Grand Rapids TMDL Implementation Plan

for *E. coli* and Aquatic Life Uses

Grand Rapids HUC-12 Subwatersheds:

0405000605 -02, -07, -12 *(mainstem Grand River)*

0405000605 -04, -06, -10 *(Indian Mill, Plaster, Buck Creeks)*

December 2019

Grand Rapids TMDL Implementation Plan for *E. coli* and Aquatic Life Uses

December 2019

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EXECUTIVE SUMMARY

The purpose of the Total Maximum Daily Load (TMDL) Implementation Plan is to develop a specific course of action on how to proceed in identifying and removing pollutant sources to meet TMDL requirements within the City. An overall watershed approach is used, which incorporates the City's ambient monitoring data into a source assessment. This data-driven framework evaluates water quality patterns with a focus on potential relationships between TMDL pollutants and other parameters measured as part of the City's program.

A key to the success of this plan depends on identifying critical areas; specifically identify those locations where projects can be implemented, which will produce measurable results and meet the TMDL requirements. The City's monitoring information represents the starting point to understand the water quality conditions and to identify critical areas.

In the springtime during high flow conditions, bacteria loads appear to be elevated and quite variable in the Grand River upstream of the City. This indicates that bacteria concentrations in the Grand River under high flow conditions are largely a function of sources upstream of the city (but not suggesting the City has no effect either). Exceedances of Michigan's bacteria criteria have been observed in the Grand River throughout the recreation season (May to October) which is the focus of the TMDL. Monitoring data suggests bacteria is entering the river with runoff from the urban area during the recreation season and causing the water quality exceedances.

For the Plaster Creek biota TMDL, fish and macroinvertebrate communities were rated poor due to impaired habitat as affected by elevated siltation and sedimentation. Siltation and sedimentation were attributed to excessive erosion due to flashy flow conditions which are the result of runoff from the urban area.

Hence the bacteria problems during the recreation season (May through October) and the biota problems in Plaster Creek are both due to runoff from the urban areas. Runoff from urban areas changes the natural hydrology and is predominately a function of the impervious surfaces. Hence from a hydrology perspective, the focus is on managing runoff from impervious surfaces for at least the water quality treatment volume (1-inch of rainfall) for bacteria and the channel protection (2-year) event for biota.

Implementing bacteria source controls is recommended first, then consider structural controls if the source controls are unsuccessful. Source controls related to correcting human sanitary sources are particularly important. The following priority order is recommended to address bacteria sources.

> ***Priority 1***. Prioritize human sanitary sources of bacteria first given the greater public health risks they may present. Examples of these sources include leaky sewer pipes, sanitary sewer connections, homeless encampments, waste dumping (e.g. RV discharges), and septic systems.
>
> ***Priority 2***. The second priority is to control non-human anthropogenic sources of bacteria. Examples of these sources include pet waste, fertilizers, trash, and leakage from dumpsters and garbage trucks.
>
> ***Priority 3***. Urban wildlife attracted due to anthropogenic impacts on the landscape and environment is the third priority. This includes example sources such as rodents attracted to trash and waterfowl attracted to open spaces.
>
> ***Priority 4***. The forth and lowest priority is to control non-anthropogenic sources. Examples of these sources include urban wildlife, plants, soils and decaying organic material.

With regards to the biota TMDL for Plaster Creek the primary strategy is to minimize directly connected impervious areas and manage stormwater runoff for at least the channel protection criteria. Management measures that emphasize retaining runoff are the priority. Emphasis should also be placed on removing sediment from the urban runoff.

Continuation of the City's instream water quality monitoring program is recommended for evaluating compliance with the TMDL program. The City participated in developing a *Monitoring Manual for NPDES MS4 TMDL Waterbodies in the Lower Grand River Watershed* with LGROW (2015) which identifies the specifics of the monitoring plan.

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ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
AMP	Asset Management Plan
BMP	Best Management Practice
cfs	cubic feet per second
CID	Corridor Improvement District
CIP	Capital Improvement Project
CMP	Comprehensive Management Plan
CNT	Center for Neighborhood Technology
EGLE	Michigan Department of Environment, Great Lakes, and Energy
FAU	Federal Aid Urban
GIS	Geographic Information System
GVMC	Grand Valley Metropolitan Council
GVSU	Grand Valley State University
HSPF	Hydrologic Simulation Program FORTRAN
HUC	Hydrologic Unit Code
I&E	Information and Education
L-THIA	Long-Term Hydrologic Impact Analysis
LGROW	Lower Grand River Organization of Watersheds
LSPC	Loading Simulation Program C++
MDEQ	Michigan Department of Environmental Quality
MDOT	Michigan Department of Transportation
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
NPS	nonpoint source
PASER	Pavement Surface Evaluation and Rating
P51	Procedure 51
PBC	partial body contact
NSC	National Stormwater Calculator
OIALW	Other Indigenous Aquatic Life and Wildlife
R-B Index	Richards-Baker Flashiness Index
SAW	Stormwater, Asset Management, and Wastewater
SOC	Stormwater Oversight Commission
SWMM	Storm Water Management Model
SWPPP	Storm Water Pollution Prevention Plan
TBC	total body contact
TIP	TMDL Implementation Plan
TMDL	Total Maximum Daily Load
TP	total phosphorus
TSS	total suspended solids
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UV	ultraviolet
WMP	Watershed Management Plan
WPCRF	Water Pollution Control Revolving Fund
WRRF	Water Resource Recovery Facility
WQS	Water Quality Standards

1.0 INTRODUCTION

The purpose of the Grand Rapids Total Maximum Daily Load (TMDL) Implementation Plan is to develop a specific course of action on how to proceed in identifying and removing pollutant sources to meet TMDL requirements within the City. An overall watershed approach is used, which incorporates information from the City's ambient water quality monitoring program into the source assessment. This data-driven methodology evaluates patterns from sample results, which includes a focus on potential relationships between TMDL pollutants and other parameters measured as part of the City's program.

This plan addresses three TMDLs developed by the State of Michigan for stream segments located within the City of Grand Rapids. One TMDL is for *E. coli* on the mainstem Grand River from Fulton Street to the Veterans Memorial Drive boat ramp downstream of the City's Water Resource Recovery Facility (WRRF). The two other TMDLs address water quality concerns in Plaster Creek; one for *E. coli* and the second for aquatic biota using total suspended solids (TSS) as the target indicator. All three TMDLs suggest that urban stormwater is the primary source of concern. Several other TMDLs have been established, which are either on the fringe of the City or are in the general vicinity. Information from these TMDLs has been considered, particularly as targets relate to overall implementation needs for the City. The applicable TMDLs include:

- *E. coli* in Plaster Creek, June 2002
- *E. coli* for Buck Creek, March 2006 (limited to a fringe portion of the City)
- *E. coli* for the Grand River, August 2006
- Biota for Plaster Creek, July 2002

EGLE developed a statewide *E. coli* TMDL in 2019 however the statewide TMDL indicates that "EGLE intends to leave the remaining watershed-based *E. coli* TMDLs intact at this time because the allocations are still appropriate, and the documents contain valuable information on the sources at the time they were approved." Hence the previously developed *E. coli* TMDLs in Kent County still apply.

There are also two statewide TMDL assessments for mercury (June 2018) and PCB (August 2013). These TMDLs cover the inland water bodies in the state primarily impacted by atmospheric deposition of the pollutant of concern. An implementation plan to address the atmospheric deposition of these pollutants is not required under the NPDES MS4 permit program at this time.

Table 1 summarizes the water quality targets identified in the TMDL assessment documents.

