:59	57.04	(25)
CRRE/2021.1						11:57-12:12	15.1	22.7	26.47	12:00	22.94	
JRR						0.4 to 3.2	7.1	13.8	16.16	12:00	12.96	(29)
						11:58-12:08			10.31			
JGfldE						0.2 to 3.3	7.6	10.5	10.80	12:00	5.99	(29)
JGfldW								10.0	10.69	12:00	9.73	(29)
CGfld		13.3	0.8	12.8	12.8	18.4						
JGfldS		0.3to 1.8		0.2 to 0.4	0.2cto 0.4	0.9 to 13.9						
CGfldS	(28)	10.8	0.9	10.0	10.0	11.2	(28)					
		00:44-01:04		00:46-01:04	00:46-01:04	11:56-12:13	2.9	-11.6 (26)	-11.20 (26)		-5.72	(26)
							11:56-12:08	11:46-12:00	11:46-12:00		11:47-12:07	
CA1		20.9	1.6	21.0	21.0	25.7	0.1 to 7.1	2.6 to 13.9	2.0 to 14.5		0.2 to 11.4	
JA1Auto21009							26.2	41.6	41.59		34.88	(25)
CFernE/2012.5		22.6	1.7	22.6	22.6	26.7	22.0	21.1	21.22	12:00	19.56	
JFern								3.4	5.44			
						11:58-12:06						
J955						2.3 to 8.4		11.0	11.45	12:00	9.04	(29)
CRoseE		24.9	2.0	24.7	24.7	31.6						
JKelley		0.4 to 2.9		0.5 to 2.4	0.4 to 2.4	0.1 to 9.6						
		00:12-01:07		00:12-01:06	00:12-01:06	11:47-12:16						
JWood		0.4 to 1.1		0.1 to 0.3	0.1 to 0.3	0.2 to 5.6		6.7	4.32	12:00	10.52	
CRose	(28)	5.4	1.7	5.2	5.2	5.5	(28)	11:52-12:00	11:51-12:00		11:57-12:01	
		00:44-01:05		00:47-01:04	00:47-01:04	11:54-12:11	0.7	3.4 to 19.1	4.1 to 19.4		0.9 to 11.9	
JRose/21012							30.7 (30)	36.0	36.01		27.54	(25)
CRoseW		34.9	4.4	33.7	33.7	39.9	31.4	31.6	27.98	12:00	26.02	
J879								7.1	10.69			
CBatesE							31.4	24.6	17.27		26.03	
JBates/21014							18.4	29.4	39.32		27.18	(25)
CBatesW		38.1	4.9	36.5	36.5	41.1	49.8	53.8	56.45		53.18	
JBarlow									8.70		4.67	(29)
CGrantW		43.6	5.6	41.2	41.2	52.1	49.8	53.8				
							11:56-12:06	11:48-12:00	11:47-12:01		11:49-12:01	
CValleyE		48.0	7.2	44.4	44.4	59.0	0.8 to 6.5	4.8 to 10.5	0.2 to 13.4		0.9 to 8.5	
JValley/21042						0.5 to 8.4	14.1	18.3	18.29		16.17	(25)
CValleyW		55.0	8.3	47.8	47.8	59.6	57.5	62.1	56.04	12:00	56.45	
						11:58-12:06						
CAlleyW		53.5	9.1	48.7	48.7	61.7						
JWdmrSE						1.0 to 7.2	5.3	3.9	9.78	12:00	7.29	(29)
JWdmrE						11:57-12:06	5.1	3.7	9.62	12:00	7.27	(29)
JWdmrW							5.0	3.7	9.59	12:00	7.31	(29)
CShorty		57.2	9.8	51.8	51.8	67.4		50.8	27.05	12:00	34.59	
								11:56-12:00	11:49-12:00		11:53-12:01	
CWdmrE	68.72	60.6	10.4	54.6	54.6	70.7	42.1	3.4 to 3.7	4.2 to 13.0		1.1 to 7.5	
JECL/21021							32.0	29.6	67.94		49.92	(25)
CWdmrW							74.0	76.7	85.34		79.71	
JBeach												
		4.9		2.8	2.8	44.1	63.6	127.1	180.85		116.17	
	68.7	60.6	10.4	54.6	54.6	70.7	74.0	76.7	85.34		79.71	
		65.4		57.4	57.4	114.8	137.6	203.8	266.19		195.88	(19)
Total Subcatchment Peak Runoff:						139.4	153.2	207.2	271.95		212.73	

OHM Multiplier: 0.538 (tabular ave/XP peak flow)

SEE SHEET 2 FOR 2– AND 10–YEAR ANALYSES AND NOTES

5-Year Infiltration/Rainfall/Runoff Data

Description	2007		Rossmiller		24-hr Rainfall			SCS Method: Surface Runoff (SRO), Calculated* (15), Ia Constant 0.05	Ia Constant 0.2	Unit SRO (q_u), Tabular, Table 7.2	Table 7-3**	MDEQ: Unit Peak Hydrograph, Calculated (17)
Soil type:	B		A									
					2 yr	P_2 =	2.09 in	--	--	0.35 in	0.47 cfs/(in-ac)	--
Curve No.	72.2	(5)	67.9	(5)	5 yr	P_5 =	2.7 in	0.990	0.645	0.65 in	0.47 cfs/(in-ac)	0.41 cfs/(in-ac)
Storage	3.85	in	4.73	in	10 yr	P_{10} =	3.21 in	--	--	0.96 in	0.47 cfs/(in-ac)	--
*Per 2007 CN						(16)	Ia =	0.192 in	0.769 in			

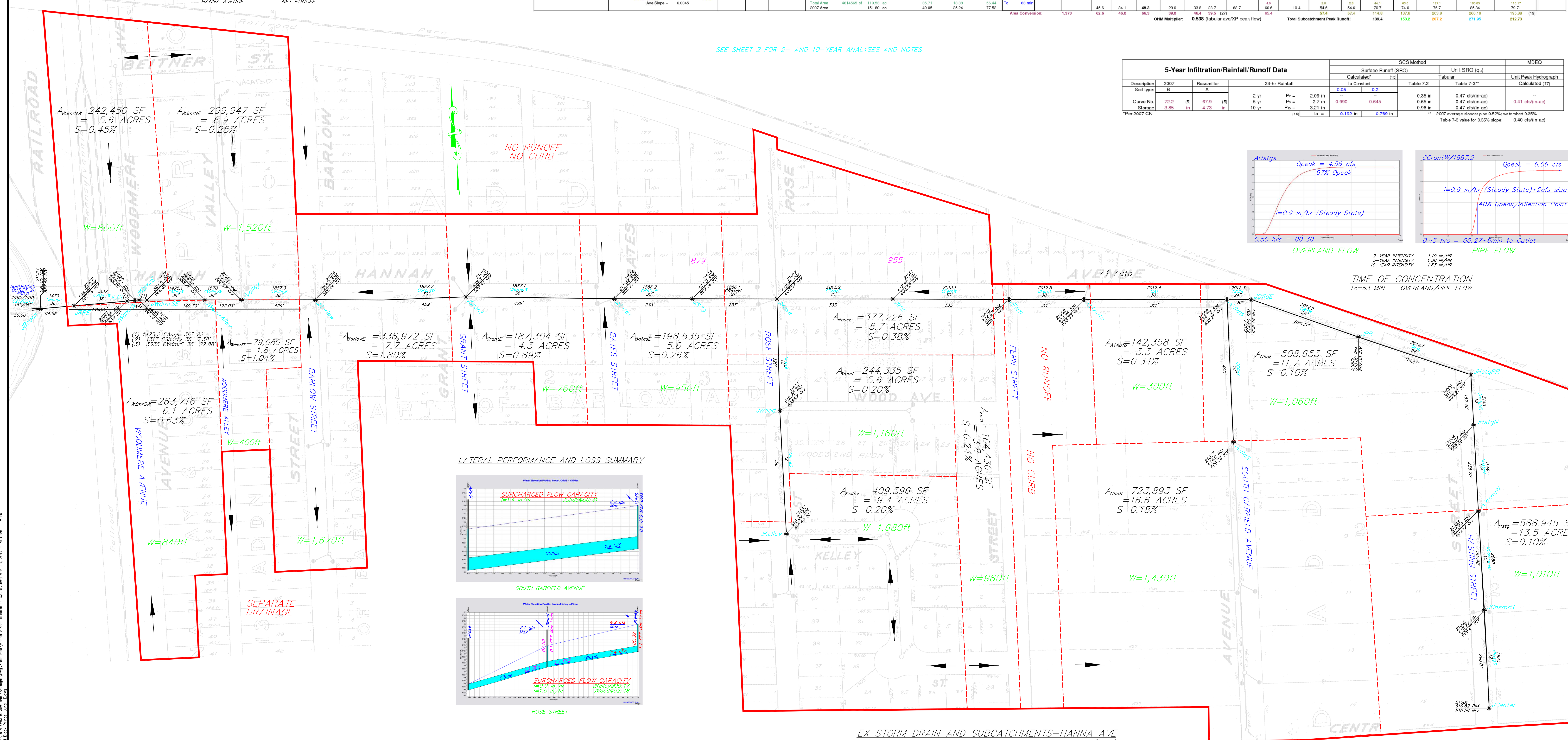
** 2007 average slopes: pipe 0.52%; watershed 0.35%
Table 7-3 value for 0.35% slope: 0.40 cfs/(in-ac)

AHstgs
Qpeak = 4.56 cfs
97% Qpeak
i=0.9 in/hr (Steady State)
0.50 hrs = 00:30
OVERLAND FLOW

CGrantW/1887.2
Qpeak = 6.06 cfs
i=0.9 in/hr (Steady State)+2cfs slug
40% Qpeak/Inflection Point
0.45 hrs = 00:27+6min to Outlet
PIPE FLOW

2–YEAR INTENSITY 1.10 IN/HR
5–YEAR INTENSITY 1.38 IN/HR
10–YEAR INTENSITY 1.63 IN/HR

TIME OF CONCENTRATION
Tc=63 MIN OVERLAND/PIPE FLOW



LATERAL PERFORMANCE AND LOSS SUMMARY

SURCHARGED FLOW CAPACITY
i=1.4 in/hr
SOUTH GARFIELD AVENUE

SURCHARGED FLOW CAPACITY
i=0.9 in/hr
i=1.0 in/hr
ROSE STREET

EX STORM DRAIN AND SUBCATCHMENTS–HANNA AVE
HANNA STREET DRAINAGE AREA 1"=100'

REVISIONS | DATE | BY | DESCRIPTION

HANNA AVENUE DRAINAGE AREA HYDROLOGY AND HYDRAULICS
EX STORM DRAIN AND SUBCATCHMENT SCHEMATIC, 5-YEAR ANALYSIS, LATERAL LOSSES, TIME OF CONCENTRATION, DRAINAGE COMPARISON, AND STORM DRAIN PERFORMANCE
TRAVERSE CITY, MICHIGAN

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DRAWN BY:	MAL
SCALE:	AS NOTED
DATE:	03/23/17
PROJECT ID:	1614-OHM
DRAWING:	Hydrology and Hydraulics Hannna Ave Drainage Area
SHEET No:	1 of 2

EPA SWMM INPUT

ROUTING – DYNAMIC WAVE
INFILTRATION – CURVE NUMBER
DURATION – 63 MIN
TIME STEPS
REPORTING – 1 MIN
DRY WEATHER – 1 MIN
WET WEATHER – 1 SEC
ROUTING MODEL – DYNAMIC WAVE
TIME SERIES
TIME – 3.0 HRS; 24 HRS
INTERVAL – 1 MIN; 0.1 HR; 0.25 HR
TYPE – 2-,5-,10-YEAR; IDF AND TYPE II
RAIN GAUGE
FORMAT – VOLUME; CUMULATIVE/INCHES
SOURCE TYPE – TIME SERIES
SUBCATCHMENT
AREA – VARIES, 110.5 AC TOTAL
WIDTH – VARIES, FEET
GROUND SLOPE – VARIES 0T TO 1.8%
IMPERVIOUSNESS – 49%
N impervious – 0.014
N pervious – 0.16, 0.30
D impervious – 0.05
D pervious – 0.127, 0.2
% impervious – 26% IMPERV OVER PERV
PARTIAL ROUTING – 100% PERV TO OUTLET

BASELINE DATA
OBSERVATION POINT – CGrant#/1887.2
Tc – 63 MIN

CURVE NUMBER
NUMBER – 55.0, 72.2
DRY TIME – 2.2/1.4

MODIFIED GREEN–AMPT
K saturated – 2 5
SUCTION HEAD – 2.575 /1.909*
DEF initial – 0.34
*MATHEMATICALLY RELATED=3.237*Ks^(–0.328)

HORTON
f maximum – 6 / 20**
f minimum – 2 / 1.4**
f drying – 2 / 1.4***
K decay – 6
**National Resources Conservation Service (a)
***BY DEFINITION; f drying=3.125*(f min)^–0.5

Hanna Avenue 2-Year Return Interval

Designations	Identification Numbers Manhole / Pipe	SWMM Junction / Conduit	MH Elevations Rim (Estimate)	MH Elevations Invert	Diameter (inches)	Cuml Dist / Length (feet)	Slope Pipe (ft/ft) (1)	Slope Land (ft/ft) (1)	Area (sq feet) (2)	Area (acres)	"Width" (feet) (3)	Proportional Land Use per Subcatchment (acres) (4): Pavement
S Hastings Street at Centre Street	21001	JCenter	616.82	610.59		5149.98						
Southerly SD reach on Hastings St	2683	CHstgS			12	290.01	0.0025					
S End Consumers Power Bldg	21002	JCnsmS	616.27	609.87		4859.97						
AHstg	2680	CConsumer			15	297.56	0.0024	0.001	588945	13.52	1010	4.37
S End Consumers Power Bldg	21003	JCnsmN	615.69	609.17		4562.41						
	3144	CHstgN			18	238.75	0.0024					
N Hastings Street	21004	JHstg N	615.07	608.59		4323.66						
	3143	CHstgRR			18	162.48	0.0023					
Hastings S/O Railroad	21005	JHstgRR	615.71	608.21		4161.18						
	2012.1	CRRE			24	374.51	0.0023					
Railroad Easement	21006	JRR	610.0	607.33		3786.67						
AGfldE	2012.2	CRRW			24	266.37	0.0032	0.001	508553	11.68	1060	3.77
Hannah at Garfield-East	21007	JGfldE	614.0	606.49		3520.30						
	2012.3	CGfld			24	82	0.0028					
S Garfield S/of Hanna	21027	JGfldS	614.0	608.80				0.0018	723893	16.62	1430	5.37
AGfldS		CGfldS			18	400	0.0028					
Hannah at Garfield-West	21008	JGfldW	614.73	607.66 / 606.26		3438.30						
AA1Auto	2012.4	CA1			30	311	0.0023	0.0034	142358	3.27	300	1.06
Hannah at A1 Auto	21009	JA1Auto	613.94	605.53		3127.30						
AFern	2012.5	CFernE			30	311	0.0012	0.0024	164430	3.77	960	1.22
Hannah at Fern	21010	JFern	614.67	605.17		2816.30						
	2013.1	CFernW			30	333	0.0017					
955 Hanna/Tan House	21011	J955	612.9	604.59		2483.30						
ARoseE	2013.2	CRoseE			30	333	0.0019	0.0038	377226	8.66	1540	2.80
Rose St @ Kelley St S/of Hanna	21032	JKelley	615.0	610.40								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Total Subcatchment Peak Runoff: 101.6 116.1 169.1 222.2 163.11

2-Year Infiltration/Rainfall/Runoff Data

Description	2007		Rossmiller		24-hr Rainfall			SCS Method: Surface Runoff (SRO) Calculated* (15) Ia Constant		Tabular Table 7.2	Unit SRO (qu) Tabular Table 7-3**	MDEQ Unit Peak Hydrograph Calculated (17)
Soil type:	B		A					0.05	0.2			
					2 yr	P_2 =	2.09 in	0.627	0.338	0.35 in	0.47 cfs/(in-ac)	--
Curve No.	72.2	(5)	67.9	(5)	5 yr	P_5 =	2.7 in	0.990	0.645	0.65 in	0.47 cfs/(in-ac)	0.41 cfs/(in-ac)
Storage	3.85	in	4.73	in	10 yr	P_{10} =	3.21 in	--	--	0.96 in	0.47 cfs/(in-ac)	--
						(16)	Ia =	0.192 in	0.769 in			

*Per 2007 CN
** 2007 average slopes: pipe 0.52%; watershed 0.35%
Table 7-3 value for 0.35% slope: 0.40 cfs/(in-ac)

HANNA AVENUE HYDROLOGY AND HYDRAULICS

2–YR RETURN PERIOD
10–YR RETURN PERIOD
HAND CALCS AND MODELING RESULTS

10-Year Infiltration/Rainfall/Runoff Data

Description	2007		Rossmiller		24-hr Rainfall			SCS Method: Surface Runoff (SRO) Calculated* (15) Ia Constant		Tabular Table 7.2	Unit SRO (qu) Tabular Table 7-3**	MDEQ Unit Peak Hydrograph Calculated (17)
Soil type:	B		A					0.05	0.2			
					2 yr	P_2 =	2.09 in	--	--	0.35 in	0.47 cfs/(in-ac)	--
Curve No.	72.2	(5)	67.9	(5)	5 yr	P_5 =	2.7 in	0.990	0.645	0.65 in	0.47 cfs/(in-ac)	0.41 cfs/(in-ac)
Storage	3.85	in	4.73	in	10 yr	P_{10} =	3.21 in	1.327	0.947	0.96 in	0.47 cfs/(in-ac)	--
						(16)	Ia =	0.192 in	0.769 in			

*Per 2007 CN
** 2007 average slopes: pipe 0.52%; watershed 0.35%
Table 7-3 value for 0.35% slope: 0.40 cfs/(in-ac)

HANNA AVE STATISTICS–2007 STORMWATER MANAGEMENT REPORT

PAVEMENT	2,136,536	SF	32.31%	CN=98	IMPERVIOUS
RESIDENTIAL	1,099,404	SF	16.63%	CN=75	IMPERVIOUS
FORESTED	3,376,651	SF	51.06%	CN=55	PERVIOUS
TOTAL	6,612,591	SF[1]	100%	CNave=70.1	
SIDEWALK	92,258	SF	2.85%[2]	<=100% TO PERVIOUS[3]	
STRUCTURE	1,004,146	SF	31.06%	<=75% TO PERVIOUS[3]	
STREET	2,136,536	SF	66.09%		
TOTAL	3,232,940	SF	100%		

[1] MULTIPLY BY 0.6107 TO OBTAIN MODIFIED CITY MODEL AREA
[2] ASSUMED % IMPERVIOUS WITH NO DEPRESSION STORAGE; ROUNDED TO 3%
[3] ASSUMED ACROSS PERVIOUS AREA: (92+(0.75*1004))/3233 ~ 26%

Hanna Avenue 10-Year Return Interval

Designations	Storm Drain Description	Slope	Subcatchment Info	Land Use Designations	Tc Input/IDF Data	Peak Flow Rate (cfs)	Pipe/Junction Identification
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Total Subcatchment Peak Runoff:

NOTES

(1) The drainage area varies significantly in elevation, with notable drops west of Grant on Hanna and north on Woodmere Alley to its intersection with Hanna. Surface slope was calculated for each subcatchment by identifying a high point and a low point and dividing their difference by their separation. The 2007 average slope of 0.0035 (L=5560 ft/dE=19.5 ft) did not appear reflective of underlying topography of the drainage area as a whole.