Table 1 TMDL Targets

Parameter	Target
E. coli	130 *E. coli* per 100 mL as a 30-day geometric mean and 300 *E. coli* per 100 mL as a daily maximum to protect the total body contact use from May 1 through October 31.
Biota (sediment)	Primary numeric target is based on the Procedure 51 biological community assessment protocol. The biota TMDL target is to achieve a macroinvertebrate community with an acceptable, reproducible score equal to or greater than -4.
	A stream habitat quality assessment will also be used. A habitat assessment target score of 65 will be used to represent adequate control of anthropogenic sediment sources to improve habitat quality and the biological community.
	Secondary target is a mean annual in-stream Total Suspended Solids (TSS) concentration of 30 mg/L. Achievement of the biological and habitat targets may override this secondary target.

2.0 WATER QUALITY ANALYSIS

Two primary sources of data are used as a part of the water quality analysis. The first primary source is the data collected by the Michigan Department of Environment, Great Lakes, and Energy (EGLE), formerly the Michigan Department of Environmental Quality (MDEQ) specifically for the development of the TMDLs. The second primary source is from the City's instream water quality monitoring program. Additionally, data from the USGS was used principally for the flow information. This section reviews the data from each source and provides some insights and observations along with prioritization information and a summary of the key points.

2.1 EGLE

The Michigan Department of Environment, Great Lakes, and Energy (EGLE), formerly the Michigan Department of Environmental Quality (MDEQ), periodically collects water quality data for a variety of reasons. One of the reasons is to assist with the development of TMDLs for example, *E. coli* surveys of Plaster Creek (2001) and the Grand River (2004). Sample results for the Grand River show a wide range of spatial and temporal variability, as indicated in Figure 1. In addition to *E. coli* concentrations at the five sampling locations, this figure also depicts daily rainfall amounts and flow in the Grand River.

The biota TMDL developed for Plaster Creek uses TSS as the target indicator to address issues associated with stormwater. Altered hydrology resulting from excess runoff affects water quality, channel stability, stream habitat, aquatic biology, and the delivery of pollutant loads. Stream flashiness, expressed through the Richards-Baker (R-B) Index, can be used to connect aquatic biology and channel stability concerns in Plaster Creek with stormwater management strategies considered.

The TMDLs connected water quality data with flow conditions using a duration curve framework to determine target reduction needs. This methodology clusters ambient monitoring information into five flow condition zones (high, moist, mid-range, dry, and low). For example, the City's Grand River bacteria sampling results at Wealthy Street are shown as a water quality duration curve in Figure 2. Note that at this location, most water quality criteria exceedances occur during runoff events under high flow and moist conditions.

Hydrology plays an important role relative to both the bacteria and biota TMDLs. Management measures that retain stormwater runoff volume will reduce bacteria loads delivered to the Grand River and Plaster Creek from the City's storm sewer system. Retaining the volume produced by most rain events (e.g., up to the two-year, 24-hour runoff storm or bank full conditions) emphasizes channel protection, influenced by stream flashiness, which in turn affects aquatic habitat and biology.

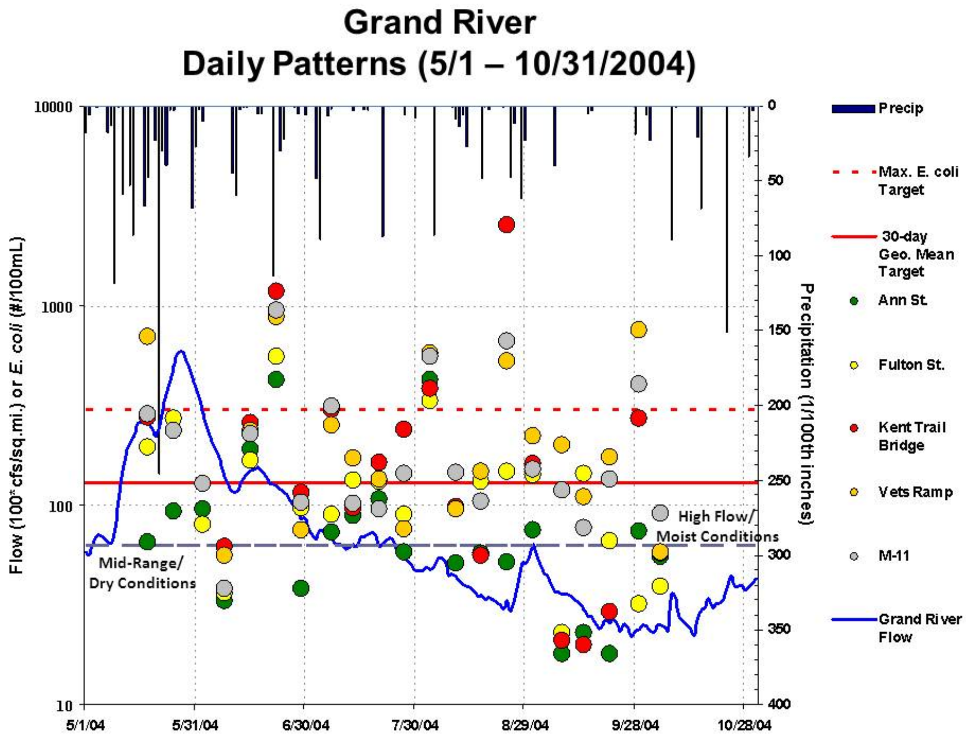

Figure 1 Grand River Bacteria Concentrations (MDEQ 2004 survey)

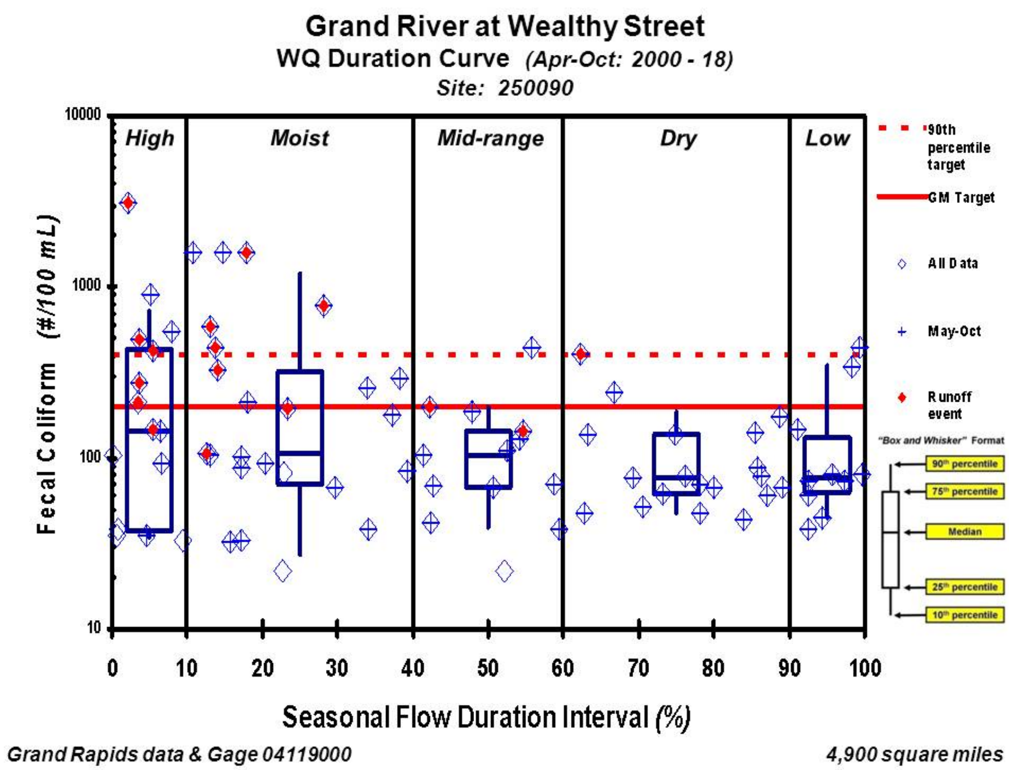

Figure 2 Grand River Bacteria Water Quality Duration Curve

2.2 CITY

The City monitors water quality at 15 locations in the Grand Rapids area; six on the mainstem Grand River and nine tributary sites (Figure 3). The spatial distribution of bacteria sampling results (Figure 4) during the recreation season (May to October) helps to identify potential areas of concern. Although Michigan's bacteria water quality standards are based on *E. coli*, the City's fecal coliform data can be compared to the older criteria to describe patterns and highlight areas of interest. The fecal coliform target values are noted in Figure 4 for general reference.

Based on the long-term monitoring information, ambient concentrations at the Northland site provide an estimate of bacteria levels in the Grand River before it enters the City. These levels increase at Wealthy Street; the next downstream location sampled by Grand Rapids and the first within the city limits. This increase could be attributed to: 1) the four monitored tributaries (Rogue River, Mill Creek, Indian Mill Creek, or Coldbrook Storm Drain) as all show concentrations above the Northland site; 2) several major stormwater outfalls located within the City upstream of Wealthy Street (including the Coldbrook Storm Drain); or 3) most likely some combination of all these inflows.

Bacteria levels continue to increase at the City's next downstream monitoring location, the Railroad North and Railroad South sites. Inflows between Wealthy Street and the two Railroad Bridge monitoring stations include several additional major stormwater outfalls, Plaster Creek, and the Grand Rapids WRRF. Relative to bacteria concentrations in the Grand River, the City's WRRF includes ultraviolet (UV) disinfection as part of its wastewater treatment process (thus, minimizing its effect as a potentially significant source). The elevated bacteria levels continue downstream to the City's next monitoring site; the M-11 (Wilson Avenue) bridge.

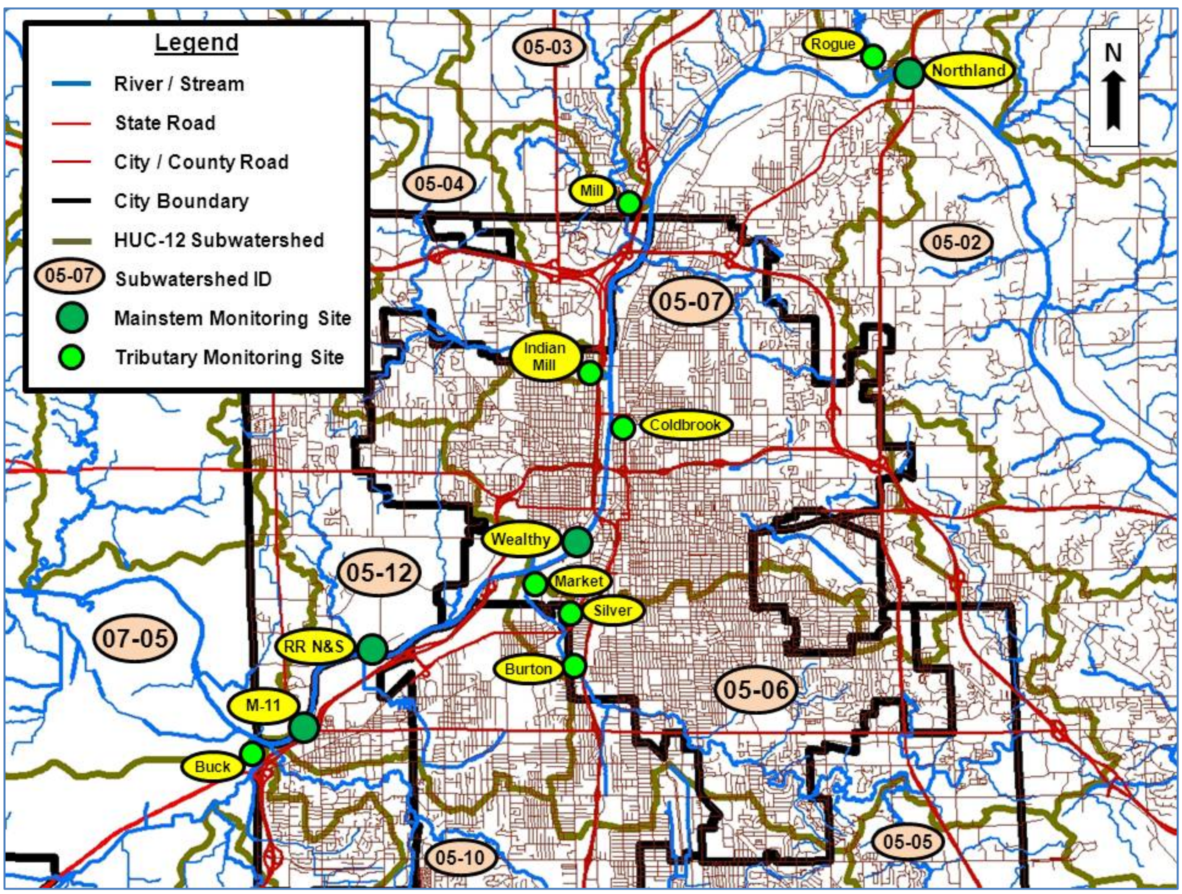

Figure 3 Grand Rapids Area Water Quality Monitoring Locations

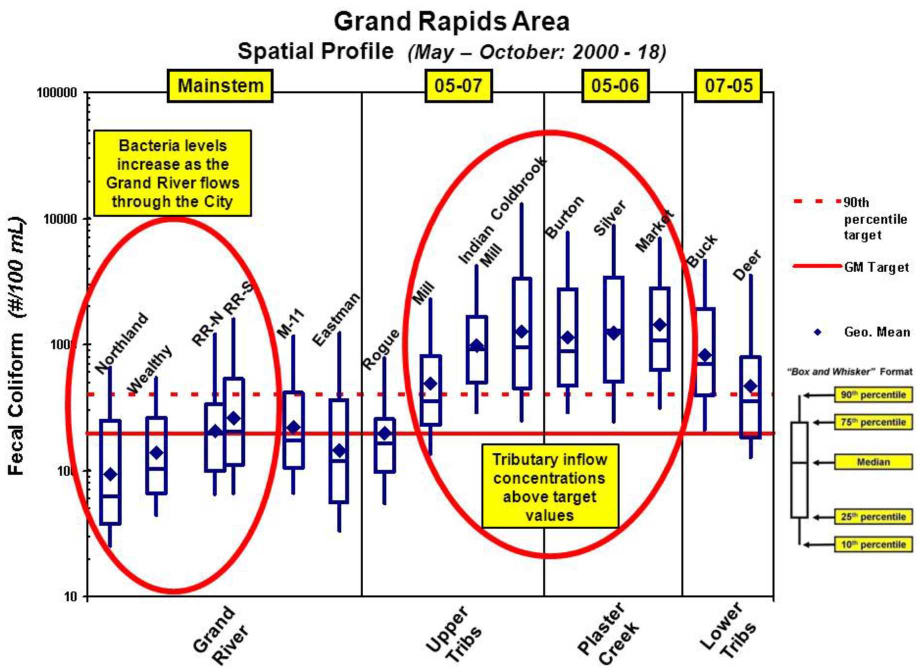

Figure 4 Spatial Distribution of Bacteria Concentrations Across Grand Rapids Area Waters

Exceedances of Michigan's bacteria criteria have been observed in the Grand River throughout the recreation season (May to October). Monitoring data suggests that the effect of the stormwater system on the Grand is most noticeable when "spike" loads elevate bacteria levels following summer storms. The magnitude of that effect appears greater from July through October (i.e., when dry and low flow conditions in the Grand occur more often and for longer periods, which indicates less river water to dilute stormwater).