(2) City storm drain maps were reviewed and the overall drainage boundary estimated based on inlet locations | The Modified City Model area was widened into the area north of Hanna identified as having no runoff to nearly match the OHM drainage area of 110.53 acres, which appears overstated. The determination of 110.53 acres was erroneously understated when additional subcatchments were found out of sequence in the OHM input file and when added, this total increased to about 163 ac, or 7% greater than the 2007 area estimate (151.80). Neither the 2007 nor the OHM areas could be substantiated based on both the storm drain maps and field visits. The City Model remains at 110.53 acres, however an argument can be made to reduce this back to the original drainage area of around 100 acres. | 2007 peak runoff determinations are proportional by area to those produced by the City Model.

(3) "Width" calculated or estimated based on EPA Storm Water Management Model (SWMM) Reference Manual Volume 1, Chapter 3 | this number is noted in documentation as a calibration value.

(4) Portions of the subarea, in acres | classified pavement, residential, and forested per the 2007 Stormwater Management Report. Note that residential area is counted in its entirety as part of the 49 percent impervious calculation, but as a 75 in the weighted curve number calculation (probably should have been counted as 98 accordingly).

(5) Average curve number of 72.2 per 2007 model which appears to have underestimated CN by weighting residential as 75, when in fact it is counted as 100 percent impervious in the overall calculations | The 67.9 curve number is based on impervious area per Rossmiller CN equation using percent impervious and the TYPE A soil constant (39).

(6) Once the drainage areas and storm drain piping were finalized, a simulation was run with only the upper subcatchment (AHstg) discharging to the storm drain plus an input of 2 cfs (pipe capacity) at the upstream (CConsumer) node, providing a "slug" of water traveling along the pipe in order to determine the time of equalibrium of 27 minutes (40% Qpeak; hydrograph inflection point) at Grant Street plus an estimated travel time of 6 minutes to the outlet at Boardman Lake. Grant Street is the location where the storm drain begins to slope downward to an elevation where backwater occurs from the outlet, which affects the output to some degree. | Overland travel time was defined at 97% Qpeak at steady state intensity equal to 0.9 in/hr (upper limit of open channel flow in the storm drain) which resulted in a 30 minute estimate; Tc estimate equals the total (27+6+30) or 63 minutes.

(7) Chosen return period and corresponding average intensity for a duration equal to the Tc calculated in (6) | average intensity is calculated using equation (Boucher, Costa County, CA, 2010) fit to NOAA DDF curves developed for rainfall data at Cherry Capital Airport (see IDF equations tab)

(8) Peak Flow Rate(cfs) = Unit SRO (qu) <see (17) below> mult by SRO < (P-Ia)^2 / (P-Ia+S) in inches> mult by Area in square miles | See (15) below for S and Ia | Note: USDA T55 Appendix f has refined qu= based on Tc (not used)

(9) The SCS/MDEQ methods typically underestimate peak runoff rates for total surface runoff (SRO) in the neighborhood of 1/2-inch or less

(10) Rational method C constant calculated using Rossmiller's equation which is dependent on several variables such as curve number (2007 Study,Type B soil), return interval, average land surface slope, rainfall intensity, and percent impervious

(11) Rational method C constant calculated using Rossmiller's equation which is dependent on several variables such as curve number (Rossmiller Type A soil), return interval, average land surface slope, rainfall intensity, and percent impervious

(12) Both C coefficients were calculated Rossmiller's equation to convert from CN, however the 2007 is based on a Type B soil while the other is based on a Type A soil per NRCS Web Soil Survey, maps and descriptions

(13) These replicate the 2007 Stormwater Management Report calculations using the tabular SCS curve method based on and land uses assumed/measured therein | the 5-year return interval (only) includes the land slope Qpeak for comparson purposes, see MDEQ Soil Erosion and Sedimentation Control Training Manual, Chpt 7 | actual peak flow is proportionally larger based on drainage area [(151.80/110.53)*28.7=39.4 cfs].

(14) It is worth noting how rational method numbers and SCS/MDEQ numbers are somewhat close to one another; although both are based on the same return period, one is entirely derived from projected local/historical intensities of the calculated rainfall duration (Tc), while the other is based on a peak runoff relationships derived from a 24-hour duration rainfall based on certain statistical correlations

(15) Total SRO in inches; based on 24-hour rainfall, curve number, and initial abstraction; TR-55 runoff equation, Appendix F; see Chapter 7 "Computing Flood Discharges for Small Ungauged Watersheds", Mich DNR, June 2010 for following equ: SRO= ((P-Ia)^2)/(S+P-Ia) where: S=storage in inches=((1000/CN)-10); CN=curve number; P= 24-hr rainfall in inches for a given return period; Ia=initial abstraction=(constant)*S; constant=0.2 normally, but 0.05 is proposed in certain instances {Table 7-2 equivalent; MDEQ Soil Erosion and Sedimentation Control Training Manual, Chapter 7; see SCS Curve Method tab}

(16) Per definition, tabular calcs reflect the 0.2 "constant", which was actually developed from a relatively diverse data set gathered througout the country; the equation approach allows varying this "constant" which is very sensative to changes; 0.05 has been proposed to replace the current 0.2 constant; see SCS Curve No. Method tab

(17) MDEQ Stormwater Management Guidebook, Chapter 7, Unit Hydrograph Peak, Equation 21: qu (unit surface runoff)= 270.9*((Tc)^-0.81) in cfs/(sq mi-in) {Table 7-3 equivalent; MDEQ Soil Erosion and Sedimentation Control Training Manual, Chapter 7} mult by area in square miles and SRO as described in (15) to determine peak runoff flow rate.

(18) An initial estimate of peak flow modeling the entire drainage area as one, using a "width" of 10,000 ft and the 2007 Stormwater Management Report average slope of 0.0035.

(19) Model run with all existing pipes oversized to 72 inches so no losses occur upstream; the purpose is to determine a maximum resultant or total peak flow rate without any system losses occurring; subcatchment runoff quantities are identical for both existing piping and oversized piping simulations

(20) Not used

(21) Modified City Model simulations incorporating 15 subcatchments discharging to 15 inputs on the storm drain system; rainfall intensity for columns [G] through [J] correspond to the time of concentration and return interval as described in (6) and (7), respectively. Column [G] reflects the Modified City Model with impervious area (pavement and residential) defined as such with the remaining pervious area (forested) defined by a 55 curve number | Column [H] is the same model as [G] but instead uses the 72.2 weighted curve number as well as area weighted OHM values for Nperv (0.16) and Dperv (0.127) | Column [K] reflects the Modified City Model performance with Green-Ampt infiltration and a 24-hour, Type II rainfall distribution imposed on the system.

(22) This simulation reflects the OHM model configuration as described in (23) with additional changes to slopes, routing, etc. which reflect those developed for the City model; a standard Type II rainfall distribution with 0.1 hr time-step increments (P_2=2.09; P_5=2.70 in) was also incorporated.

(23) This simulation reflects the OHM model configuration as described in (24) except areas of Subcatchments 21005, 21014, and 21021 proportioned downward to reflect areas within the City Model (totalling 110.53 acres).

(24) This simulation reflects the OHM model configuration with inputs (slopes, routing, etc.) reflecting those developed for the OHM model including the 15-minute, Type II rainfall distribution (OHM P_2=2.27; P_5=2.76 in); maximum runoff equals that generated OHM's EPA SWMM (as converted from XP-SWMM and provided to the City for review) for all subcatchments; the OHM model has 5 input points along storm drain, each having 3 subcatchments connected (it is not clear why the system was modeled this way).

(25) Totals of peak subcatchment surface runoff except XP where Area 3s are routed across Area 1s; nearly the same as generated in OHM's XP-SWMM output as provided February 3, 2017

(26) Flow rate of this magnitude is "forced" into storm drain with a certain amount of the subcatchment runoff traveling to the next upstream node and reported as "flooding" at this rate

(27) Peak flows proportioned upward based soley on the ratio (110.53/151.8) of 2007 drainage areas to Modified City Model area; identical to flows calc'd in 2007 Stormwater Management Report

(28) The period of "flooding" is approximately 25 minutes for each of the simulations and is either a result of erroneous data and/or flows approaching system capacity. The results of these analyses indicate it may be prudent to observe system performance within this vicinity as time permits to either verify or dispute the validity of this ouput.

(29) Intermediate junction losses (at 12:00) between subcatchment outlet/connections to the storm drain in the model; note the water balance between upstream and downstream junction maintanins continuity.

(30) Discontinuity in water balance due to oscillations of incoming flow

REVISIONS
DATE BY DESCRIPTION

HANNA AVENUE DRAINAGE AREA HYDROLOGY AND HYDRAULICS
2-YEAR AND 10-YEAR ANALYSES, NOTES, AND GENERAL INFORMATION
TRAVERSE CITY, MICHIGAN

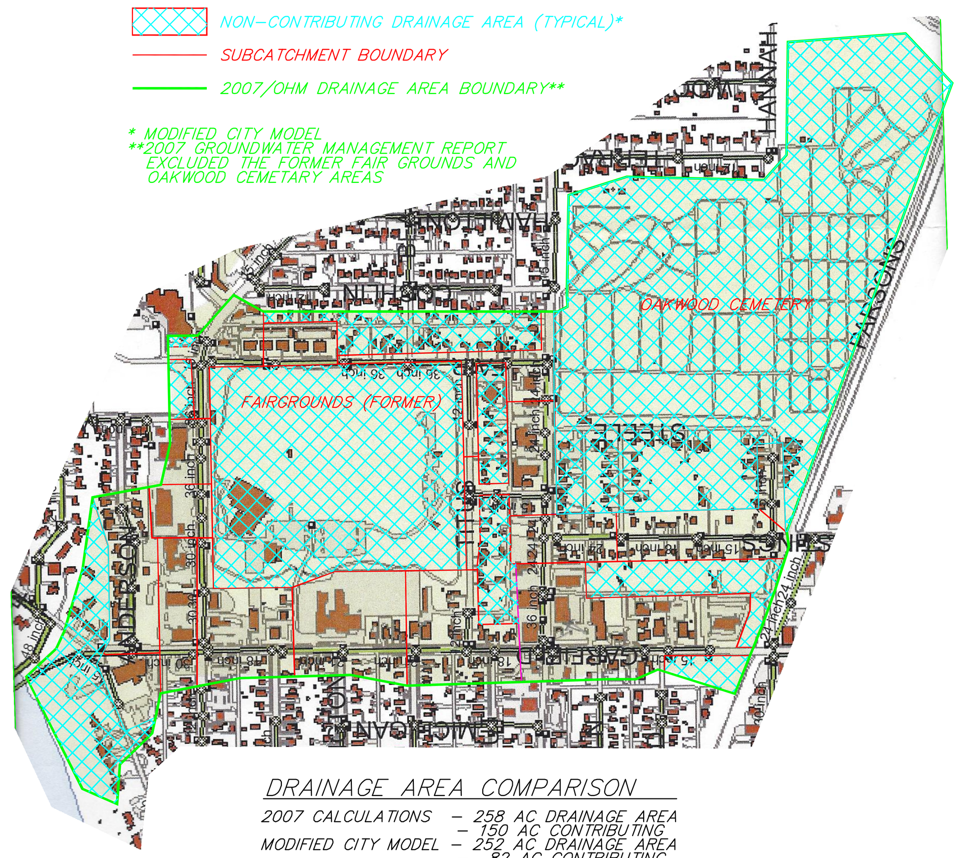
Prince-Lund Engineering, PLLC
P.O. Box 2361, Traverse City, Michigan 49685
(888) 418-2895
www.prince-lund.com

DRAWN BY: MAL
SCALE: AS NOTED
DATE: 03/23/17
PROJECT ID: 1614-OHM
DRAWING: Hydrology and Hydraulics Hanna Ave Drainage Area
SHEET No: 2 of 2

LEGEND

NON-CONTRIBUTING DRAINAGE AREA (TYPICAL)*
SUBCATCHMENT BOUNDARY
2007/OHM DRAINAGE AREA BOUNDARY**

* MODIFIED CITY MODEL
** 2007 GROUNDWATER MANAGEMENT REPORT EXCLUDED THE FORMER FAIR GROUNDS AND OAKWOOD CEMETARY AREAS



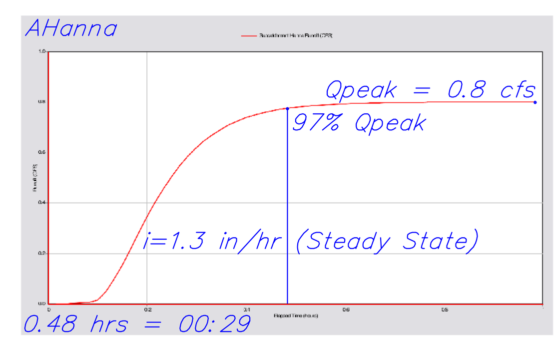
DRAINAGE AREA COMPARISON

2007 CALCULATIONS – 258 AC DRAINAGE AREA – 150 AC CONTRIBUTING
MODIFIED CITY MODEL – 252 AC DRAINAGE AREA – 82 AC CONTRIBUTING

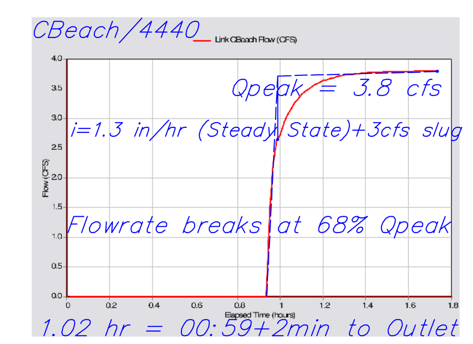
BRYANT PARK STATISTICS–2007 STORMWATER MANAGEMENT REPORT

PAVEMENT	2,725,060 SF	41.75%	CN=98	IMPERVIOUS
RESIDENTIAL	981,529 SF	15.04%	CN=75	IMPERVIOUS
FORESTED	2,821,089 SF	43.21%	CN=55	PERVIOUS
TOTAL	6,527,678 SF [1]	100%	CNave=76.0	
SIDEWALK	156,323 SF	4.22% [2]	<=100% TO PERVIOUS [3]	
STRUCTURE	825,207 SF	22.26%	<=85% TO PERVIOUS [3]	
STREET	2,725,060 SF	73.52%		
TOTAL	3,706,590 SF	100%		

[1] MULTIPLY 2007 AREAS BY 0.5480 TO OBTAIN MODIFIED CITY MODEL AREA
[2] ASSUMED % IMPERVIOUS WITH NO DEPRESSION STORAGE; ROUNDED TO 4.2%
[3] ASSUMED% ROUTED ACROSS PERVIOUS AREA: (156+(0.85*825))/3706 ~ 23%



OVERLAND FLOW

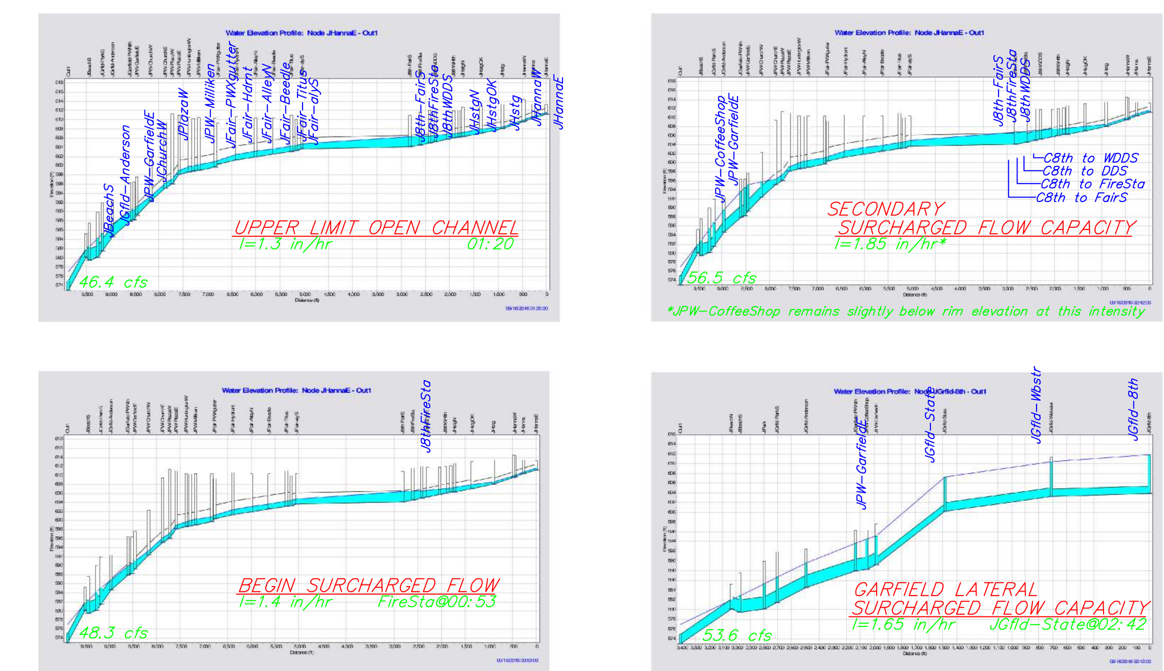


PIPE FLOW

2–YEAR INTENSITY 0.86 IN/HR
5–YEAR INTENSITY 1.07 IN/HR
10–YEAR INTENSITY 1.27 IN/HR

TIME OF CONCENTRATION

Tc=90 MIN OVERLAND/PIPE FLOW



NOTE: THE ABOVE ANALYSES REFLECT A CONSTANT RAINFALL INTENSITY WITH THE BEGINNING OF OCCURRENCES AT NOTED TIMES

STORM DRAIN PERFORMANCE

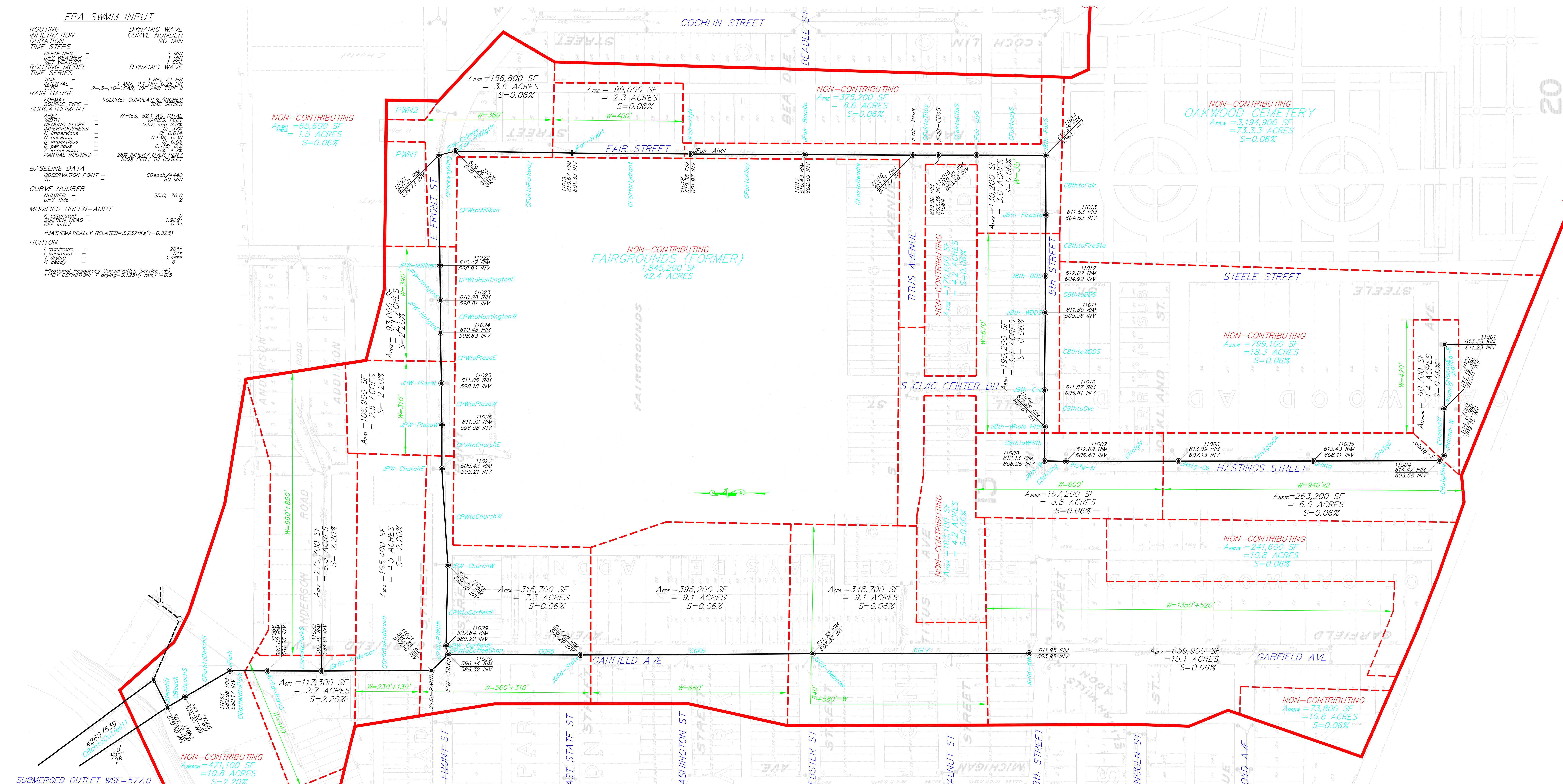
BRYANT PARK NET RUNOFF

EPA SWMM INPUT

ROUTING	DYNAMIC WAVE
INFILTRATION	CURVE NUMBER
DURATION	90 MIN
TIME STEPS	
REPORTING –	1 MIN
DRY WEATHER –	1 MIN
WET WEATHER –	1 SEC
ROUTING MODEL	DYNAMIC WAVE
TIME SERIES	
TIME –	3 HR; 24 HR
INTERVAL –	1 MIN; 0.1 HR; 0.25 HR
TYPE –	2–,5–,10–YEAR; IDF AND TYPE II
RAIN GAUGE	
FORMAT –	VOLUME; CUMULATIVE/INCHES
SOURCE TYPE –	TIME SERIES
SUBCATCHMENT	
AREA –	VARIES, 82.1 AC TOTAL
WIDTH –	VARIES, FEET
GROUND SLOPE –	0.6% and 2.2%
IMPERVIOUSNESS –	0; 57%
N impervious –	0; 0.014
N pervious –	0.138; 0.30
D impervious –	0; 0.05
D pervious –	0.115; 0.2
Z impervious –	0%; 4.2%
PARTIAL ROUTING –	26% IMPERV OVER PERV 100% PERV TO OUTLET
BASELINE DATA	
OBSERVATION POINT –	CBeach/4440
Tc –	90 MIN
CURVE NUMBER	
NUMBER –	55.0; 76.0
DRY TIME –	2
MODIFIED GREEN–AMPT	
K saturated –	5
SUCTION HEAD –	1.909*
DEF initial	0.34
HORTON	
I maximum –	20**
I minimum –	5**
T drying –	1.4***
K decay –	6

*MATHEMATICALLY RELATED=3.237*Ks^(–0.328)

**National Resources Conservation Service (±)
***BY DEFINITION; T drying=3.125*(I min)^–0.5



EX STORM DRAIN AND SUBCATCHMENTS–BRYANT PARK

BRYANT PARK DRAINAGE AREA 1"=120'

BRYANT PARK DRAINAGE AREA HYDROLOGY AND HYDRAULICS

EX STORM DRAIN AND SUBCATCHMENT SCHEMATIC, TIME OF CONCENTRATION, DRAINAGE AREA COMPARISON
2007 DRAINAGE AREA STATISTICS, STORM DRAIN PERFORMANCE, AND EPA SWMM INPUT
TRAVERSE CITY, MICHIGAN

Prince-Lund Engineering, PLC
P.O. Box 1268, Traverse City, Michigan 49685
(888) 418-2695
www.build-on-prince.com

REVISIONS | DESCRIPTION | DATE | BY

DRAWN BY: MAL
SCALE: AS NOTED
DATE: 03/23/17
PROJECT ID: 1614-OHM
DRAWING: Hydrology and Hydraulics Bryant Park Drainage Area
SHEET No: 1 of 2

Bryant Park 2-Year Return Interval

[illegible]

Water Surface Elev: 577.0		
Total Area:	10997300	252.46
Cont'b Area:	3577100	82.12
Non Cont'b:	7420200	170.34
2007 Cont'b Area:		149.55

Prop Area Totals: 34.28 12.35 35.49 — Tc 90 min

21.1	18.7	18.4	11.5	16.5	14.8	40.5	35.34	6.6	30.6	30.58	49.90	51.2	52.49	53.92	53.92
36.5	34.0	33.5	21.0	30.1	27.0 (27)				30.6	30.58	57.06	55.0	98.43	166.23	106.53 (19)

Total Subcatchment Peak Runoff: 78.74 66.44 130.56 225.09 151.01

2-Year Infiltration/Rainfall/Runoff Data							SCS Method: Surface Runoff (SRO), Calculated* (15), Ia Constant		SCS Method: Unit SRO (q_u), Tabular, Table 7.2	Tabular, Table 7-3**	MDEQ: Unit Peak Hydrograph, Calculated (17)
Description	2007	Rossmiller	24-hr Rainfall								
Soil type:	B	A					0.05	0.2			
			2 yr	P_2 =	2.09 in		0.732	0.460	0.474 in	0.39 cfs/(in-ac)	--
Curve No.	76.0 (5)	72.5 (5)	5 yr	P_5 =	2.7 in		1.132	0.817	0.83 in	0.39 cfs/(in-ac)	0.31 cfs/(in-ac)
Storage	3.16 in	3.79 in	10 yr	P_{10} =	3.21 in		--	--	1.168 in	0.39 cfs/(in-ac)	--
*Per 2007 CN				(16)	Ia =		0.158 in	0.633 in			

** 2007 average slopes: pipe 0.47%; watershed 0.30% (0.30% appears in error)
Table 7-3 value for 0.30% slope: 0.35 cfs/(in-ac)

5-Year Infiltration/Rainfall/Runoff Data							SCS Method: Surface Runoff (SRO), Calculated* (15), Ia Constant		SCS Method: Unit SRO (q_u), Tabular, Table 7.2	Tabular, Table 7-3**	MDEQ: Unit Peak Hydrograph, Calculated (17)
Description	2007	Rossmiller	24-hr Rainfall								
Soil type:	B	A					0.05	0.2			
			2 yr	P_2 =	2.09 in		--	--	0.474 in	0.39 cfs/(in-ac)	--
Curve No.	76.0 (5)	72.5 (5)	5 yr	P_5 =	2.7 in		1.132	0.817	0.83 in	0.39 cfs/(in-ac)	0.31 cfs/(in-ac)
Storage	3.16 in	3.79 in	10 yr	P_{10} =	3.21 in		--	--	1.168 in	0.39 cfs/(in-ac)	--
*Per 2007 CN				(16)	Ia =		0.158 in	0.633 in			

** 2007 average slopes: pipe 0.47%; watershed 0.30% (0.30% appears in error)
Table 7-3 value for 0.30% slope: 0.35 cfs/(in-ac)

Bryant Park 5-Year Return Interval

[illegible]

Variable Input Parameters Provided By OHM

Subcatchment Outlet Junction Reference	Converted EPA SWMM: Area (acres)	"Width" (feet)	Surface Slope (%)	% Impervious	Routing to:	5-Year Subcatchment Peak Runoff (cfs)	Final OHM XP-SWMM: "Width" (feet)	Surface Slope (%)	% Impervious	Routing to:	5-Year Subcatchment Peak Runoff (cfs) City Model
STM-011006 JHaig-Ok	95.73	2471.4	3.7	0	Outlet	89.00	2471.4	0.3	0	Outlet	62.283
	19.55	2471	3.7	100	Outlet		2471	0.3	100	Outlet	62.50
	6.52	2471	3.7	100	Outlet		2471	0.3	100	0% Imp	
STM-011016 JFair-Titus	30.32	1193.5	3.7	0	Outlet	26.02	1193.5	1.4	0	Outlet	19.599
	5.69	1193.5	3.7	100	Outlet		1193.5	1.4	100	Outlet	19.72
	1.90	1193.5	3.7	100	Outlet		1193.5	1.4	100	0% Imp	
STM-011021 JPW-College	17.63	1100	4.8	0	Outlet	57.67	1100	1.0	0	Outlet	42.513
	12.71	1100	4.8	100	Outlet		1100	1.0	100	Outlet	42.81
	4.24	1100	4.8	100	Outlet		1100	1.0	100	0% Imp	
STM-011030 JPW-Garfield	26.50	735	5.1	0	Outlet	103.53	735	1.0	0	Outlet	64.826
	24.00	735	5.1	100	Outlet		735	1.0	100	Outlet	65.22
	8.00	735	5.1	100	Outlet		735	1.0	100	0% Imp	

Area Adjustments
2007/OHM to Modified City

City Model Area Adjustment: 7.44 / 121.80 = 0.0610

Areas (ac)		OHM	Revised
STM-011006 JHaig-Ok	-1	95.73	5.84
	-2	19.55	1.19
	-3	6.52	0.40
		121.80 ac	7.44 ac

Width: 1606

City Model Area Adjustment: 5.87 / 34.58 = 0.1698

Areas (ac)		OHM	Revised
STM-011021 JPW-College	-1	17.63	2.99
	-2	12.71	2.16
	-3	4.24	0.72
		34.58 ac	5.87 ac

Width: 388

City Model Area Adjustment: 11.19 / 37.91 = 0.2953

Areas (ac)		OHM	Revised
STM-011016 JFair-Titus	-1	30.32	8.95
	-2	5.69	1.68
	-3	1.90	0.56
		37.91 ac	11.19 ac

Width: 782

City Model Area Adjustment: 57.62 / 58.50 = 0.9849

Areas (ac)		OHM	Revised
STM-011030 JPW-Garfield	-1	26.50	26.10
	-2	24.00	23.64
	-3	8.00	7.88
		58.50 ac	57.62 ac

Width: 1141

Area Totals

2007/OHM	252.8 ac
Mod City	82.1 ac
Ave Slope	0.0063*

*Average slope is the weighted average of the area specific averages listed in the table below.

(1) Average ground slope (0.3%; 2007) is based on distance from underwater outlet to far corner of cemetary (6644') however the resultant drop from the cemetary lands at 603, something corresponding to Anderson Road; distance should should be between the far corner of the cemetary and the beach side of Peninsula Dr (5980'); change in elevation is approximately 23' (623-600), resulting in an average slope of 0.0038 [0.39 cfs/(in-ac)]; that said, average slope should be lower due to the based on weighted distance, since sharp drops occur in the relatively short distance from the south to the north sides of Grandview Parkway; use: (623-620)/5060=0.00059 or 0.06% [0.22 cfs/(in-ac)]to the Parkway, then (620-600)/920=0.0217 or 2.2% [1.46 cfs/(in-ac)] to the lake shore
(2) GIS maps were provided (prior to City storm drain maps), scaled, and new boundaries established with the assistance of Google Earth; larger area omitted than 2007 but results of the analyses are approximately proportional based on area; areas noted in red represent those which, based on soils information, will not contribute flows to the storm drain system due to extremely high conductivities
(3) "Width" calculated or estimated based on EPA Storm Water Management Model (SWMM) Reference Manual Volume 1, Chapter 3
(4) Portions of the subarea, in acres; classified impervious, residential, and forested per the 2007 Stormwater Management Report
(5) Average curve number per 2007 model | curve number based on impervious area per Rossmiller CN equation using TYPE A soil constant of 39; Note: using Type B constant is 61, resulting CN is 82 slightly higher than 2007 CN; See (17) for S
(6) Once the drainage areas and storm drain piping were finalized, a simulation was run with only the upper subcatchment (Hanna) discharging to the storm drain plus an input of 3 cfs (near pipe capacity) at the upstream (JHannaE) node, providing a "slug" of water traveling along the pipe in order to determine the pipe travel time of 61 minutes at the outlet (68% Qpeak; steep curve at inflection 59 minutes, probably conservative, plus two minutes past measuring point to end of pipe) . | Overland travel time was defined at 97% Qpeak at steady state intensity equal to 1.3 in/hr (upper limit of open channel flow in the storm drain) which resulted in a 29 minute estimate; Tc estimate equals the total (61+29) or 90 minutes. Overland was entered into the spreadsheet and pipe velocity adjusted until total Tc equaled 90 minutes, thereby providing a check to see if resulting pipe flow velocities are realistic.
(7) Peak Flow Rate(cfs) = Unit SRO (qu) <see (17) below> mult by SRO < (P-Ia)^2 / (P-Ia+S) in inches> mult by Area in square miles See (15) below for S and Ia Note: USDA T55 Appendix f has refined qu= based on Tc (not used)
(8) Chosen return period and corresponding average intensity for a duration equal to the Tc calculated in (6); average intensity is calculated using equation (Boucher, Costa County, CA, 2010) fit to NOAA DDF curves developed for rainfall data at Cherry Capital Airport (see IDF equations tab)
(9) The SCS/MDEQ methods typically underestimate peak runoff rates for total surface runoff (SRO) less than 1/2 in
(10) Rational method C constant calculated using Rossmiller's equation which is dependent on several variables such as curve number (2007 Study,Type B soil), return interval, average land surface slope, rainfall intensity, and percent impervious
(11) Rational method C constant calculated using Rossmiller's equation which is dependent on several variables such as curve number (Rossmiller Type A soil), return interval, average land surface slope, rainfall intensity, and percent impervious
(12) Both C coefficients were calculated Rossmiller's equation to convert from CN, however the 2007 is based on a Type B soil while the other is based on a Type A soil per NRCS Web Soil Survey, maps and descriptions
(13) These replicate the 2007 Stormwater Management Report calculations using the tabular SCS curve method using areas and land uses assumed/measured therein; see MDEQ Soil Erosion and Sedimentation Control Training Manual, Chpt 7
(14) It is worth noting how close rational method numbers and SCS/MDEQ numbers are close to one another; although both are based on the same return period, one is entirely derived from projected local/historical intensities of the calculated rainfall duration (Tc), while the other is based on a peak runoff relationships derived from a 24-hour duration rainfall based on certain statistical correlations
(15) Total SRO in inches; based on 24-hour rainfall, curve number, and initial abstraction; TR-55 runoff equation, Appendix F; see Chapter 7 "Computing Flood Discharges for Small Ungauged Watersheds", Mich DNR, June 2010 for following equ: SRO= ((P-Ia)^2)/(S+P-Ia) where: S=storage in inches=((1000/CN)-10); CN=curve number; P= 24-hr rainfall in inches for a given return period; Ia=initial abstraction=(constant)*S; constant=0.2 normally, but 0.05 is proposed in certain instances {Table 7-2 equivalent; MDEQ Soil Erosion and Sedimentation Control Training Manual, Chapter 7}
(16) Per definition, however for tabular calcs do not account for this, only the equation approach and numbers are very sensative to changes; 0.05 has been proposed to replace the current 0.2 constant; see (7) and SCS Curve No. Method tab
(17) MDEQ Stormwater Management Guidebook, Chapter 7, Unit Hydrograph Peak, Equation 21: qu (unit surface runoff)= 270.9*((Tc)^-0.81) in cfs/(sq mi-in) {Table 7-3 equivalent; MDEQ Soil Erosion and Sedimentation Control Training Manual, Chapter 7} mult by area in square miles where=> S= (1000/CN) - 10 Note: USDA T55 Appendix f has refined qu= based on Tc (not used)
(18) An initial estimate of peak flow modeling the entire drainage area as one, using a "width" of 8,000 ft and a calculated average surface slope of 0.0038 [See (1) above]
(19) Model run with all existing pipes oversized to 60 inches so no losses occur upstream; the purpose is to determine a maximum resultant or total peak flow rate without any system losses occurring; runoff quantities are identical for both existing piping and oversized piping simulations; constant 50 cfs discharge from adjacent storm drain system assumed entering easterly parallel outfall
(20) Modified City Model simulations incorporating 16 subcatchments discharging to 16 inputs on the storm drain system; rainfall intensity for columns [F] through [J] correspond to the time of concentration and return interval as described in (6) and (8), respectively. Column [K] reflects the Modified City Model performance with a 24-hour, Type II rainfall distribution imposed on the system.
(21) This simulation reflects the OHM model configuration as described in (22) with additional changes to slopes, routing, etc. which reflect those developed for theModified City Model; a 24-hr Type II rainfall distribution with 0.1 hr time-step increments (P2=2.09; P5=2.70 in) was also incorporated based on the 2007 calculations
(22) This simulation reflects the OHM model configuration as described in (23) except areas of subcatchments proportioned mostly downward to reflect subcatchment area discharging to OHM model junctions based on the Modified City Model configuration (82.1 acres); No other changes were made to the OHM model for this simulation
(23) This simulation reflects the OHM model configuration with inputs (slopes, routing, etc.) reflecting those developed for the OHM model including the 15-min increment, 24-hr Type II rainfall distribution (OHM P2=2.27; P5=2.76 in); maximum runoff equals that generated OHM's EPA SWMM (as converted from XP-SWMM and provided to the City for review) for all subcatchments; the OHM model has 4 input points along storm drain, each having 3 subcatchments connected
(24) This is the final configuration of the OHM model provided for analysis. It is the same as described in (23), but revised to reflect the final values for perviousness and slope as well as inter-routing of subcatchments at certain nodes.
(25) Peak subcatchment surface runoff; indentical in most cases as generated in converted OHM EPA SWMM output as provided; runoff in (parenthesis) represents off-peak subcatchment runoff flow used to illustrate water balance at or near peak pipe flow.
(26) Simulation oscilates,creating nearly equal flows from both up and downstream pipes causing up and downstream flows to converge and "flood" at junction; negative flow is water filling the upstream reaches while downstream is flowing full.
(27) Peak flows proportioned upward based soley on the ratio (252/82) of 2007/OHM drainage areas to those identified for the Modified City Model; resulting flows are order-of-magnitude and about 25 percent higher than those generated in the 2007 Stormwater Management Report.
(28) The varying flow rates appear to be a time-delayed response in depth as peak flows enter the pipe at different junctions with higher flows occuring immediately downstream with flows further downstream remaining lower proportionally to distance from upstream inputs as well as their variation with respect to time (increasing at the referenced point in time).
(29) The 2-year distribution indicates a peak flow in CPWto CoffeeShop of 38.14 cfs while the incoming flows are 11.49 cfs in the Parkway, 18.72 cfs in Garfield, and 5.18 cfs from the Garfield 4 subcatchment for a total of 35.39 cfs which is less than that occurring at 12:02; apparent discontinuity.
(30) SWMM infiltration methodology does not support curve numbers weighted with impervious areas as these results illustrate; instead, use the percent impervious and appropriate routing in conjunction with a representative pervious CN (55)
(31) Results of using weighted curve number [76.0] with SWMM infiltration; results are much lower than other approaches