Data collected by the City in 2016 indicates that fecal coliform target exceedances started in June of that year (Figure 5); the highest occurred most frequently at the Railroad North site. At the same time, flows in the Grand River were consistently in the "Mid-Range/Dry Condition" area (as indicated by the gray dashed line) from June through September (with an exception during one week of extended rainfall across the region). It is also worth noting that bacteria concentrations at the Northland location (above the influence of Grand Rapids) were consistently low. Results of the City's tributary water quality monitoring data during the same period in 2016 are shown in Figure 6. Unit area stream flows for Plaster Creek are included in the graph. These two figures provide a visual illustration that tributary flows and concentrations are higher during runoff events. Because flows in the Grand are lower, the potential to elevate pollutant levels in the river is greater.

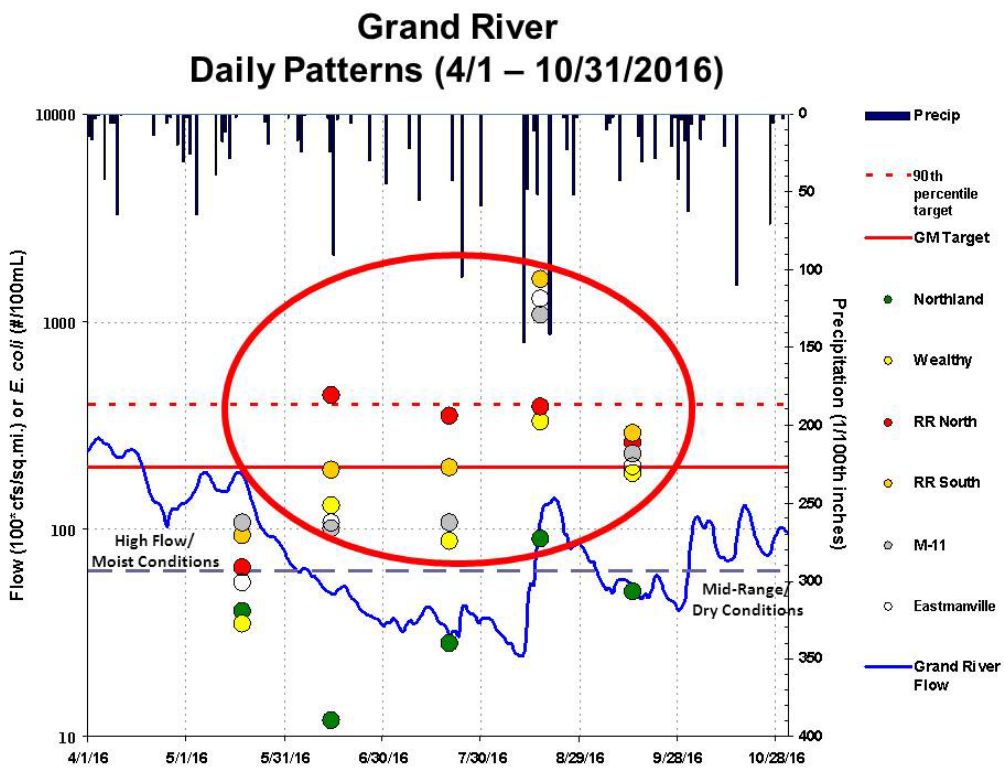

Figure 5 Grand River Bacteria Concentrations (2016)

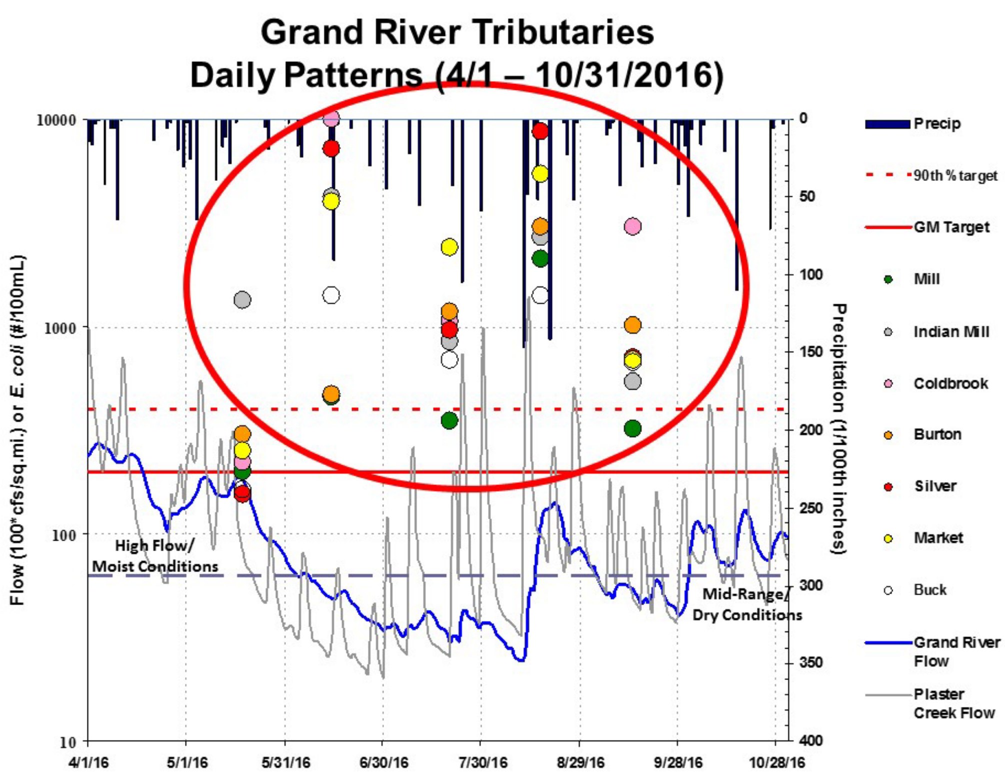

Figure 6 Grand Rapids Area Tributaries Bacteria Concentrations (2016)

Hydrology is a key factor in determining effective implementation strategies that address water quality criteria exceedances in the Grand River and Plaster Creek. Flows vary seasonally, as well as in response to precipitation events based on land use and watershed size. The U.S. Geological Survey (USGS) has measured flow in the Grand River at Grand Rapids for decades. This information can be used to depict seasonal variation, as shown in Figure 7 (note that flows are expressed on a unit area basis for comparison to other watersheds).

In a drainage system such as the Grand by the time it reaches Grand Rapids, flow is typically driven by large watershed-scale factors that influence groundwater levels and runoff (e.g., snowmelt, drought, regional weather systems). In the mid- to late-summer months, flows are generally stable. It is during these dry or low flow conditions that water quality in the Grand River is more prone to the effects of local stormwater runoff. By comparison, smaller watersheds, such as Plaster Creek, are flashier and have higher unit area flows in response to storm events (Figure 8). These effects are even more pronounced if the contributing drainage area contains greater percentages of impervious surfaces (e.g., priority stormwater outfalls).