Weighted Averages
% Impervious/%Routed/Slope

STM-011006 JHaig-Ok A-Reference	Area	Impervious	%*Area	Routed to Pervious	%*Area	Slope	S*Area
Hanna	1.39 ac	57.0 %	79.43	23.0 %	32.05	0.0006	0.001
HSTG	6.04	57.0	344.41	23.0	139.97	0.0006	0.004
Total	7.44 ac		423.84		171.02		0.004
Average		57.0 %		23.0 %		0.0006	

STM-011016 JFair-Titus A-Reference	Area	Impervious	%*Area	Routed to Pervious	%*Area	Slope	S*Area
Bth2	3.84 ac	57.0 %	218.79	23.0 %	88.28	0.0006	0.002
Bth1	4.37	57.0	248.88	23.0	100.43	0.0006	0.003
FR2	2.99	57.0	170.37	23.0	68.75	0.0006	0.002
Total	11.19 ac		638.04		257.46		0.007
Average		57.0 %		23.0 %		0.0006	

STM-011021 JPW-College A-Reference	Area	Impervious	%*Area	Routed to Pervious	%*Area	Slope	S*Area
FR1	2.27 ac	57.0 %	129.55	23.0 %	52.27	0.0006	0.001
PW3	3.60	57.0	205.18	23.0	82.79	0.0220	0.079
Total	5.87 ac		334.72		135.06		0.081
Average		57.0 %		23.0 %		0.0137	

STM-011030 JPW-Garfield A-Reference	Area	Impervious	%*Area	Routed to Pervious	%*Area	Slope	S*Area
PW2	2.13 ac	57.0 %	121.69	23.0 %	49.10	0.0220	0.047
PW1	2.45	57.0	139.88	23.0	56.44	0.0220	0.054
GF7	15.15	57.0	863.51	23.0	348.43	0.0006	0.009
GF6	8.01	57.0	456.29	23.0	184.12	0.0006	0.005
GF5	9.10	57.0	518.44	23.0	209.20	0.0006	0.005
GF4	7.27	57.0	414.41	23.0	167.22	0.0006	0.004
GF3	4.49	57.0	255.69	23.0	103.17	0.0220	0.099
GF2	6.33	57.0	360.76	23.0	145.57	0.0220	0.139
GF1	2.69	57.0	153.49	41.0	110.41	0.0220	0.059
Total	57.62 ac		3284.17		1373.66		0.42
Average		57.0 %		23.8 %		0.0073	

10-Year Infiltration/Rainfall/Runoff Data							SCS Method: Surface Runoff (SRO), Calculated* (15), Ia Constant		SCS Method: Unit SRO (q_u), Tabular, Table 7.2	Tabular, Table 7-3**	MDEQ: Unit Peak Hydrograph, Calculated (17)
Description	2007	Rossmiller	24-hr Rainfall								
Soil type:	B	A					0.05	0.2			
			2 yr	P_2 =	2.09 in		--	--	0.474 in	0.39 cfs/(in-ac)	--
Curve No.	76.0 (5)	72.5 (5)	5 yr	P_5 =	2.7 in		1.132	0.817	0.83 in	0.39 cfs/(in-ac)	0.31 cfs/(in-ac)
Storage	3.16 in	3.79 in	10 yr	P_{10} =	3.21 in		1.498	1.157	1.168 in	0.39 cfs/(in-ac)	--
*Per 2007 CN				(16)	Ia =		0.158 in	0.633 in			

** 2007 average slopes: pipe 0.47%; watershed 0.30% (0.30% appears in error)
Table 7-3 value for 0.30% slope: 0.35 cfs/(in-ac)

Bryant Park 10-Year Return Interval

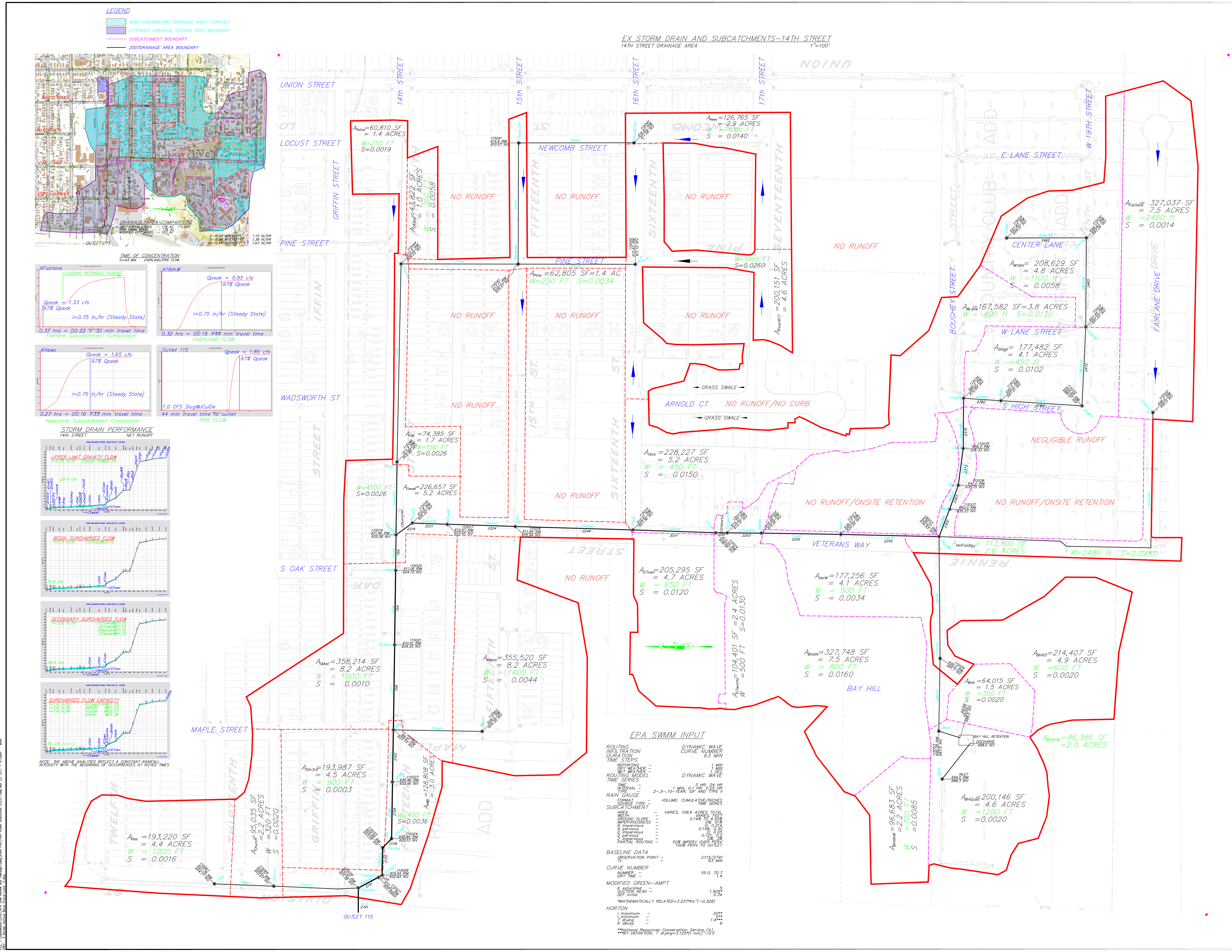
[illegible]

REVISIONS — DATE — BY — DESCRIPTION

BRYANT PARK DRAINAGE AREA HYDROLOGY AND HYDRAULICS
2-YEAR, 5-YEAR, AND 10-YEAR ANALYSES, NOTES, AND GENERAL INFORMATION
TRAVERSE CITY, MICHIGAN

Prince-Lund Engineering, PLC
P.O. Box 1035, Traverse City, Michigan 49685
(888) 418-2695

DRAWN BY:	MAL
SCALE:	AS NOTED
DATE:	03/23/17
PROJECT ID:	1614-OHM
DRAWING:	Hydrology and Hydraulics Bryant Park Drainage Area
SHEET No:	2 of 2



14TH STREET DRAINAGE AREA HYDROLOGY AND HYDRAULICS

EX STORM DRAIN AND SUBCATCHMENT SCHEMATIC, TIME OF CONCENTRATION,
DRAINAGE AREA COMPARISON, STORM DRAIN PERFORMANCE, AND EPA SWMM INPUT
TRAVERSE CITY, MICHIGAN

Prince-Lund Engineering, PLC

DRAWN BY: MAL
SCALE: AS NOTED
DATE: 03/23/17
PROJECT ID: 1614-CHM
DRAWING: Hydrology and Hydraulics 14th St Drainage Area

14th Street 2-Year Return Interval

[illegible]

2-Year Infiltration/Rainfall/Runoff Data

[illegible]

5-Year Infiltration/Rainfall/Runoff Data

[illegible]

10-Year Infiltration/Rainfall/Runoff Data

[illegible]

14th Street 5-Year Return Interval

[illegible]

(1) The drainage area varies significantly in elevation, with notable drops from south to north and from either side of Veterans Drive to its right-of-way. The 2007 average slope of 0.0148 (L=4110 ft/dE=61 ft) was not representatitve of most subcatchments within the model so surface slope was estimated for each subcatchment by identifying a high point and a low point and dividing their difference by their separation as noted on the drawing.
(2) City storm drain maps were reviewed and the overall drainage boundary estimated based on inlet locations. Although the Modified City model area was extended to include the State Police Post on Pine Street, the overall 2007 drainage area was reduced significantly within its boundary by excluding wooded areas (including slopes), neighborhoods without curb and gutter, and other developed tracts where runoff contribution potential appeared negligible. The revised area totals 109 acres as compared to the 2007 178-acre drainage area used in both City calculations and the OHM model. For purposes of this exercise, hand calculations provided herein are proportional to those developed in 2007 and included below each (Columns [A] through [E2]).
(3) "Width" calculated or estimated based on EPA Storm Water Management Model (SWMM) Reference Manual Volume 1, Chapter 3; this number is noted in documentation as a calibration value.
(4) Portions of the subarea, in acres; classified pavement, residential, and forested per the 2007 Stormwater Management Report; *adjusted per site conditions where warranted.*
(5) Average curve number of 70.7 per 2007 model | The 70.1 curve number is based on impervious area per Rossmiller CN equation using TYPE A soil constant (39).
(6) Once the drainage areas and storm drain piping were finalized, a simulation was run with only the upper subcatchment (A_{19thW}) discharging to the storm drain plus an input of 1 cfs (near pipe capacity) at the upstream (J_{CulDe}) node, providing a "slug" of water traveling along the pipe in order to determine the pipe travel time of 44 minutes (97% Qpeak; steep curve, no inflection) at the outlet. | Overland travel time was defined at 97% Qpeak at steady state intensity equal to 0.75 in/hr (upper limit of open channel flow in the storm drain) which resulted in a 19 minute estimate; Tc estimate equals the total (19+44) or 63 minutes. Overland was entered into the spreadsheet and pipe velocity adjusted until total Tc equaled 63 minutes, thereby providing a check to see if resulting pipe flow velocities are realistic.
(7) Chosen return period and corresponding average intensity for a duration equal to the Tc calculated in (6); average intensity is calculated using equation (Boucher, Costa County, CA, 2010) fit to NOAA DDF curves developed for rainfall data at Cherry Capital Airport (see IDF equations tab)
(8) Peak Flow Rate(cfs) = Unit SRO (qu) <see (17) below> mult by SRO < (P-Ia)^2 / (P-Ia+S) in inches> mult by Area in square miles See (16) below for S and Ia Note: USDA T55 Appendix f has refined qu= based on Tc (not used)
(9) The SCS/MDEQ methods typically underestimate peak runoff rates for total surface runoff (SRO) in the neighborhood of 1/2-inch or less
(10) Rational method C constant calculated using Rossmiller's equation which is dependent on several variables such as curve number (2007 Study,Type B soil), return interval, average land surface slope, rainfall intensity, and percent impervious
(11) Rational method C constant calculated using Rossmiller's equation which is dependent on several variables such as curve number (Rossmiller Type A soil), return interval, average land surface slope, rainfall intensity, and percent impervious
(12) Both C coefficients were calculated from Rossmiller's equation to convert from CN, however the 2007 is based on a Type B soil while the other is based on a Type A soil per NRCS Web Soil Survey, maps and descriptions
(13) These replicate the 2007 Stormwater Management Report calculations using the tabular SCS curve method based on and land uses assumed/measured therein; the 5-year return interval (only) includes the land slope Qpeak for comparson purposes; see MDEQ Soil Erosion and Sedimentation Control Training Manual, Chpt 7;actual peak flow is proportionally larger based on drainage area per Area Conversion, bottom row
(14) It is worth noting how rational method numbers and SCS/MDEQ numbers are somewhat close to one another; although both are based on the same return period, one is entirely derived from projected local/historical intensities of the calculated rainfall duration (Tc), while the other is based on a peak runoff relationships derived from a 24-hour duration rainfall based on certain statistical correlations
(15) Total SRO in inches; based on 24-hour rainfall, curve number, and initial abstraction; TR-55 runoff equation, Appendix F; see Chapter 7 "Computing Flood Discharges for Small Ungauged Watersheds", Mich DNR, June 2010 for following equ: SRO= ((P-Ia)^2)/(S+P-Ia) where: S=storage in inches=((1000/CN)-10); CN=curve number; P= 24-hr rainfall in inches for a given return period; Ia=initial abstraction=(constant)*S; constant=0.2 normally, but 0.05 is proposed in certain instances {Table 7-2 equivalent; MDEQ Soil Erosion and Sedimentation Control Training Manual, Chapter 7; see SCS Curve Method tab}
(16) Per definition, tabular calcs reflect the 0.2 "constant", which was actually developed from a relatively diverse data set gathered througout the country; the equation approach allows varying this "constant" which is very sensative to changes; 0.05 has been proposed to replace the current 0.2 constant; see (6) and SCS Curve No. Method tab
(17) MDEQ Stormwater Management Guidebook, Chapter 7, Unit Hydrograph Peak, Equation 21: qu (unit surface runoff)= 270.9*((Tc)^-0.81) in cfs/(sq mi-in) {Table 7-3 equivalent; MDEQ Soil Erosion and Sedimentation Control Training Manual, Chapter 7} mult by area in square miles and SRO as described in (15) to determine peak runoff flow rate.
(18) An initial estimate of peak flow modeling the entire drainage area as one, using a "width" of 9,570 ft and a calculated average surface slope of 0.0185.
(19) Model run with all existing pipes oversized to 72 inches so no losses occur upstream; the purpose is to determine a maximum resultant or total peak flow rate without any system losses occurring; runoff quantities are identical for both existing piping and oversized piping simulations
(20) City Model simulations incorporating 27 subcatchments discharging to 22 inputs on the storm drain system; rainfall intensity for columns [G] through [J] correspond to the time of concentration and return interval as described in (6) and (7), respectively. Column [K] reflects the City Model performance with a 24-hour, Type II rainfall distribution imposed on the system.
(21) This simulation reflects the OHM model configuration as described in (22) with additional changes to slopes, routing, etc. which reflect those developed for the City model; a standard Type II rainfall distribution with 0.1 hr time-step increments (P_2=2.09; P_5=2.70 in) was also incorporated based on the 2007 calculations
(22) This simulation reflects the OHM model configuration as described in (23) except areas of subcatchments proportioned mostly downward to reflect subcatchment area discharging to OHM model junctions based on the Modified City Model configuration (108.6 acres).
(23) This simulation reflects the OHM model configuration with inputs (slopes, routing, etc.) reflecting those developed for the OHM model including the 15-minute, Type II rainfall distribution (OHM P_2=2.27; P_5=2.76 in); maximum runoff equals that generated OHM's EPA SWMM (as converted from XP-SWMM and provided to the City for review) for all subcatchments; the OHM model has 5 input points along storm drain, each having 3 subcatchments connected
(24) This is the final configuration of the OHM model provided for analysis. It is the same as described in (23), but revised to reflect the final values for perviousness and slope as well as inter-routing of subcatchments at certain nodes.
(25) Peak subcatchment surface runoff; indentical in most cases as generated in converted OHM EPA SWMM output as provided
(26) Unidentifiable discontinuity in the SWMM output; negative flow is water filling the upstream reaches while downstream is flowing full.
(27) Negative flow is water filling the upstream reaches while downstream is flowing full.
(28) Routes through ABHillNW
(29) These peak flows appear discontiuous until the timing of peak offset is incorporated; flows are as follows at J16th: @00:13 CGTown15.39 +A16thW1.93+CGTown1.86 = CVetRes19.17 cfs(peak); @01:04 CGTown 10.36+A16thW4.24(peak)+ CGTown4.19(peak) -J16th1.27(loss)= CVetRes17.54 cfs; @01:13 CGTown 15.48(peak)+A16thW1.46+CGTown1.24 = CVetRes18.18 cfs

Variable Input Parameters Provided By OHM

Subcatchment Outlet Junction Reference	Converted EPA SWMM: Area (acres)	"Width" (feet)	Surface Slope (%)	% Impervious	Routing to:	5-Year Subcatchment Peak Runoff (cfs)	Final OHM XP-SWMM: "Width" (feet)	Surface Slope (%)	% Impervious	Routing to:	5-Year Subcatchment Peak Runoff (cfs) City Model
STM-115044	33.68	2173.5	6.8	0	Outlet	66.62	2173.5	2.8	0	Outlet	52.355
	14.92	2173.5	6.8	100	Outlet		2173.5	2.8	100	Outlet	52.82
	4.31	2173.5	6.8	100	Outlet		2173.5	2.8	100	0% Imp	
STM-115014	54.08	2054.95	11.2	0	Outlet	104.1	2054.95	5.5	0	Outlet	79.18
	22.62	2054.95	11.2	100	Outlet		2054.95	5.5	100	Outlet	79.76
	7.54	2054.95	11.2	100	Outlet		2054.95	5.5	100	0% Imp	
STM-115016	6.06	1176.5	4.06	0	Outlet	24.62	1176.5	0.5	0	Outlet	19.154
	5.32	1176.5	4.06	100	Outlet		1176.5	0.5	100	Outlet	19.05
	1.77	1176.5	4.06	100	Outlet		1176.5	0.5	100	0% Imp	
STM-115062	6.06	1156.56	4.06	0	Outlet	24.61	1156.56	0.7	0	Outlet	19.429
	5.32	1156.56	4.06	100	Outlet		1156.56	0.7	100	Outlet	19.31
	1.77	1156.56	4.06	100	Outlet		1156.56	0.7	100	0% Imp	
STM-115028	6.84	474.07	3.33	0	Outlet	25.78	474.07	0.5	0	Outlet	18.019
	5.68	474.07	3.33	100	Outlet		474.07	0.5	100	Outlet	18.02
	1.90	474.07	3.33	100	Outlet		474.07	0.5	100	0% Imp	

14th STREET STATISTICS—2007 STORMWATER MANAGEMENT REPORT

PAVEMENT	1,830,265 SF	23.61%	CN=98	IMPERVIOUS
RESIDENTIAL	2,131,277 SF	27.50%	CN=75	IMPERVIOUS
FORESTED	3,787,571 SF	48.89%	CN=55	PERVIOUS
TOTAL	7,749,113 SF/177.9 AC	100%	CNave=70.1	
SIDEWALK	1,108,611 SF**	27.98%	<=100% TO PERVIOUS*	
STRUCTURE	1,022,666 SF	25.81%	<=85% TO PERVIOUS*	
STREET	1,830,265 SF	46.21%		
TOTAL	3,961,542 SF /90.4 AC	100%		

* ASSUMED% ROUTED ACROSS PERVIOUS AREA: (1109+(0.85*1023))/3962 ~ 50%
** ASSUMED % IMPERVIOUS WITH NO DEPRESSION STORAGE; ROUNDED TO 28%

Weighted Averages
% Impervious/%Routed/Slope

115044/JPine14th A-Reference	Area	Impervious	%*Area	Routed to Pervious	%*Area	Slope	S*Area
Police	1.40 ac	51.0 %	71.40	51.0 %	71.40	0.0019	0.00266
14thN	1.01	51.0	51.51	100.0	101.00	0.0058	0.00586
Pine	1.44	90.0	129.60	100.0	144.00	0.0034	0.00490
Newc	2.91	75.0	218.25	100.0	291.00	0.014	0.04074
Pine1617	4.59	51.0	234.09	100.0	459.00	0.026	0.11934
Total	11.35 ac		704.85		1066.40		0.17349
Average		62.1 %		94.0 %		0.0153	

115014/JGTown A-Reference	Area	Impervious	%*Area	Routed to Pervious	%*Area	Slope	S*Area
19thW	4.79 ac	42.2 %	202.14	44.3 %	212.20	0.0058	0.02778
WLane	3.85	51.0	196.35	50.0	192.50	0.0130	0.05005
SHigh	4.07	51.0	207.57	50.0	203.50	0.0102	0.04151
VetFairBgy	2.60	90.0	234.00	0.0	0.00	0.0450	0.11700
Fairlane	7.51	42.2	316.92	0.0	0.00	0.0014	0.01051
BHillS	4.92	51.0	250.92	50.0	246.00	0.0020	0.00984
BHill	1.50	51.0	76.50	50.0	75.00	0.0020	0.00300
Quad	4.60	51.0	234.60	50.0	230.00	0.0020	0.00920
VetW	4.07	51.0	207.57	50.0	203.50	0.0034	0.01384
BHillN	7.52	51.0	383.52	50.0	376.00	0.0160	0.12032
BHillNW	2.22	51.0	113.22	50.0	111.00	0.0085	0.01887
GTownHts	2.40	51.0	122.40	50.0	120.00	0.0130	0.03120
Total	50.05 ac		2545.71		1969.70		0.45313
Average		50.9 %		39.4 %		0.0091	

115016/J16th A-Reference	Area	Impervious	%*Area	Routed to Pervious	%*Area	Slope	S*Area
16th	5.24 ac	51.0 %	N/A	50.0 %	N/A	0.0130	N/A
GTown	4.71	51.0	N/A	50.0	N/A	0.0130	N/A
	9.95 ac	51.0 %		50.0 %		0.0130	

115062/JMenlo A-Reference	Area	Impervious	%*Area	Routed to Pervious	%*Area	Slope	S*Area
Menlo	8.16 ac	51.0 %	N/A	50.0 %	N/A	0.0044	N/A

115028/JDivision A-Reference	Area	Impervious	%*Area	Routed to Pervious	%*Area	Slope	S*Area
FOE	1.71 ac	51.0 %	87.21	50.0 %	85.50	0.0026	0.00445
Cwash	5.20	90.0	468.00	0.0	0.00	0.0026	0.01352
SMall	8.22	51.0	419.22	0.0	0.00	0.0010	0.00822
5th3rd	4.45	51.0	226.95	50.0	222.50	0.0003	0.00134
NWB	2.96	51.0	150.96	50.0	148.00	0.0036	0.01066
Church	2.18	51.0	111.18	50.0	109.00	0.0020	0.00436
Res	4.44	51.0	226.44	50.0	222.00	0.0160	0.07104
Total	29.16 ac		1689.96		787.00		0.11358
Average		58.0 %		27.0 %		0.0039	

Area Adjustments
2007/OHM to Modified City

City Model Area Adjustment: 11.35 / 52.91 = 0.2145

Areas (ac)	OHM	Revised
STM-115044 #1	33.68	7.22
#2	14.92	3.20
#3	4.31	0.92
	52.91 ac	11.35 ac

Width: 2850 ft

City Model Area Adjustment: 8.16 / 13.15 = 0.6205

Areas (ac)	OHM	Revised
STM-115062 #1	6.06	3.76
#2	5.32	3.30
#3	1.77	1.10
	13.15 ac	8.16 ac

Width: 1400 ft

City Model Area Adjustment: 50.05 / 84.24 = 0.5941

Areas (ac)	OHM	Revised
STM-115014 #1	54.08	32.13
#2	22.62	13.44
#3	7.54	4.48
	84.24 ac	50.05 ac

Width: 1600 ft

City Model Area Adjustment: 29.16 / 14.42 = 2.0222

Areas (ac)	OHM	Revised
STM-115028 #1	6.84	13.83
#2	5.68	11.49
#3	1.90	3.84
	14.42 ac	29.16 ac

Width: 7870 ft

City Model Area Adjustment: 9.95 / 13.15 = 0.7567

Areas (ac)	OHM	Revised
STM-115016 #1	6.06	4.59
#2	5.32	4.03
#3	1.77	1.34
	13.15 ac	9.95 ac

Width: 2055 ft

Area Totals

2007/OHM	**178 ac**
Mod City	**109 ac**

14th Street 10-Year Return Interval

[illegible]

REVISIONS | DATE | BY | DESCRIPTION

14TH STREET DRAINAGE AREA HYDROLOGY AND HYDRAULICS
2-YEAR, 5-YEAR, AND 10-YEAR ANALYSES, NOTES, AND GENERAL INFORMATION
TRAVERSE CITY, MICHIGAN

Prince-Lund Engineering, PLC
P.O. Box 1268, Traverse City, Michigan 49685
(888) 418-2695 www.build-on-prince.com

DRAWN BY: MAL
SCALE: AS NOTED
DATE: 03/23/17
PROJECT ID: 1614-OHM
DRAWING: Hydrology and Hydraulics 14th St Drainage Area
SHEET No: 2 of 2

APPENDIX J

TWC updates to GTBWPP specific to the City's SAW grant

TWC updates to GTBWPP specific to the City's SAW grant

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- Update as needed w/ SAW info... will do with entire WPP update

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- Update needed: This whole section will need to be updated eventually with the larger WPP update. Existing stormwater information for the City will be discussed here.

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- Need to break out priority and critical areas separately... will do with larger WPP update
- Specific areas and sites in TC? TC is already a critical area in the Boardman Prosperity Plan and will be in GTBWPP as well.

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- Break current three things in Chapter 5.5 out into separate sections:
  - Master Plan and Zoning to be its own chapter - Chapter 5.5
    - Include general info and format used in Boardman Prosperity Plan as it pertains to focus areas of GTBWPP
    - Add City of TC subsection
      - Include specific info from BPP on City of TC
      - SAW grant info and accomplishments related to utility, stormwater ordinance, geothermal polity
  - Stormwater and Lack of Buffer are together as subsections in next chapter - Chapter 5.6 Special Sources of Concern:
    - Special Sources of Concern: Stormwater
      - Subsection for City of TC: discuss issues and summarize SAW Grant work, summarize BMP efforts, street and catch basin cleaning efforts, critter problems causing high EColi
      - Subsection for other WS areas: discuss issues and BMP efforts to date
    - Special Sources of Concern: Lack of Buffer (already done)

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3.11 Existing Water Quality Information and Results for GTBWatershed

Add stormwater data - NOTE: Not sure of final format for the section, write up below for TC SAW Stormwater Plan. Same info in bullet points below. Excel tables are included here.

Storm Drain Monitoring Results:
It is important to note when looking at water quality results from stormdrains whether or not discharge or flow measurements were taken during sampling. Most stormwater samples are taken using the 'grab sample' method, which are only taken once during a rain event and represent a snapshot in time of the water quality at that particular storm drain. However, during rain events there are typically fluctuating volumes of water and concentrations of different types of pollutants coming out of a drain, which in turn will affect the pollutant load coming out of each drain (pollutant load calculated by multiplying volume by concentration). The higher the concentration of pollutant or the volume of water coming out of the drain, the higher the pollutant load.

Only thorough sampling during multiple rain events will lead to a clear picture of pollutant loadings to a watershed. Care should be taken not to make broad assumptions on stormwater quality in an urban area based solely on grab samples taken at a particular time during a rain event. In lieu of a potentially time consuming and expensive stormwater monitoring program, the use of models can be an effective way to approximate the amount of pollution to a watershed from stormdrains. Additionally, results from similar urban areas that have done stormwater monitoring can also be used to approximate pollutant loads.

A wide variety of water quality parameters have been tested in stormdrains throughout the City of Traverse City, with some testing dating back to 1980. However, a thorough stormwater analysis, including discharge and flow volumes, has not been conducted on a city-wide basis to date. Water quality results from a select number stormdrains in the City from 2009-2015 were averaged from 10 locations for Nitrate, Total Phosphorus (TP), and Total Suspended Solids (TSS). Results were as follows:

- Nitrate average - 0.47 mg/L
- TSS average = 96 mg/L
- TP average = 0.10 mg/l (100ug/L).

Data sources are from TWC-led studies including stormdrain testing program with City of Traverse City funds (2009), GLRI Project at Bryant Park (2011/2012), and BMP effectiveness testing at GLRI East Bay Park project (2013-2015).

Comparisons of stormwater results were also made on select storm drains with data from the 1990s to more recent results from 2009 and after - 8th Street, Bryant Park, East Bay Park (north and south drains), and Hannah Park. At these select sites Nitrates appear to have increased since the 1990s, TP has decreased, TSS was inconclusive (see Table below). Again, caution should be taken when comparing stormwater results where only grab samples were taken.

Location	timeframe	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)
8th Street	Historic	0.01	0.27	30
	Recent	0.56	0.1	49
Bryant Park	Historic	0.10	0.20	43
	Recent	0.66	0.08	68
East Bay Par (north)	Historic	0.29	0.56	76
	Recent	0.29	0.12	47
East Bay Park (south)	Historic	4.5	0.20	n/a
	Recent	n/a	0.09	145
Hannah Park	Historic	0.01	0.46	91
	Recent	0.42	0.095	59

**Historic - 1991, 1992, 2000*

**Recent - 2009-2015*

Bacteria levels of *E. coli* in stormdrains are high throughout the City of TC during rain events. Summarized results from 11 outfalls confirm this (8th Street, Bryant Park (2 locations), East Bay Park (2 locations), Hannah Park, Holiday Inn, Hope Street, Maple Street, Sunset Park, and West End Beach). The highest results were noted at 8th Street, Bryan Park, East Bay Park, Sunset Park. *E. coli* is discussed at length in the Grand Traverse Bay Watershed Protection Plan.

- General disclaimers:
  - Only summarizing Nitrate, TP, TSS, and EColi
  - Nothing has been calculated to show pollutant loads from the stormdrains - no discharge measurements were taken during sampling. When interpreting stormwater sampling results you need to be careful. Most samples are taken using the 'grab sample' method, which are only taken once during a rain event and represent a snapshot in time of the water quality at the storm drain. However, during rain events there are typically fluctuating volumes of water and concentrations of different types of pollutants coming out of a drain. Only thorough sampling during multiple rain events will lead to a clear picture of pollutant loadings to a watershed. This is why the use of models is a widely used practice among watershed managers, where acres of different types of land use are input and an estimate of different types of pollutant loads can be obtained (discussed later in pollutant load section, which is next).

- **City of TC**
  - **Current data from various sources**
    - Compiled from 10 locations
    - Range from 2009 - 2015
    - TSS average = 96 mg/L; TP average = 0.10 mg/l (100ug/L); Nitrate average - 0.47 mg/L; Ecoli average = 13,314 col/100mL
    - Data sources are from TWC led studies including stormdrain testing program with City of Traverse City funds (2009), GLRI Project at Bryant Park (2011/2012), and BMP effectiveness testing at GLRI East Bay Park project (2013-2015)
  - **Historical data comparison**
    - Compiled numerous stormwater results from a variety of historic reports and found 5 common sites that have both historic (1990s) and current (after 2000) data - 8th Street, Bryant Park, East Bay Park (north and south drains), and Hannah Park
    - Nitrates appear to have increased, TP has decreased, TSS was inconclusive
    - Data sources:
      - *Shuey, J.A., C.A. Harris, and G.M. DeGraeve. 1992. Final Report for the Grand Traverse Bay Watershed Initiative: Part II, Water Quality of the Bay and Tributaries. Great Lakes Environmental Center, Traverse City, MI. (Note: The Grand Traverse Bay Watershed Initiative is now known as The Watershed Center Grand Traverse Bay.)*
      - *City of Traverse City Waste Water Treatment Plant and Operations Management International. 1992. Stormwater Sewer Study*
      - *Great Lakes Environmental Center (GLEC). 2001. Stormwater Source Identification, Sampling, and Analysis at Select Storm Drains and Tributaries to Grand Traverse Bay (Lake Michigan). Prepared for The Watershed Center Grand Traverse Bay as part of an DEQ, Coastal Zone Management Study. (Principal Contact at GLEC: Dennis McCauley)*
      - *TWC - GLRI Project at Bryant Park (2011/2012)*
      - *TWC - BMP effectiveness testing at GLRI East Bay Park project (2013-2015)*
      - *TWC Project with City of Traverse City funds (2009)*
    - Much more data available on TWC's interactive Online Water Quality Database: http://www.gtbay.org/resources/water-quality-database/
  - **EColi**
    - Results for 11 stormwdrain outfalls: 8th Street, Bryant Park (2 locations), East Bay Park (2 locations), Hannah Park, Holiday Inn, Hope Street, Maple Street, Sunset Park, and West End Beach
    - Most drains tested high for Ecoli bacteria during rain events
    - Highest were: 8th Street, Bryan Park, East Bay Park, Sunset Park
    - State water quality standards indicate no body contact above 1,000 col/100mL
    - Data sources:
      - *TWC Stormwater Project with City of Traverse City funds (2009)*
      - *TWC Beach testing with City of Traverse City funds (2015)*

        - *TWC - GLRI Project at Bryant Park (2011/2012)*
        - *TWC - GLRI Project at East Bay Park (2011/2012)*
        - *USGS funded stormdrain study 2010-2012*
- **Boardman Lake Shoreline Survey**
    - Inspect 1-1.5 mile of shoreline along north half of Boardman Lake (within City Limits) for evidence of erosion, illicit discharges, unstable banks along the shoreline, and other physical characteristics that could impact water quality. Establish a shoreline rating system and assign rating through the studied reach.
    - TWC staff conducted the shoreline erosion survey in Summer 2015. The inventory consisted of a visual inspection of the shoreline by kayak with staff looking for signs of current or potential sources of water quality pollution. Locations of potential pollution sources or spots of concern were noted by GPS, pictures were taken, and notes were taken about the site. Results were summarized in an Excel spreadsheet and divided into four categories: Erosion Spots, Lack of Riparian Buffer, Stormwater Outfalls, and Boat Launch Runoff.
    - A map was produced showing noted locations where pictures and notes were taken.
    - No major sources of concern were found, however there are several areas of minor erosion along the lake, mostly from foot traffic to access the lake and from steep banks. These are localized areas and aren't contributing large amounts of sediment to the lake. Additionally, a few places were noted where there is no riparian buffer along the lake and grass extends all the way to the water's edge. This could lead to excess nutrients entering the water (as evidenced by the excessive plant/algae growth) and waterfowl congregating (see accompanying pictures).
    - Seven locations were noted where pipes (ranging from small plastic to larger concrete) outet to the water. These were noted on the map as well.