The duration curve framework provides a method to examine flow and water quality relationships. Monitoring data can be combined with flow estimates to develop a load duration curve, as shown in Figure 9 for the City's Grand River site at Wealthy Street. In this instance, median loads exceed the geometric mean target under high flow conditions. A spatial profile of bacteria load patterns at the City's other Grand River monitoring locations under high flow conditions offers some perspective, as shown in Figure 10. Bacteria loading targets for the Wealthy Street site are included simply to provide a frame of reference. Potentially significant inputs are also included in this graph.

The variation in bacteria loads between the monitoring locations is not unexpected. However, these loads appear to be elevated and quite variable at the Northland site. This indicates that bacteria concentrations in the Grand River under high flow conditions are largely a function of sources above Grand Rapids (but not suggesting the City has no effect either).

As flows in the Grand become progressively lower, the potential effect of stormwater inputs downstream of the Northland site become more pronounced as the river moves through the City. Spatial profiles of dry and low flow conditions are shown in Figure 11 and Figure 12. Median and 90th percentile loads for each duration curve zone are summarized in Table 4, both using the City's ambient monitoring data and the 2004 EGLE survey results. These graphs and the table indicate that the City's TMDL implementation efforts should focus on stormwater management activities that reduce bacteria loads during the more stable Grand River flow conditions, particularly the months between July and October.