Stormwater Results for Total Suspended Solids, Total Phosphorus, Nitrate, and E.coli for Various Locations in the City of Traverse City

Location	date	TSS (mg/L)	TP (mg/L)	Nitrate (mg/L)	Ecoli (col/100mL)
8th Street - #1 u/s OG separator	July 2009	51	0.14	0.56	>2419
	August 2009	17	0.09	ND	>2419
	Sept 2013	8	0.06		2,950
	October 2013	120	0.11		72,700
Bryant Park (drain #1)	July 2009	37	0.08	0.54	>2419
	August 2009	3	0.03	1.82	1,203
	December 2011	92	0.08	0.36	>2419
	March 2012	186	0.03	0.22	4,654
Bryant Park (drain #2)	December 2011	20	0.18	0.35	>2419
East Bay Park - #1 u/s OG separator	July 2009	23	0.07	0.29	>2419
	August 2009	7	0.05	0.29	>2419
East Bay Park - Front St. Influent	Summer 2013 (av.)	36.2	0.17		
	Summer 2014 (av.)	115.2	0.09		15,329
	Summer 2015 (av.)	52.2	0.214		46,413
East Bay Park - Shawnee Influent	Summer 2013 (av.)	107.8	0.11		
	Summer 2014 (av.)	41.1	0.08		40,729
	Summer 2015 (av.)	286.6	0.09		2,072

East Bay Park - Iroquois Influent	Summer 2013 (av.)	243	0.14		
	Summer 2014 (av.)	91.4	0.21		6,551
	Summer 2015 (av.)	646.2	0.08		1,073
Holiday Inn - #1 u/s OG separator	August 2009	5	ND	0.24	5
Hannah Park - #1 u/s OG separator	July 2009	65	0.07	0.55	1,986
	August 2009	53	0.12	0.29	1,733
West End	July 2009	70	0.07	0.36	1,986
	August 2009	22	ND	0.3	326
	Average	**96**	**0.10**	**0.47**	**13,314**

Historical (1990s) vs. Current (after 2009) Stormwater Test Results for Various Locations in Traverse City

Location ID from Study

8th Street	**Report***	**Date**	**Nitrate (mg/L)**	**TP (mg/L)**	**TSS (mg/L)**	**Ecoli col/100mL**
Site #122	1	7/1/1991		0.596		
Site #122	1	7/22/1991		0.218		
Site #122	1	7/29/1991		0.0848		
Storm Sewer #9	2	4/16/1992	0.011	0.075	47	
Storm Sewer #9	2	6/5/1992	bdl	0.58	27	
Storm Sewer #9	2	7/10/1992	0.028	0.17	23	
Storm Sewer #9	2	8/18/1992	0.001	0.2	37	
Storm Sewer #9	2	9/18/1992	0.02	0.078	22	
Storm Sewer #9	2	11/2/1992	0.001	0.16	23	
E8S	3			0.56533		51,300
		AVERAGE:	**0.01**	**0.27**	**30**	**51,300**
8th Street - #1 u/s OG separator	6	July 2009	0.56	0.14	51	>2419
8th Street - #1 u/s OG separator	6	August 2009	ND	0.09	17	>2419
8th Street - #1 u/s OG separator	4	Sept 2013		0.06	8	2,950
8th Street - #1 u/s OG separator	4	October 2013		0.11	120	72,700
		AVERAGE:	**0.56**	**0.1**	**49**	**37,825**

Bryant Park	Report*	Date	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	Ecoli col/100mL
Storm Sewer #7	2	4/16/1992	0.012	0.085	74	
Storm Sewer #7	2	6/5/1992	0.48	0.27	34	
Storm Sewer #7	2	7/10/1992	0.024	0.19	60	
Storm Sewer #7	2	8/18/1992	0.037	0.27	21	
Storm Sewer #7	2	9/18/1992	0.014	0.061	15	
Storm Sewer #7	2	11/2/1992	0.003	0.16	53	
BP	3	11/9/2000		0.372		15,300
		AVERAGE:	**0.10**	**0.20**	**43**	**15,300**
Bryant Park (drain #1)	6	July 2009	0.54	0.08	37	>2419
Bryant Park (drain #1)	6	August 2009	1.82	0.03	3	1,203
Bryant Park (drain #1)	4	December 2011	0.36	0.08	92	>2419
Bryant Park (drain #1)	4	March 2012	0.22	0.03	186	4,654
Bryant Park (drain #2)	4	December 2011	0.35	0.18	20	>2419
		AVERAGE:	**0.66**	**0.08**	**68**	**2,929**

East Bay Park - north drain	Report*	Date	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	Ecoli col/100mL
Storm Sewer #8	2	4/16/1992	0.005	0.046	26	
Storm Sewer #8	2	6/5/1992	bdl	0.33	31	
Storm Sewer #8	2	7/10/1992	0.019	0.14	21	
Storm Sewer #8	2	8/18/1992	bdl	0.35	96	
Storm Sewer #8	2	9/18/1992	0.014	0.067	14	
Storm Sewer #8	2	11/2/1992	0.011	4	269	
EBP	3	11/9/2000		0.44		80,000
Site #100	1	2/5/1991	1.4	0.0323		
Site #100	1	7/1/1991		0.488		
Site #100	1	7/22/1991		0.228		
Site #100	1	7/29/1991		0.0814		
		AVERAGE:	**0.29**	**0.56**	**76**	**80,000**
East Bay Park - #1 u/s OG separator	6	July 2009	0.29	0.07	23	>2419
East Bay Park - #1 u/s OG separator	6	August 2009	0.29	0.05	7	>2419
East Bay Park - Front St. Influent	5	Summer 2013		0.17	36.2	
East Bay Park - Front St. Influent	5	Summer 2014		0.09	115.2	15,329
East Bay Park - Front St. Influent	5	Summer 2015		0.214	52.2	46,413
		AVERAGE:	**0.29**	**0.12**	**47**	**30,871**

East Bay Park - south drain	Report*	Date	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	Ecoli col/100mL
Site #104	1	2/5/1991	4.5	0.0486		
Site #104	1	7/1/1991		0.456		
Site #104	1	7/22/1991		0.2016		
Site #104	1	7/29/1991		0.0848		
		AVERAGE:	**4.5**	**0.20**		
East Bay Park - Shawnee Influent	5	Summer 2013		0.11	107.8	
East Bay Park - Shawnee Influent	5	Summer 2014		0.08	41.1	40,729
East Bay Park - Shawnee Influent	5	Summer 2015		0.09	286.6	2,072
		AVERAGE:		**0.09**	**145**	**21,400**

Hannah Park	Report*	Date	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	Ecoli col/100mL
Storm Sewer #3	2	4/16/1992	0.011	0.069	66	
Storm Sewer #3	2	6/5/1992	bdl	0.61	14	
Storm Sewer #3	2	7/10/1992	0.025	0.12	34	
Storm Sewer #3	2	8/18/1992	0.001	0.34	229	
Storm Sewer #3	2	9/18/1992	0.011	0.11	40	
Storm Sewer #3	2	11/2/1992	0.004	1.5	163	
		AVERAGE:	**0.01**	**0.46**	**91**	
Hannah Park - #1 u/s OG separator	6	July 2009	0.55	0.07	65	1,986
Hannah Park - #1 u/s OG separator	6	August 2009	0.29	0.12	53	1,733
		AVERAGE:	**0.42**	**0.095**	**59**	**1,860**

*Data sources:

1. *Shuey, J.A., C.A. Harris, and G.M. DeGraeve. 1992. Final Report for the Grand Traverse Bay Watershed Initiative: Part II, Water Quality of the Bay and Tributaries. Great Lakes Environmental Center, Traverse City, MI. (Note: The Grand Traverse Bay Watershed Initiative is now known as The Watershed Center Grand Traverse Bay.)*
2. *City of Traverse City Waste Water Treatment Plant and Operations Management International. 1992. Stormwater Sewer Study*
3. *Great Lakes Environmental Center (GLEC). 2001. Stormwater Source Identification, Sampling, and Analysis at Select Storm Drains and Tributaries to Grand Traverse Bay (Lake Michigan). Prepared for The Watershed Center Grand Traverse Bay as part of an DEQ, Coastal Zone Management Study. (Principal Contact at GLEC: Dennis McCauley)*
4. *TWC - GLRI Project at Bryant Park (2011/2012)*
5. *TWC - BMP effectiveness testing at GLRI East Bay Park project (2013-2015)*
6. *TWC Project with City of Traverse City funds (2009)*

E.Coli Results for Various Stormdrains 2000-2015

Site	Date	Ecoli (col/100mL)
8th Street		
8th Street	11/9/2000	51,330
8th Street - u/s separator	7/22/2009	>2419
8th Street - d/s separator	7/22/2009	>2419
8th Street - u/s separator	8/3/2009	>2419
8th Street - d/s separator	8/3/2009	>2419
8th Street Drain u/s separator	9/19/2013	2,950
8th Street Drain d/s separator	9/19/2013	15,530
8th Street Drain u/s separator	10/3/2013	72,700
8th Street Drain d/s separator	10/3/2013	38,700
8th Street Drain	7/3/2012	61,300
8th Street Drain	7/25/2012	21,430
8th Street Drain	8/16/2012	241,920
8th Street Drain	9/7/2012	198,630
Bryant Park		
Bryant Park	11/9/2000	15,300
Bryant Park	7/22/2009	>2419
Bryant Park	8/3/2009	1,203
Bryant Park (drain #1)	8/10/2010	35
Bryant Park (drain #1)	8/12/2010	210
Bryant Park (drain #1)	8/19/2010	>2419
Bryant Park (drain #1)	9/1/2010	>2419
Bryant Park (drain #1)	9/2/2010	>2419
Bryant Park (drain #1)	9/20/2010	387
Bryant Park (drain #1)	9/23/2010	899
Bryant Park (drain #1)	10/26/2010	>4838
Bryant Park (drain #1)	8/2/2011	9,208
Bryant Park (drain #1)	9/19/2011	3,448
Bryant Park (drain #1)	9/21/2011	10,460
Bryant Park (drain #1)	12/14/2011	>2419
Bryant Park (drain #1)	3/12/2012	4,654
Bryant Park (drain #2)	8/19/2010	>2419
Bryant Park (drain #2)	9/1/2010	>2419
Bryant Park (drain #2)	9/2/2010	1,046
Bryant Park (drain #2)	9/23/2010	3,921
Bryant Park (drain #2)	10/26/2010	>4838
Bryant Park (drain #2)	8/2/2011	19,863
Bryant Park (drain #2)	9/19/2011	17,329
Bryant Park (drain #2)	9/21/2011	5,040
Bryant Park (drain #2)	12/14/2011	>2419

Site	Date	Ecoli, MPN col/100mL
East Bay Park		
East Bay Drain North	8/2/2011	6,867
East Bay Drain North	9/19/2011	>24,192
East Bay Drain North	9/21/2011	32,550
East Bay Drain North	12/14/11	>2419
East Bay Drain North	3/12/12	445
East Bay Drain North	5/2/12	3,090
East Bay Drain North	7/3/2012	14,700
East Bay Drain North	7/25/2012	19,180
East Bay Drain North	8/16/2012	19,350
East Bay Drain North	9/7/2012	241,920
East Bay Park - #1 u/s	7/22/2009	>2419
East Bay Park - #1 u/s	8/3/2009	>2419
East Bay Park North	11/9/2000	80,000
East Bay Drain South	8/2/2011	17,329
East Bay Drain South	9/19/2011	24,192
East Bay Drain South	9/21/2011	6,500
East Bay Drain South	12/14/11	>2419
East Bay Drain South	3/12/12	160
East Bay Drain South	5/2/12	4,570
East Bay Drain South	7/3/2012	13,100
East Bay Park - #2 d/s	7/22/2009	>2419
East Bay Park - #2 d/s	8/3/2009	1,986
Hannah Park		
Hannah Park - #1 u/s separator	7/22/2009	1,986
Hannah Park - #2 d/s separator	7/22/2009	>2419
Hannah Park - #1 u/s separator	8/3/2009	1,733
Hannah Park - #2 d/s separator	8/3/2009	921
Holiday Inn		
Holiday Inn - #1 u/s separator	8/3/2009	5
Holiday Inn - #2 d/s separator	8/3/2009	26
Hope Street		
Hope Street	11/9/2000	487
Maple Street		
Maple Street	11/9/2000	2,700

Site	Date	Ecoli, MPN col/100mL
Sunset Drain	8/18/2015	3
Sunset Drain	8/19/2015	517
Sunset Drain	8/24/2015	100
Sunset Drain	9/3/2015	620
Sunset Park Drain	7/3/2012	130,000
Sunset Park Drain	7/25/2012	5,760
Sunset Park Drain	8/16/2012	111,990
Sunset Park Drain	9/7/2012	7,890
West End Beach/Park		
West End	7/22/2009	1,986
West End	8/3/2009	326
West End Drain	7/3/2012	1,200
West End Drain	7/25/2012	1,850
West End Drain	9/7/2012	19,180
West End Drain #2 (West)	9/7/2012	9,600
West End West Drain	7/3/2012	4,400
West End West Drain	7/25/2012	1,850
West End West Drain	8/16/2012	5,460
West End West Drain	9/7/2012	12,740

Chapter in GTBWPP:

4.2 Impacted Designated uses in the Grand Traverse Bay Watershed

Add section on Kids Creek, bulk of info is in Boardman Prosperity Plan, update with most current work

Chapter in GTBWPP:

5.3 Priority Protection and Critical Areas

NOTE: Not sure of final format for this section, will most likely be changed extensively with overall GTBWPP revision

- **Critical Areas - these will most likely be grouped into 'General' and 'Acute' areas**
- **In Boardman Prosperity Plan, the City of TC is Acute Critical Area #4 and Kids Creek Subwatershed was #5**
    - **Can drill down further and create more acute critical areas in TC, like downtown corridor, GTBay shoreline, ? Or, just leave it as is and put specific projects in the Implementation Task section...**

    - **#4: Traverse City and surrounding urban area, roughly defined by the land area encompassed by South Airport Road, Garfield Avenue, US31 North to Grand Traverse Bay (includes Traverse City and Garfield Township).** This highly urbanized portion of the watershed in Traverse City contributes pollutants to the river and Grand Traverse Bay via stormwater runoff. While a number of stormwater reduction and filtration projects have been implemented, there is still a significant need to reduce the amount of oils, greases, litter, and other pollutants to the river in this portion of the watershed.

    - **#5: Kids Creek subwatershed.** As discussed in Chapter 4.3, Kids Creek is the only impaired waterbody on MDEQ's 303(d) list. Water quality in the creek is severely impacted by stormwater and sedimentation. TWC launched a large-scale Kids Creek Restoration Project a number of years ago that included stormwater reduction BMPs on tributaries A and AA of the creek, streambank stabilizations, and "daylighting" a portion of Tributary A (See Chapter 4.3 and Figure 14 for more detail). Restoration efforts must continue on Kids Creek to further aid in efforts for its removal from the impaired waters list


E Front St
Traverse City
W Front St
E Eighth St
S Cass St
Woodmere Ave
S Garfield Ave
Garfield Avenue
US 31 N
Silver Lake Rd
Veterans Dr
Boardman Lake
Wolf Lodge
Cherry Cap
Park Dr
W South Airport Rd
South Airport Road
W South Airport Rd
Grand Traverse Mall
620
Lafranier Rd
N Garfield Rd
31

Chapter in GTBWPP:

5.5 Master Planning and Zoning Ordinances

- **Include general info and format used in Boardman Prosperity Plan as it pertains to focus areas of GTBWPP**
- **Add City of TC subsection**

City of TC Subsection

- **Keep/utilize info in existing GTBWPP**
- **Add in additional from BPP**
- **Stormwater utility update (if any)**
- **Updated geothermal policy (if any)**
- **Updated stormwater ordinance (if any)**
- **TWC working with City on riparian vegetation ordinances to protect water quality (will start in 2017, update with larger GTBWPP)**

Chapter in GTBWPP:

5.6 Special Sources of Concern: Stormwater

Keep general discussion

- **include typical pollutant concentrations from SE Michigan study, Table 31 from original GTBWPP**
- **add pollutant loads from 1mi2 (640 acres) of different land uses using Region 5 spreadsheet tool (see table below)**

Pollutant (lbs/yr)	Commercial	Industrial	Institutional	Transportation	Multi-Family	Residential	Agriculture	Vacant	Open Space
TSS (tons/yr)	337	354	377	646	377	88	44	29	17
TN	13,440	8,960	7,040	8,320	7,040	3,840	1,536	640	640
TP	832	960	896	1,152	896	518	115	141	250
Lead	659	1,011	235	1,709	235	150	1	17	10
Copper	128	134	64	358	64	31	3	6	6
Zinc	1,024	832	365	2,048	365	576	44	64	51
Cadmium	5	16	2	13	2	1	0	0	0
BOD	54,400	32,000	33,280	32,000	33,280	14,080	1,920	1,280	640
COD	376,960	166,400	204,800	563,840	204,800	89,600	17,920	40,960	29,440

Add section for City of TC

Stormdrains in city

- incorporate any language in existing GTBWPP - 1900 drainage structures and manholes, 54 miles of storm sewers open channels and culverts and more than 90 points of entry into area streams, rivers, lakes and the Grand Traverse Bay. (this is from 2003 Prezo copy and GTBWPP says 51 outfalls... which one is it?)
- Reference Stormwater Mngt Plan from SAW grant (discussed later)

Compare monitoring results from Water Quality Section to stream, lake, and Bay values

- Saginaw/GTBay Monitoring Report (1993-2004)
  - TP values greater than 10 ug/L (0.01 mg/L) indicative of impaired water quality and contributes to increased plant growth
  - Chlorophyll a values greater than 4ug/L indicate mesotrophic conditions, greater than 10 ug/L indicate eutrophic conditions
  - Saginaw Bay - all stations at or above 0.01 mg/L TP; Nitrate higher than most inland lakes and Bays in MI; Chlorophyll a values all above 4ug/L, with some around 12ug/L

  - GT Bay - TP all below 0.01 mg/L which indicate oligotrophic and excellent water quality; same for nitrate and Chlorophyll a
  - Saginaw Bay showing signs of water quality impairments and mesotrophic status - GT Bay watershed doesn't want to get to that point - Protection is KEY
- From Section 3.11 in original GTBWPP - GTBay TP is 5ug/L (.005mg/L) - TP values in storm drains range between 0.03 - 0.2 mg/L (average of 0.1 mg/L) which is an average of twenty times higher than water in GTBay
- DEQ communication with G.Goudy: TP Lake values should be around 10ug/L (.01 mg/L), stormdrains are ten times higher
- DEQ communication with G.Goudy: TP Stream values should be 10-20 ug/L (.01 - .02 mg/L); Boardman River averages 0.012 mg/L (from Boardman Prosperity Plan); TP values are ten times higher than Boardman River
- **TAKE AWAY** - While our concentration values of nutrients and sediments in stormwater runoff may be less than is seen in areas downstate, our water quality in the Grand Traverse Region is also of a much higher quality. Therefore we must do better to protect the Bay and streams/lakes in the watershed from degradation.

EColi and critters in stormdrains

- EColi is a major problem in stormdrains in the City of TC as is seen by values from Table above. Many stormdrains outlet adjacent to public lands as well, with many of the public lands being designated beach areas.
- Reference later discussion on BMP projects with the City to reduce beach pathogens at East Bay and Bryant Parks
- Drains, especially on east side of TC, have large numbers of raccoons living in them. City has done camera work in drains and found multiple piles of raccoon droppings; and city workers cleaning out fire hydrants routinely see raccoon families coming in and out of catch basins.
- Other sources of EColi in stormdrains are from pet waste runoff, wildlife and waterfowl, and urban runoff

Summarize stormwater BMP efforts to date

TWC projects - will be summarized in larger table with all TWC completed BMP projects and pollutant savings elsewhere in plan, so we can reference that table as a whole. Notable projects include:

Kids Creek Restoration Project (to be discussed in-depth in a separate section in Chapter 4) -

Work on TWC's large-scale Kids Creek Restoration Project started in 2013 with the goal of reducing the impact of stormwater and sedimentation on Kids Creek and its tributaries so it could be removed from the State's 303(d) Impaired Waters List. Thus far, project work has focused on reducing stormwater inputs to Kids Creek from urban areas using green infrastructure and low impact development techniques. However, the next phase of the restoration project will also include work within the channel to restore habitat and provide floodplain storage during periods of high flow. To date, TWC has received more than $4.2 million in MDEQ, EPA-GLRI, and private funding to implement key portions of the Kids Creek Action Plan as part of the Kids Creek Restoration Project. Much of this work has focused on installing green infrastructure and low impact development techniques in the vicinity of Tributaries A and AA of Kids Creek which includes a large hospital campus (Munson Medical Center), senior assisted living center (Grand Traverse Pavilions), and an historic preservation and adaptive reuse redevelopment called the Village at Grand Traverse Commons. The amount of stormwater generated in these urban areas are a concern, as well as the amount of water being conveyed down both tributaries and the main branch of Kids Creek during rain events from upstream sources. A large amount of stormwater is generated by the vast areas of impervious surfaces (rooftops, parking lots, and roads), carrying high sediment loads as well as a variety of other pollutants normally found in stormwater (nutrients, oil/grease, litter). In addition, in-stream habitat has been negatively impacted due to excessive sand, silt, and impaired water flow. A summary of BMPs either completed or to be completed as part of the Kids Creek Restoration Project through previous grant funding follows:

Munson Medical Center

- Relocated 900 feet of underground culverts and channelized ditches of Kids Creek Tributary A to a natural meandering channel 1,275 feet in length and eliminated 72,000 ft^2 of impervious surfaces. Also restored natural sinuosity, meanders, riffles, and pools as well as established a native riparian buffer of 15-30 feet along the entire new section of creek and more than 27,000 ft^2 of vegetated floodplain. *(completed)*
- Installed green roof, underground infiltration trenches, and rain garden at the Cowell Family Cancer Center *(completed)*
- Installed 4 downspout planter boxes, converted parking lot to pervious pavers, and retrofitted existing detention basin to a rain garden at Building 29 on west side of parking garage *(completed)*
- Retrofitted ~3,100 ft^2 of roof on Munson Hospital Tower A to a green roof *(completed)*
- Installing bioretention basins and pervious pavement around the Munson Medical Center helipad parking lots *(to be completed 2017)*
- Installing tree box planters or rain gardens to reduce stormwater runoff from Medical Campus Drive *(to be completed 2017)*.
- Excavating and enlarging the wetlands on the corner of Elmwood Avenue and Medical Campus Drive so more water can enter during storm events and be slowly released into Kids Creek *(to be completed 2017)*
- Installing LID techniques with new parking garage at main Munson parking lot *(to be completed 2018)*
- Restoring natural stream function and connecting Kids Creek Tributary A to floodplain along 6th/Elmwood Streets *(to be completed 2018)*

Grand Traverse Pavilions

- Restoring the natural floodplain and installing a buffer on Tributary AA between the Grand Traverse Pavilions and Grand Traverse Commons *(to be completed 2017)*
- Installing rain gardens to collect and filter rooftop, parking lot, and road runoff around Grand Traverse Pavilions *(to be completed 2017)*

Grand Traverse Commons

- Converting lined and rock-filled detention areas off of Cottageview Drive into functioning rain gardens *(to be completed 2017)*
- Reducing erosion and runoff issues by paving Yellow Drive and directing stormwater into a series of rain gardens *(to be completed 2017)*

Other

- Completed sediment basin reconstruction work at West Front Primary Care to prevent direct sediment input from parking lot runoff into Kids Creek Tributary A *(completed)*
- Installing a rain garden and bioswale to collect and infiltrate water from Elmwood Avenue and the parking area of the Traverse City State Office Building *(to be completed 2017)*
- Reducing sediment and stormwater runoff from industrial business near headwaters of Tributary A *(to be completed 2017)*

GLRI Bryant Park-

The goal of this project was to implement a stormwater infiltration system at one of two large storm drain outlets at Bryant Park to reduce bacterial contamination at the beach, with the ultimate goal of delisting the beach from the

State's Impaired Water's list. This project was paid for through a 2010 EPA Great Lakes Restoration Initiative (GLRI) grant awarded to the MDEQ and subawarded to TWC and was completed in June 2012. The chosen treatment system consists of the following components and was designed to treat the first flush of stormwater volume for 75% of the annual storm events:

1. Diversion Weir - This component will divert up to the first 12 inches of flow in the 30 inch diameter pipe to the treatment system
2. Oil Grit Separator - This component will separate soils and remove grit up to 125 microns
3. Traverse City Treatment Box - This component will remove neutrally buoyant material (i.e. cigarettes) and fine sediment.
4. Chamber Infiltration System - This component will remove any fine sediment in the isolator row and provide for sand infiltration of the stormwater flow entering and draining to the ground via the chamber system.

GLRI East Bay Park -

This project implemented a three-step stormwater filtration system at East Bay Park to reduce bacterial contamination at the beach and was installed Spring 2013. It was paid for through a 2011 EPA-GLRI grant awarded to TWC, who worked collaboratively to achieve project goals with the City of Traverse City, who served as a subrecipient of grant funds for project implementation. As part of this project the City investigated and number of differenty types of stormwater treatment option to see which would work best with given conditions at the site. The plans consisted of utilizing an end of the pipe treatment cartridge filter system for stormwater coming from three stormdrains that outlet at the Park (two on north side, and another small one on south edge). The three drain lines have the following components and were designed to treat the first flush of stormwater volume for 75% of the annual storm events:

1. Diversion weir to allow for stormwater entry to filter system, and provide for overflow during heavy rain events
2. Oil/grit separator - This component will separate soils and remove grit up to 125 microns
3. Sediment Settling Tanks ('Traverse City Treatment Box') - This component will remove neutrally buoyant material (i.e. cigarettes) and fine sediment. It will also have a 1/4" x 1/4" stainless steel screen and chambers acting as sediment traps.
4. Helix Cartridge Filtration System - These are manufactured, replaceable high flow cartridges effective at treating pathogens using treated foam filter media and increased contact time (through helix design). The cartridges also help remove sediment, hydrocarbons, and nutrients. We chose to use the Fabco Industries' Helix Filter (http://www.fabco-industries.com).
5. The drain lines were then combined to one outlet after treatment, which was located at the southern edge of the park, south of the bathing beach to prevent the outflow from stagnating in the beach's swimming area.

Oil/Grit Separators -

TWC has installed 7 oil/grit separators in the City of Traverse City using funding from numerous DEQ Nonpoint Source Unit grants. They were all installed in 2007. (Additional info from city re maintenance or how much 'stuff' removed?)

- Cass Street Outfall
- Union Street Outfall
- 8th Street
- East Bay Park
- Holiday Inn
- Hannah Park (2)

Pervious Pavement Demonstration - Parking Lot K -

TWC in conjunction with the City of TC installed 4 different types of pervious pavement systems in a heavily used parking lot near the Post Office downtown in 2007. Types of pervious pavement used were: porous asphalt, porous concrete, paver stones, and Gravel Pave. This project was not as successful as initially hoped due to issues with incorrect installation of some of the types of pavement. Additionally, this project was done when the use of pervious pavement was not yet widely used and we believe technology has come a long way as it pertains to installation and maintenance with pervious pavement systems.

Stormdrain BMPs city has done w/o TWC

City GIS Dept has list and map

BMP effectiveness results -

- **Oil-grit separators:** In Summer 2009 TWC, in conjunction with the City of TC tested four storm drains during two rain events where oil/grit separators had been installed in 2007 to see how well the BMPs were performing. While two grab samples at random times during the duration of a rain event is not a robust sampling program, the spot checks did indicate that the oil/grit separators were reducing Total Suspended Solids by some amount. Total Phosphorus amounts also seemed to be reduced comparing samples taken before and after the BMP system.

2009 BMP Effectiveness Tests for Oil/Grit Separators at 4 Locations in Traverse City

Location	**Date**	**E.Coli Col/100mL**	**TSS (mg/L)**	**TP (mg/L)**	**Nitrate (mg/L)**
East Bay Park - #1 u/s	7/22/2009	>2419	23	0.07	0.29
East Bay Park - #2 d/s	7/22/2009	>2419	22	0.1	ND
East Bay Park - #1 u/s	8/3/2009	>2419	7	0.05	0.29
East Bay Park - #2 d/s	8/3/2009	1986	8	0.04	0.38
8th Street - #1 u/s	7/22/2009	>2419	51	0.14	0.56
8th Street - #2 d/s	7/22/2009	>2419	26	0.1	0.48
8th Street - #1 u/s	8/3/2009	>2419	17	0.09	ND
8th Street - #2 d/s	8/3/2009	>2419	14	0.06	ND
Holiday Inn - #1 u/s	8/3/2009	5	5	ND	0.24
Holiday Inn - #2 d/s	8/3/2009	26	4	ND	0.24
Hannah Park - #1 u/s	7/22/2009	1986	65	0.07	0.55
Hannah Park - #2 d/s	7/22/2009	>2419	59	ND	0.55
Hannah Park - #1 u/s	8/3/2009	1733	53	0.12	0.29
Hannah Park - #2 d/s	8/3/2009	921	27	0.08	0.32
ND = Non Detect	*Limit of Detection: TP - 0.05 mg/L; Nitrate - 0.1 mg/L*				

- **GLRI East Bay park:** In 2013, 2014, and 2015 TWC conducted testing stormdrains at East Bay Park to see how well the recently installed BMP system was working.
  - Three drains tested (Front Street, Shawnee, and Iroquois) for TSS, TP, and EColi
  - Testing program was not robust and shouldn't be considered statistically significant. Autosamplers were installed to get first flush at beginning of rain event, even if it was during the night. Even with autosamplers it was difficult to capture rain events that were within the right timeframe for holding sample time and when the water quality analysis lab was open (i.e. many rain events happened early evening and on weekends and could not be used b/c holding times would have been exceeded).
  - Overall the system did reduce all parameters tested, although not consistently all the time. It appeared that, during heavy rain events, the system was overwhelmed and

pollutant reductions were not observed. It was most effective on reducing TSS, but reduction in TP and EColi were observed as well.

- **Managerial BMPs instituted**
  - **Street sweeping and catch basin cleaning:**
    - Current catch basins cleaned once per year - 1,200 basins - 126 tons a year (wet weight)
    - Storm filters cleaned twice a year - 15 to 20 cubic yards of debris each year (includes filters, oil/grit separator chambers, and sediment settling boxes)
    - Street sweeping
    - Schedule varies: all curb and gutter streets once/week; all city streets, alleys, and parking lots once/year in spring; non curb and gutter streets once /year in spring for winter sand cleanup; addtional sweepings may occur on as-needed basis
    - 870 tons of sand/debris swept up each year
  - 1980 Historical Report - compared ____ and targeted outreach to streets with no BMPs or education
    - 1974 GTBay study by MiSeaGrant, 3 drains: Spruce, Bryant North, East Bay... study developed pollution baseline
    - 1980 Study used those same sites for baseline to compare two stormwater BMP approaches: Spruce = control; Bryant North = aggressive education; East Bay = increased street sweeping and catch basin cleaning (sweep every 3-5 days)
    - in general there was a 67% less unit load for suspended solids where streets were swept ad catchbasins cleaned, and a 40% reduction of unit load where citizen education was implemented compared to the control basin
    - Shows importance of the impact of the simple practice of catch basin cleaning and street sweeping, in addition to public education.
    - *Northwest Michigan Regional Planning and Development Commission. 1980. Stormwater Management: An Experiment & Demonstration in Traverse City, Michigan. December 1980. Prepared by: Environmental Research Group, Inc., Ann Arbor, MI.*

Summary of SAW grant

- The City of Traverse City received an MDEQ Stormwater, Asset Management, and Wastewater (SAW) grant to identify stormwater issues within the city limits, including hydrologic analyses for specific areas, including the impaired portion of Kids Creek that runs through the west side of Traverse City. The SAW grant also outlined BMPs to reduce stormwater impacts from the city's drains to surrounding waters.
  - **what did it do**
  - **recommendations**
  - **timeline**
  - **stormwater utility??**

Rural Stormwater

- **Issues**
- **Monitoring results? Suttons Bay, Northport, Elk Rapids?**
- **Stormwater Action Plans**
- **BMP efforts and projects**

Chapter in GTBWPP:

7.2 Best Management Practices

- **Add section on Low Impact Development.... take wording from Boardman Prosperity Plan**
- **Somewhere in this chapter discuss all BMP efforts to date for entire watershed, maybe after the general BMP section**
- **Break out section for just City of TC BMPs, include any BMP effectiveness monitoring... City's SMP plan will have summary of all City BMPs and map**

Chapter in GTBWPP

7.3 List of Implementation Tasks By Category

- **Revise/add city of TC tasks as relevant**
- **Revise milestones for city as relevant**
-

NOTE: Not sure of final format for this section so looks may change, will most likely look like BPP format

*Tasks from Prosperity Plan are on following pages.... TC stormwater ones highlighted

Categories (from BPP):

1. Shoreline Stabilization and Protection
2. Stormwater
3. Transportation/Stream Crossings (i.e. roads, railroads, etc.)
4. Planning, Zoning, and Land Use
5. Land Protection and Management
6. Habitat, Fish, and Wildlife
7. Human Health Strategies
8. Hydrology and Groundwater
9. Water Quality Monitoring
10. Wetland
11. Invasive Species
12. Agriculture
13. Wastewater and Septics

Stormwater Category ADD:

- Whenever a road is rebuilt and soil types allow, install drywell with TC Stormdrain cover and microbial skirt or other water quality treatment system
  - $1,200/ea;
  - 1 street/year; West Front by 2018
- More frequent street sweeping
- Increased catch basin cleaning
  - fall and spring cleanup
- Monitor more frequently and maintain existing BMPs already installed
- Hire regional stormwater outreach coordinator

Human Health Category ADD:

- Reduce pathogen input from stormdrains at area beaches by installing appropriate BMPs, including LID-based and end-of-pipe treatment filters.

Monitoring Category ADD:

- More thorough stormwater monitoring including composite sampling to determine pollutant loads during rain events
- Monitor chloride levels in stormwater outfalls and streams from winter road salt practices

TABLE 36. Watershed-wide Actions and Related Goals/Objectives

	Watershed Wide Actions	Goals/ Objectives Addressed	Priority	Milestones	Estimated Costs	Potential Partners	Y1: 2017	Y2: 2018	Y3: 2019	Y4: 2020	Y5: 2021	Y6: 2022	Y7: 2023	Y8: 2024	Y9: 2025	Y10: 2026
Shoreline Stabilization and Protection Strategies																
WW.SS.1	Update GTCD's streambank erosion and road stream crossing inventory every five years to reflect newly identified road stream crossings and streambank erosion sites and restoration progress. Update the online River Restoration in Northern Michigan database accordingly (http://www.northernmichiganstreams.org/boardmansbe.asp). (CRA, N.d.)	1.1; 1.3	High	By 2018	$25,000	GTCD TWC GTB CRA										
WW.SS.2	Work with public and private landowners to stabilize and restore eroding streambank sites at priority sites with biotechnical and soft engineering techniques.	1.1; 1.3	High	Complete 200 linear feet (LF) of restoration/ stabilization by 2020; 500 LF by year 2025	$100/LF; Total $50,000	GTCD TWC CRA										
WW.SS.3	Post dam removal - Monitor and restore resulting eroding streambanks.	1.1; 1.3	High	Restore a minimum of 100 LF per year	$10,000/yr	GTCD GTB CRA										
WW.SS.4	Inventory riparian corridors on private property to identify a list of priority riparian buffer installation or restoration sites.	1.1; 1.3; 5.2	Low	--	Total = $30,600	TWC GTCD										
WW.SS.5	Post dam removal - re-establish riparian zone vegetation along new stream channel to provide bank stability, shading, and other riparian zone benefits as soon as possible.	1.1; 1.3	High	Plant a minimum of 5,000 native trees and shrubs per year	$16,000/yr	GTCD GTB TWC										
WW.SS.6	Install vegetated riparian buffers on private property in identified priority areas, with particular emphasis on tree preservation (where trees exist) or tree planting (where no or insufficient tree canopy exists).	1.1; 1.3; 5.2	Low	Install at least 1 riparian buffer on private land each year	Total costs TBD depending on sites. Average cost/acre ranges from $220 to $730	TWC GTCD										
WW.SS.7	Work with public landowners to install vegetated riparian buffers in priority areas, with particular emphasis on tree preservation (where trees exist) or tree planting (where no or insufficient tree canopy exists).	1.1; 1.3; 5.2	Medium	Install at least 1 riparian buffer each year	Total costs TBD depending on sites. Average cost/acre ranges from $220 to $730	TWC GTCD										
WW.SS.8	Install barriers, signage, or stairs where needed to manage human access to stream and lakeside banks at risk of erosion (steep slopes, sandy soils) from recreational foot traffic	1.3; 4.1; 4.2	Low	--	<$10,00 year; S/V = $1,400 year Total = $4,200	GTCD GTB MDNR										