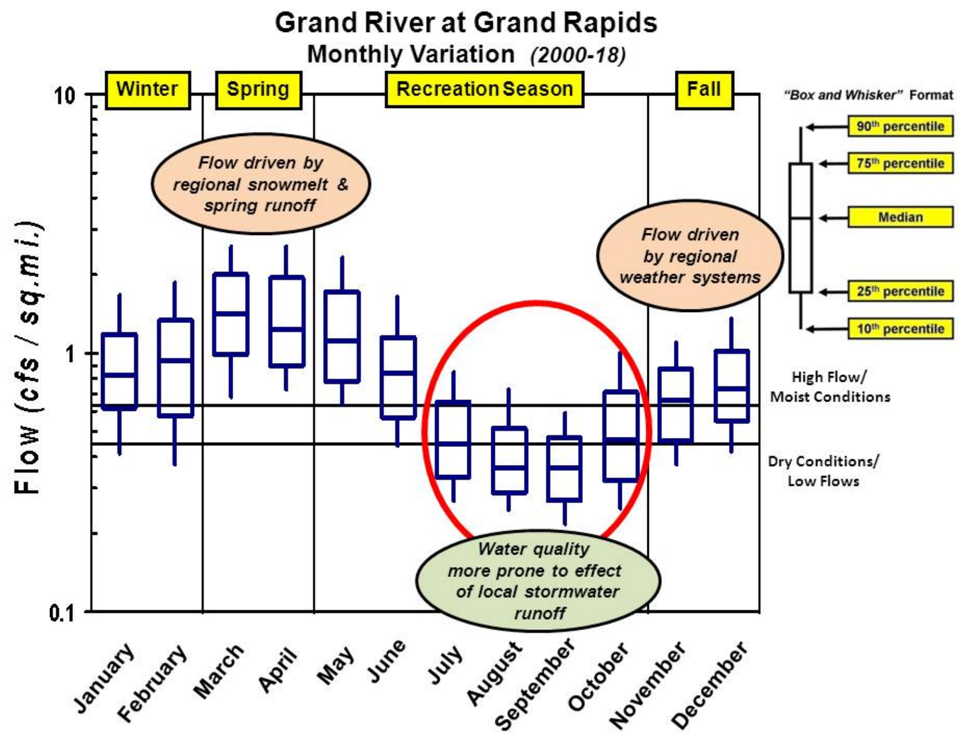

Figure 7 Grand River Seasonal Flow Patterns

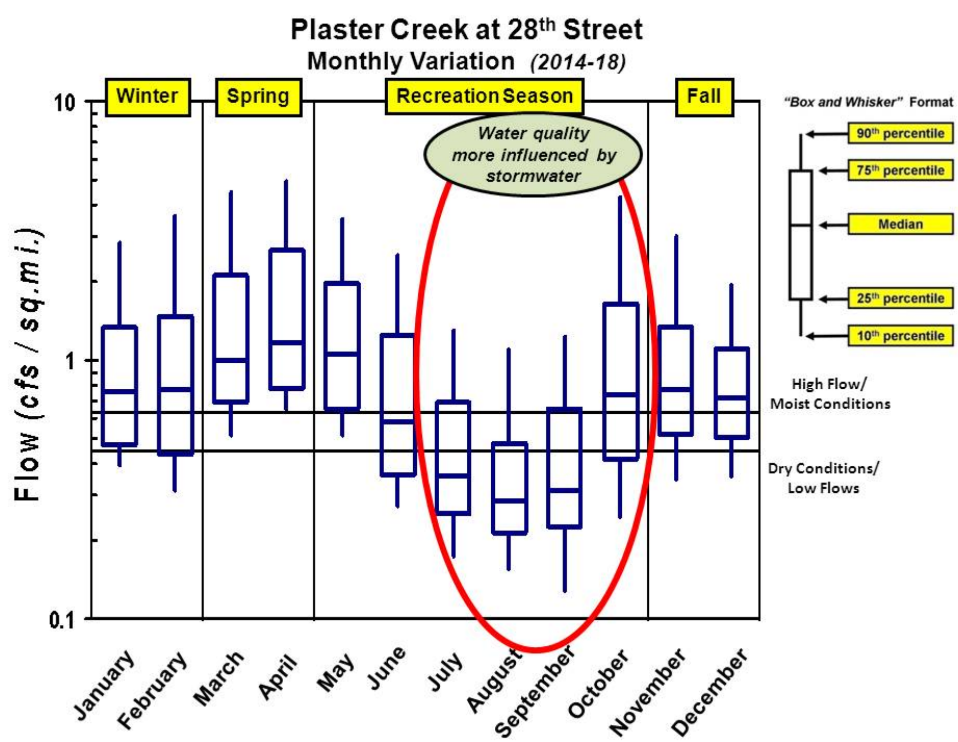

Figure 8 Plaster Creek Seasonal Flow Patterns

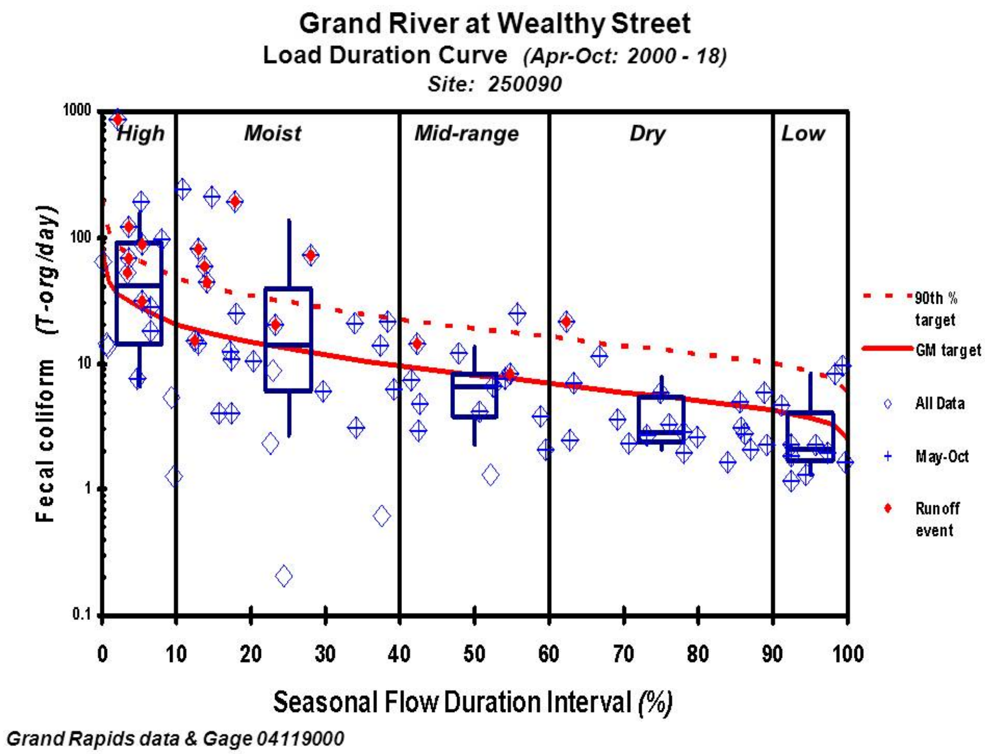

Figure 9 Grand River Bacterial Load Duration Curve

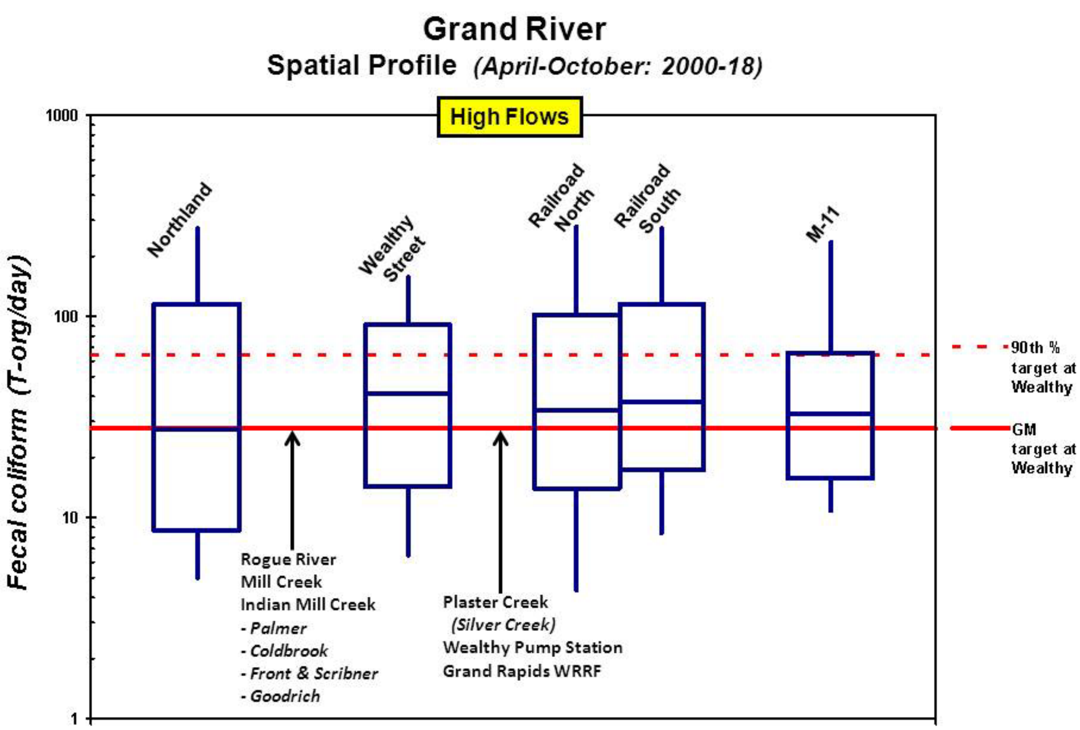

Figure 10 Spatial Distribution of Grand River Bacteria Loads Under High Flow Conditions