Stormwater Strategies																
WW.St.1	Work with local governments, area businesses, and property owners to install the following stormwater BMPs in urban areas where appropriate. Vegetative Filter Strips: Filter Strips/Aquatic Buffers, Wet Swales, Dry Swales, Grass Channels Stormwater Filtering Systems: Bioretention and Surface, Perimeter, Organic, Underground, Pocket Sand Filters Infiltration Practices: Infiltration Trench or Basin, Porous Pavement Retention and Detention Ponds Other Low Impact Design Elements: Rain/Roof Gardens, Native Plantings, Riparian Buffers	1.1; 1.3	High	Complete one LID project each year	Implementation costs vary Estimate ~$200K/yr Total - $2million	TWC										
WW.St.2	Upgrade or update applicable ordinances for local governments to accommodate and encourage more innovative forms of stormwater management *See Planning, Zoning, and Land Use*	--	--	--	--	--										
	Watershed Wide Actions	**Goals/ Objectives Addressed**	**Priority**	**Milestones**	**Estimated Costs**	**Potential Partners**	**Y1: 2017**	**Y2: 2018**	**Y3: 2019**	**Y4: 2020**	**Y5: 2021**	**Y6: 2022**	**Y7: 2023**	**Y8: 2024**	**Y9: 2025**	**Y10: 2026**
Transportation/Stream Crossings Strategies																
WW.TSX.1	Update Grand Traverse Conservation District's (GTCD) Boardman River Watershed Report every five years to reflect newly identified road stream crossings and streambank erosion sites and restoration progress. Update the online River Restoration in Northern Michigan database accordingly (http://www.northernmichiganstreams.org/boardmansbe.asp). *See Shoreline Stabilization and Protection*	--	--	--	--	--										
WW.TSX.2	Where priority transportation stream crossings have been identified, improve, repair, or replace outdated, failing, or eroding crossings by implementing the appropriate BMPs from the following; Crossings: Remove obstructions that restrict flow through the culvert; Replace undersized (too small or too short) culverts; Remove and replace perched or misaligned culverts to avoid erosion and provide for fish passage; Install bottomless culverts and bridges where possible; Replace culverts with a culvert that is 2x the bankfull width and a length that allows for $\geq$ 3:1 slope on embankments; Revegetate all disturbed or bare soils on embankments Approaches: Create diversion outlets and spillways to direct road runoff and stormwater away streams; Pave steep, sandy approaches where feasible; Dig or maintain ditches where needed and construct check dams if required Maintenance: Encourage Road Commissions and railroad officials to look at the long-term savings of crossing improvements over cumulative maintenance costs Construction and Closure: Minimize the number of access roads needed for oil, timber and gas exploration; When constructing new roads, avoid streams if possible and maintain natural channels to greatest extent possible; Close	1.1, 1.3	High	Complete upgrade of at least one priority transportation crossings per year.	Depends on size of crossing. $75,000–$100,000 per crossing; Total over 10 years = $750,000 to $1M	GTCD TWC CRA										

	private roads and trails that are no longer needed. Remove culvert and restore stream channel.															
Planning, Zoning, and Land Use Strategies																
WW.PZL.1	Assist townships with drafting and updating zoning and master plans to protect water quality and natural resources. Examples of topics include: sufficient building setbacks from bodies of water, minimizing development clearings by landowners, minimizing vegetation removal and mowing to the water's edge, stormwater management, reducing impervious surfaces near water bodies, establishing riparian buffers along waterways, eliminating the dumping of grass clippings and other yard/solid wastes into the water, prohibiting the feeding of waterfowl near water bodies, and protecting wetlands.	1.1, 1.2, 1.5	High	Ongoing	S = $5,000/yr	TWC LGOV										
WW.PZL.2	Encourage local governments to establish policies and undertake projects that prioritize the protection of water quality on public land, including streets, roads, parking lots, and park land. This includes implementing green infrastructure into the planning and design phases of capital projects related to publically-owned infrastructure, such as street maintenance, building renovations, parking lot surfacing, and landscaping.		High	Ongoing	S = $5,000/yr	TWC LGOV										
WW.PZL.3	Upgrade or update applicable ordinances for local governments in the watershed to accommodate and encourage more innovative forms of stormwater management, including LID.	1.1	High	TC - by 2019 Garf Twp - by 2021	S = $10,000/yr	TWC LGOV										
WW.PZL.4	Integrate LID standards and other innovative techniques into sedimentation control ordinances throughout the watershed.	1.1	High	Ongoing	S = $5,000/yr	TWC LGOV										
WW.PZL.5	Ensure that zoning ordinances in all watershed communities include provisions to identify and protect scenic vistas, agricultural lands, and historic or cultural sites.	2.3; 3.4; 5.1	Low	Ongoing	S = $2,800	LGOV GTCD GTRLC										
WW.PZL.6	Any future road capacity or upgrade analyses associated with new housing or economic development projects should be consistent with the approach in the Grand Vision, include an analysis of the Boardman River water quality and habitat implications, and support the Prosperity Plan's emphasis on clustering housing and jobs to limit the need for larger roads.	1.1; 1.2; 1.3; 3.2	Low	--	No cost	TWC GTCD LGOV										
WW.PZL.7	Develop a Boardman River Recreation Plan that addresses and guides all current and future recreational uses of the river, including points of access and establishes a "carrying capacity" for each use as to protect and enhance the important resource values.	1.1; 1.2	High	Complete Plan by 2017	$50,000	GTCD MDNR GTB										
	Watershed Wide Actions	**Goals/ Objectives Addressed**	**Priority**	**Milestones**	**Estimated Costs**	**Potential Partners**	**Y1: 2017**	**Y2: 2018**	**Y3: 2019**	**Y4: 2020**	**Y5: 2021**	**Y6: 2022**	**Y7: 2023**	**Y8: 2024**	**Y9: 2025**	**Y10: 2026**
Land Protection and Management Strategies																
WW.LPM.1	Work with local units of government to develop and promote local initiatives that preserve open space and sensitive/important natural areas.	1.2; 4.2; 5.1; 5.2	Medium	--	S = 2,500/yr	GTRLC TWC LGOV										

WW.LPM.2	Identify priority private lands for conservation and work to acquire conservation easements or other permanent protection of these priority parcels.	1.2; 4.2; 5.1; 5.2	High	Acquire five priority easements by 2023	S/V time = $1,750–$2,450/year; Total = $17,500 to $24,500. Acquisition costs TBD	GTRLC										
Habitat, Fish, and Wildlife Strategies																
WW.HFW.1	Collect information that exists, and conduct stream inventories where needed, to evaluate appropriate sites for in-stream habitat improvement projects. Criteria to be assessed includes: woody debris, bank stability, floodplain connectivity, riparian vegetation, in-stream cover, flow dynamics, and fish population structure	1.1, 1.2	High	Complete by 2021	$35,000	GTCD TWC CRA MDNR GTB										
WW.HFW.2	Install in-stream habitat improvements where appropriate, according to the inventory above.	1.1, 1.2	Medium	After inventory, one site/year	$50,000/year (after inventory) Total= $200K	GTCD TWC CRA MDNR GTB										
WW.HFW.3	Continue to implement the Conservation Resource Alliance's Wild-Link program to protect and enhance fish and wildlife habitat on private property within ecological corridors throughout the watershed.	1.2; 1.4; 1.5; 5,1; 5.2	Low	Work with at least four or five landowners each year	~$20,000 per year, plus S/V = $1,400/year, Total = $214,000	CRA										
Human Health Strategies																
WW.HH.1	Conduct post-rain-event *E. coli* monitoring on inland lakes and Boardman River every two years in areas identified as potentially threatened by storm–water inputs of pathogens.	1.1	Low	Sample sites/ 2 yrs	$10,000–$15,000 Total = $50,000–-$75,000	TWC										
Hydrology and Groundwater Strategies																
WW.HG.1	Work with owners and operators of dams and lake-control structures to ensure these structures are operated so that they mimic natural flow conditions of the river. Where possible, seek permission for removal.	1.1, 1.2, 1.3	Medium	Contact two property owners annually	S=$2,500/yr	GTCD TWC LGOV										
WW.HG.2	Remove inoperative, failing, or economically unfeasible dams as well as priority dams that are blocking fish passage. Utilize 2015 small dam inventory as resource.	1.1, 1.2, 1.3,	High	(See above) Contact two property owners annually	Cost vary depending on size of dam	GTCD TWC CRA GTB LGOV MDNR MDEQ BDIT										
WW.HG.3	Eliminate improperly or uncapped abandoned wells to prevent contaminants from moving into and among groundwater aquifers via this route. Tasks will be to 1) inventory existing abandoned wells through surveys, well logs, and landowner interviews and 2) properly plug the abandoned wells.	1.1	Low	Contact all property owners that have known improperly or uncapped abandoned wells	$25,000 (well inventory only) $250K/county/yr (plugging wells)	MSUE HDept, MDEQ										
	Watershed Wide Actions	**Goals/ Objectives Addressed**	**Priority**	**Milestones**	**Estimated Costs**	**Potential Partners**	**Y1: 2017**	**Y2: 2018**	**Y3: 2019**	**Y4: 2020**	**Y5: 2021**	**Y6: 2022**	**Y7: 2023**	**Y8: 2024**	**Y9: 2025**	**Y10: 2026**

Water Quality Monitoring Strategies						
WW.WQ.1	Develop and implement a Comprehensive Water Quality Monitoring (CWQM) program to regularly monitor standard water quality parameters every three years (e.g., phosphorus, nitrogen, temperature, suspended solids, fecal bacteria), as well as fish and benthic communities. At a minimum, monitoring must include sites in identified Priority and Critical Areas to ensure pollutant concentrations remain the same or decrease *Details in Chapter 11.2 Water Quality Monitoring Plan*	1.1	High	Ongoing	$50,000/year	MDEQ TWC BDIT GTCD
WW.WQ.2	Continue TWC's Adopt A Stream program that monitors macroinvertebrates and covers the Boardman River Watershed and expand to include additional streams.	1.1, 1.2	High	Yearly	$10,000/year	TWC LA Schools
WW.WQ.3	Continue MDEQ collection and identification of macroinvertebrates from randomly selected stations on a 5-year rotating schedule, consistent with present sampling program.	1.1, 1.2	High	2018 2023	No Cost	MDEQ
WW.WQ.4	Support the MDNR and the GT Band in their efforts to determine fish population estimates and trends throughout the watershed	1.1, 1.2	Medium	Ongoing/Yearly	$5,000/year	MDNR GTB
WW.WQ.5	Synthesize raw temperature data collected by GTCD since 2013	1.1	High	By 2018	Intern or College Grad: $5,000	GTCD
WW.WQ.6	Update appropriate online databases as new water quality information becomes available (eg: TWC, MiCorps, northernmistreams.org, BeachGuard)	1.1	Low	Update as needed	S=$1,000/yr	TWC GTCD CRA GTB
WW.WQ.7	Undertake further evaluation and monitoring of nutrient, bacterial and toxic pollution sites identified in the Boardman Lake Watershed Management Plan.	1.1	Medium	Study complete by 2025	$50,000	TWC TC GarfTwp GTB
WW.WQ.8	Conduct clean-up event(s) on Boardman Lake and downstream in Boardman River to remove tires, drums, various scrap metal, wooden pallets, bricks, ceramics and other debris.	1.1, 1.2	Low	ongoing	$2,000/clean-up	GTCD TWC,
WW.WQ.9	Seek grant funding for research on (1) the impacts of climate change on Boardman River water quality; (2) ecosystem recovery following Boardman Dams removal; and (3) the impact of oil and gas extraction on Boardman River watershed natural resources.	1.1; 1.2	Low		S/V = $2,100/year; Total = $21,000	TWC GTCD
WW.WQ.10	***Invasive Species monitoring tasks are located in the Invasive Species Category*	1.4				
Wetland Strategies						
WW.W.1	Protect and restore existing wetlands through the use of setback buffers, enforcement of wetlands regulations, and removal/management of invasive species.	1.2; 1.4	Low	ongoing	S=$5,250 year; Total = $52,500	GTCD TWC LGOV

TABLE 41. Zone 5 Actions and Related Goals/Objectives (Encompassing Critical Areas #4, #5, and #6)

	Zone 5 Actions	Goals/ Objectives Addressed	Priority	Milestones	Estimated Costs	Potential Partners	Y1: 2017	Y2: 2018	Y3: 2019	Y4: 2020	Y5: 2021	Y6: 2022	Y7: 2023	Y8: 2024	Y9: 2025	Y10: 2026
Shoreline Stabilization and Protection Strategies																
Z5.SS.1	Stabilize severe and moderate streambanks along Kids Creek noted in the Kids Creek Action Plan. *See Zone 4 Tasks*	1.1, 1.2	High	30 sites by 2018	Included in Zone 4 Task											
Z5.SS.2	Work with residents and municipalities in the Kids Creek subwatershed to install riparian buffers where possible.	1.1	Medium	--	$75/LF											
Z5.SS.3	Work with the DEQ to develop and implement plans to stabilize sections of Kids Creek stream channel where needed to restore natural function, eliminate erosion, and transport storm events effectively. This will most likely entail the creation of sections of two-stage ditches along the creek to match the pattern dimension and profile to that of other sections of the creek so it can reduce flow velocities on the banks and store more water during times of high flow. Site #1: Tributary A along 6th street and Elmwood Ave Site #2: Kids Creek main branch u/s of Silver Lake Road	1.1, 1.2	High	Site 1 - by 2019 Site 2 - by 2023	Site 1 - $250,000 Site 2 - $500,000											
Z5.SS.4	Monitor streambanks upstream of Union Street Dam to determine if they are slumping and how severe the problem may be. If necessary, work with the City of Traverse City and other stakeholders to determine a solution.	1.1, 1.2	Medium	Set up monitoring benchmarks by 2017	TBD (depends on BMP chosen)											
Z5.SS.5	Work with the City of Traverse City and the Downtown Development Authority to stabilize river access sites from Boardman Lake to the Mouth.	1.1, 1.2	Medium		TBD (depends on BMP chosen by City)											
Stormwater Strategies																
Z5.St.1	Complete monitoring and assessments in the Kids Creek subwatershed to determine potential priority locations for LID BMP installations to reduce stormwater inputs to creek.	1.1	High	Complete by 2020	$40,000	TWC MDEQ										
Z5.St.2	Implement stormwater BMPs in Kid's Creek including low impact design elements, riparian buffers and filter strips, and stormwater filtering and retention systems.	1.1; 1.2	High	One large-scale BMP/yr	~$200,000/project $2,000,000 total	TWC MDEQ EPA LGOV										
Z5.St.3	Implement stormwater BMPs in the urban areas of Traverse City and Garfield Township to reduce runoff impacts to Boardman River and Lake.	1.1	Medium	1st project by 2019 2nd project by 2022 3rd project by 2025	$200,000/project $600,000 total	TWC LGOV DEQ										
Transportation/Stream Crossings Strategies																
Z5.TSX.1	Install road crossing BMPs at priority locations in the Kids Creek subwatershed. *See general road crossing task for details*	1.1, 1.4	Medium	1st crossing by 2019 2nd crossing by 2022 3rd crossing by 2025	~$200,000/crossing (Depends on site & Selected BMP) ~ $600,000 total	TWC GTCD TC LGOV NRCS RC										
Z5.TSX.2	Replace the South Airport Road crossing if deemed necessary by monitoring accumulated sediments *See Monitoring task in Zone 4 related to Sabin Dam removal*	1.1, 1.4	Medium	Depends on monitoring results	~$4 million	GTCD RC										
Planning, Zoning, and Lane Use Strategies																

	Zone 5 Actions	Goals/ Objectives Addressed	Priority	Milestones	Estimated Costs	Potential Partners	Y1: 2017	Y2: 2018	Y3: 2019	Y4: 2020	Y5: 2021	Y6: 2022	Y7: 2023	Y8: 2024	Y9: 2025	Y10: 2026
Z5.PZL.1	Continue discussions and work with the City of Traverse City to determine whether storm water may be addressed through alternative funding structures, such as a fee system or public utility, to improve water quality in priority areas and incentivize LID projects.	1.1	High		S = $5,600	TWC TC										
Z5.PZL.2	Upgrade or update applicable ordinances for Traverse City and Garfield Township to accommodate and encourage more innovative forms of stormwater management, including LID.	1.1, 1.2, 1.4	High	Ongoing	S = $3,000/yr $30,000 total	TWC TC Garf.Twp										
Z5.PZL.3	Work with Traverse City on recommendations to update ordinances to improve preservation of urban vegetation resources to manage stormwater, particularly along shorelines, and ensure adequate water setbacks for all districts	1.1, 1.2, 1.4	High	Recommendations made by 2019	S = $30,000	TWC TC										
Habitat, Fish, and Wildlife Strategies																
Z5.HFW.1	Hire a professional consultant or firm to lead stakeholders through a neutral process that results in a recommendation to the MDNR and GTB regarding the passage of non-native Great Lakes fish in the Boardman River above Union Street Dam.	1.2, 1.4	High	By 2017	$25,000	BDIT										
Human Health Strategies																
Z5.HH.1	Conduct E.Coli monitoring on Kids Creek in Traverse City urban areas.	1.1	Low	Monitoring every 5 years	$2,000	TWC GTHDept TC										
Hydrology and Groundwater Strategies																
Z5.HG.1	Implement cleanup or remediation efforts in the Boardman Lake area to improve water quality following recommendations made in WQ Monitoring task below.	1.1	Low	Funding secured and project initiated by 2024	TBD	TWC TC GarfTwp MDEQ EPA										
Water Quality Monitoring Strategies																
Z5.WQ.1	Conduct monitoring to evaluate current status of areas in southern Boardman Lake and downstream of Boardman Lake outlet previously identified in the Boardman Lake WS Plan as contaminated.	1.1	Low	Monitoring by 2021 Remediation started by 2023	Monitoring: $25,000 Remediation: TBD	TWC TC MDEQ EPA										
Z5.WQ.2	Seek long-term funding for the installation and support of a USGS gauging station below Union Street Dam	1.1	High	Installed by 2017	$25,000	TC GTB USGS										
Invasive Species Strategies																
Z5.IS.1	Design and implement Union Street Dam modifications to limit passage of sea lamprey upstream.	1.4	Low	By 2025	>$2million	BDIT										

Chapter in GTBWPP

7.4 Information and Education Strategy

- Already a lot of general tasks in GTBWPP re stormwater
- Any specific for TC (i.e. general education, stormwater utility)

Chapter in GTBWPP

7.5 Evaluation Procedures

- Add Monitoring Section related to evaluation... think about monitoring needs for TC stormwater and Kids creek
- Discuss Monitoring category tasks from Chapter 7