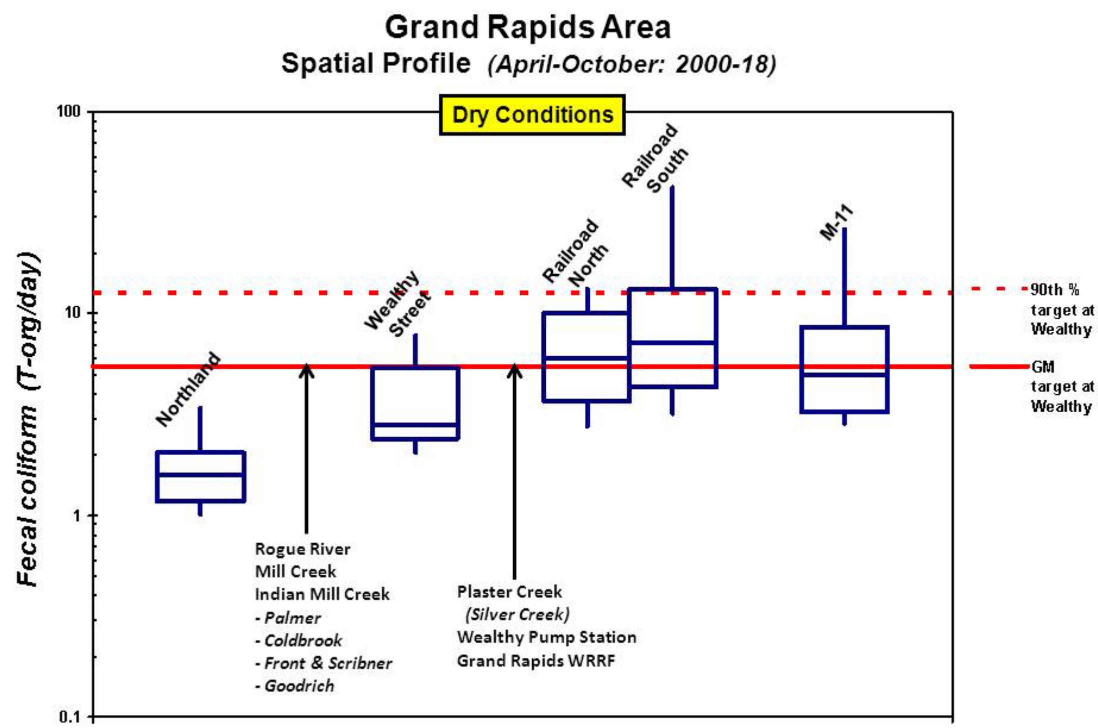

Figure 11 Spatial Distribution of Grand River Bacteria Under Dry Conditions

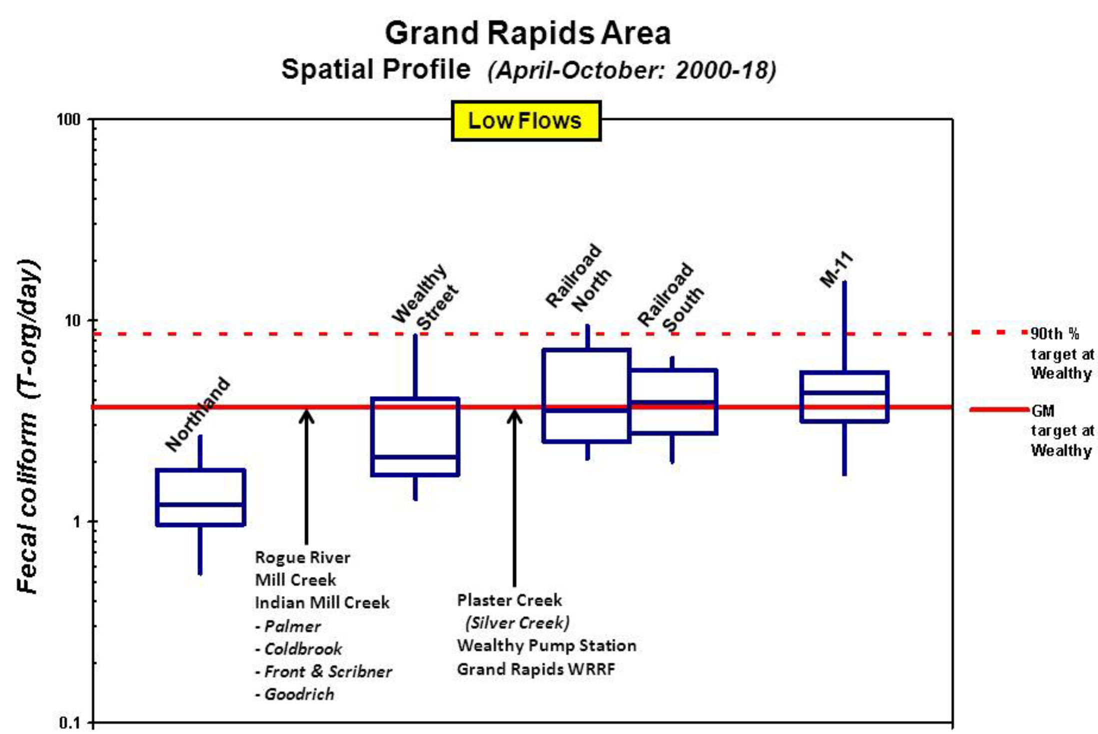

Figure 12 Spatial Distribution of Grand River Bacteria Under Low Flow Conditions

Table 2 Grand River Bacteria Load Summary

Location	Bacteria Load *(T-org/day)*									
	Median					90th Percentile				
	High	*Moist*	*Mid-Range*	*Dry*	*Low*	*High*	*Moist*	*Mid-Range*	*Dry*	*Low*
Grand Rapids Data										
Northland	27.3	12.0	**3.2**	**1.6**	**1.2**	276	76	**24.5**	**3.4**	**2.7**
Wealthy	41.7	14.1	**6.6**	**2.8**	**2.1**	156	137	**13.7**	**7.8**	**8.4**
RR North	34.2	17.9	**8.8**	**6.0**	**3.5**	277	158	**25.4**	**13.3**	**9.4**
RR South	37.4	22.5	**10.8**	**7.2**	**3.9**	274	170	**34.4**	**42.5**	**6.5**
Wilson	32.9	22.0	6.9	5.0	4.4	233	147	25.4	26.1	15.4
DEQ 2004 Survey										
Ann	27.8	6.9	**9.7**	**1.4**	**0.9**	79	49	**33.5**	**4.2**	**3.6**
Fulton	32.0	10.3	**14.6**	**4.2**	**1.7**	162	62	**21.0**	**11.5**	**5.0**
KTB	46.6	15.8	**17.3**	**3.8**	**2.4**	100	153	**30.2**	**66.2**	**8.3**
VM Boat	46.2	16.4	18.3	5.5	4.3	262	104	33.5	18.0	20.8
Wilson	45.2	10.2	19.6	5.8	4.0	144	116	34.1	21.7	11.8

The lack of flow data on tributary sites monitored by Grand Rapids poses a major challenge in estimating relative loads that these subwatersheds contribute to water quality concerns in the Grand River. Results from SWMM and the Hydrologic Simulation Program FORTRAN (HSPF) watershed model for the Grand River help fill that gap by including load estimates from three key tributary sites monitored by the City: Plaster at Market, Coldbrook Storm Drain, and Silver Creek (Figure 13).

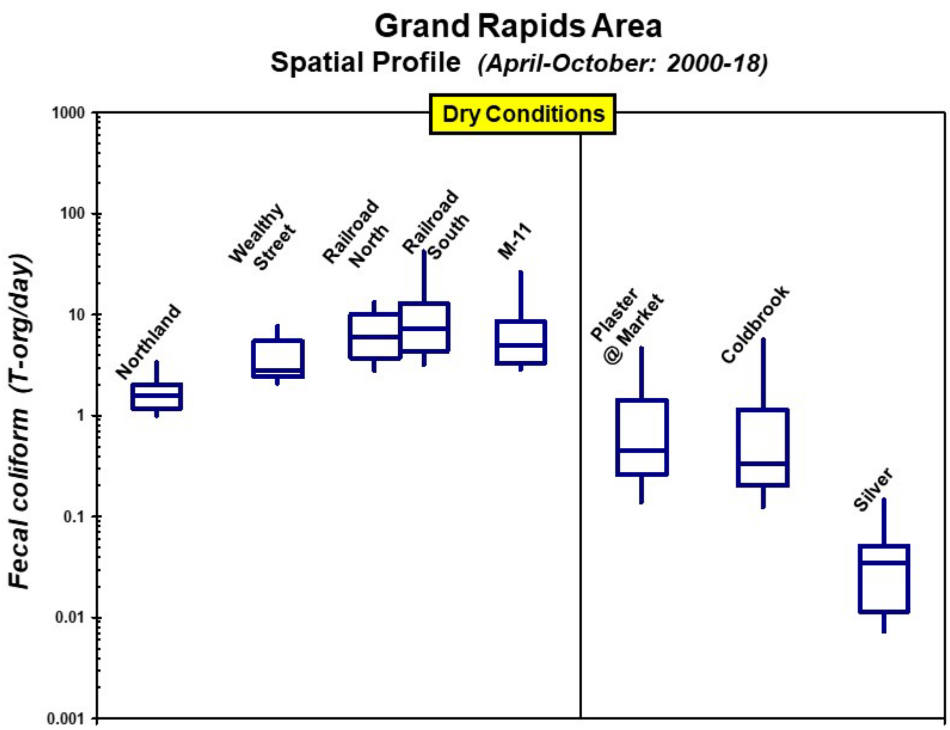

Figure 13 Relative Contribution of Monitored Tributary Bacteria Loads Under Dry Conditions

Model results combined with the City's ambient data can be used to estimate bacteria loads by duration curve zone for the same three key tributary sites (Figure 14 through Figure 16). Loads are clearly the greatest under high flow conditions, which highlights the importance of BMPs that reduce runoff volume. However, loads also exceed target values under mid-range, dry, and low flow conditions indicating the importance of other source types (e.g., illicit discharges, pet/urban wildlife waste build-up/washoff during lower intensity rain events, bacteria regrowth in catch basins/gravity storm sewers). Similar relationships likely exist for stormwater discharges from other priority outfalls.

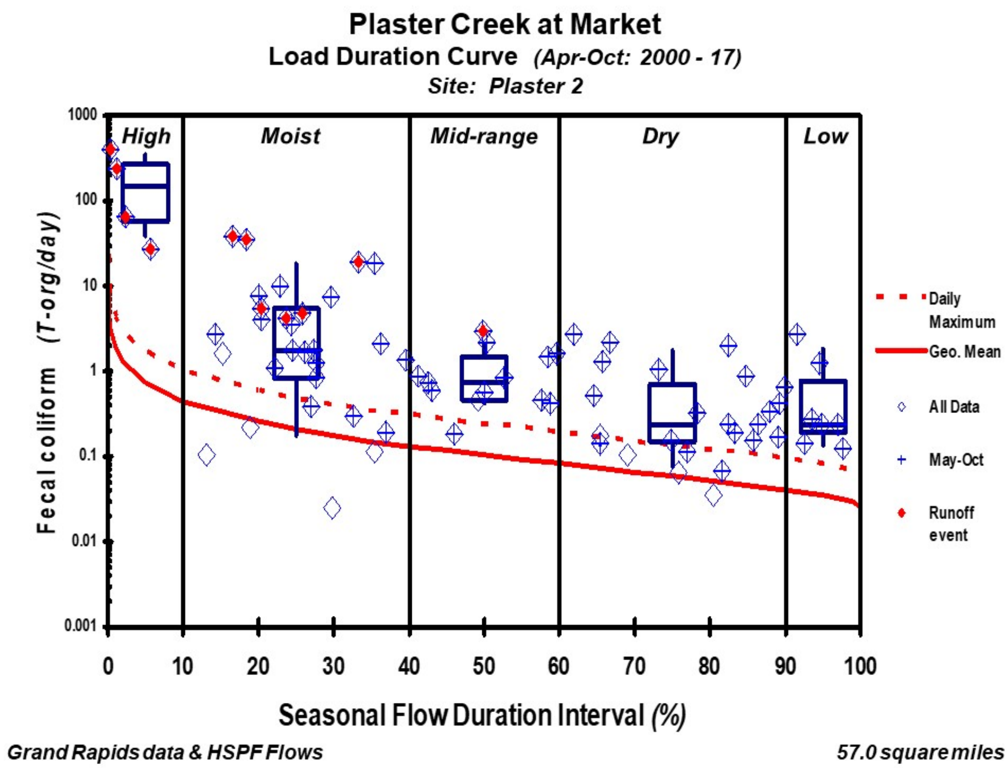

Figure 14 Plaster Creek Bacteria Load Duration Curve

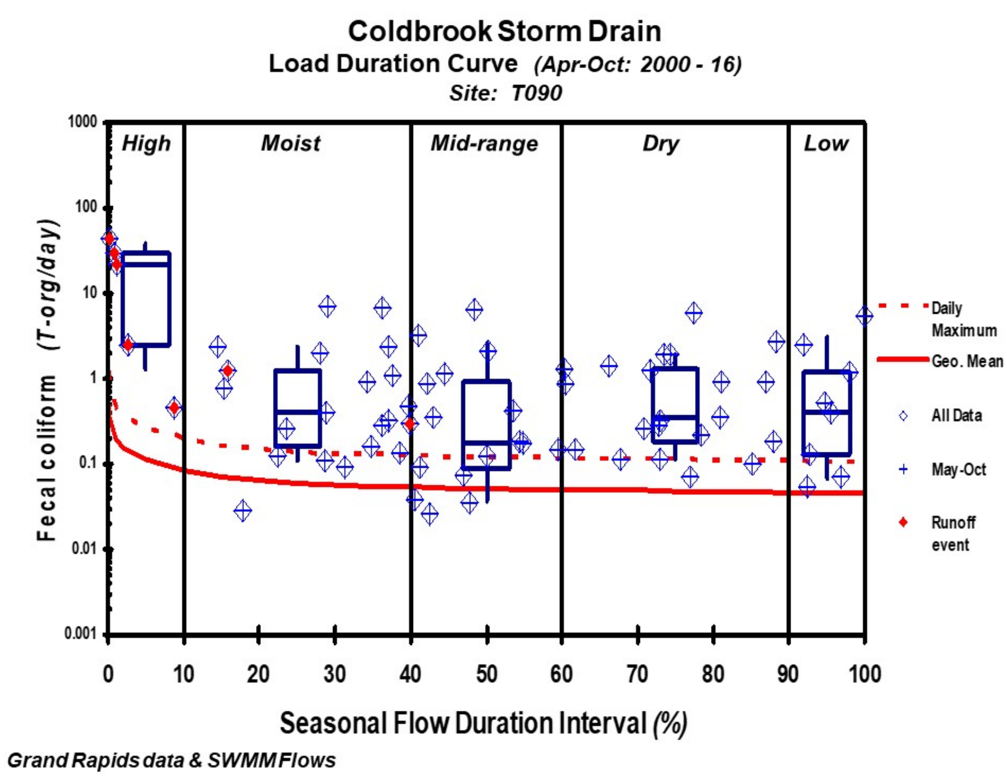

Figure 15 Coldbrook Storm Drain Bacteria Load Duration Curve

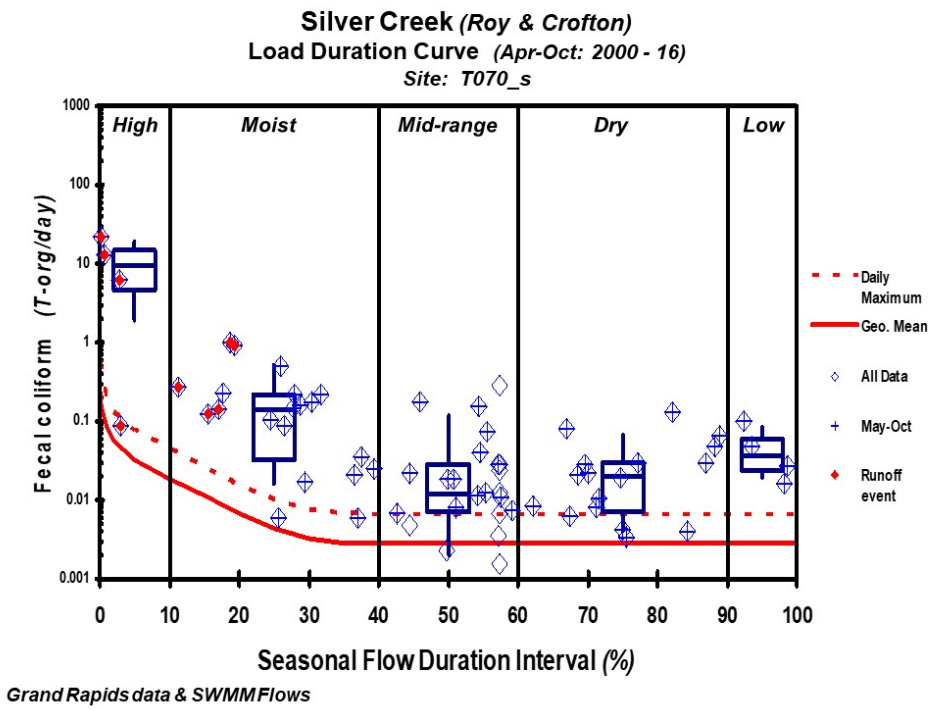

Figure 16 Silver Creek Bacteria Load Duration Curve

2.3 PRIORITIZATION

In terms of larger source areas, Plaster Creek clearly exerts a major effect on water quality in the Grand River. However, the 2001 DEQ survey indicated that bacteria levels were above criteria values across the entire length of the stream prior to entering the City (Figure 17). For that reason, prioritization is focused on basic information (e.g. metered/model flows, impervious surface composition) for key outfalls located within Grand Rapids.

Information from the stormwater collection system SWMM allows the prioritization of key outfalls to evaluate relative contribution (Figure 18). Coldbrook Storm Drain contributes the greatest amount from all outfalls (also reflected in the bacteria load analysis). In addition to Silver Creek, other priority outfalls based on volume include Front & Scribner, Goodrich, and the Wealthy Pump Station.

Impervious cover composition for priority outfalls provides an initial indication of potential opportunity areas; roads consistently represent a significant portion in each (Figure 19). This reflects the importance of the Vital Streets program in addressing water quality problems in Grand Rapids. It also highlights the need for integrated inventory information that brings multiple factors together. In addition to impervious surface composition, other factors including street type, mode, and corridor improvement district.

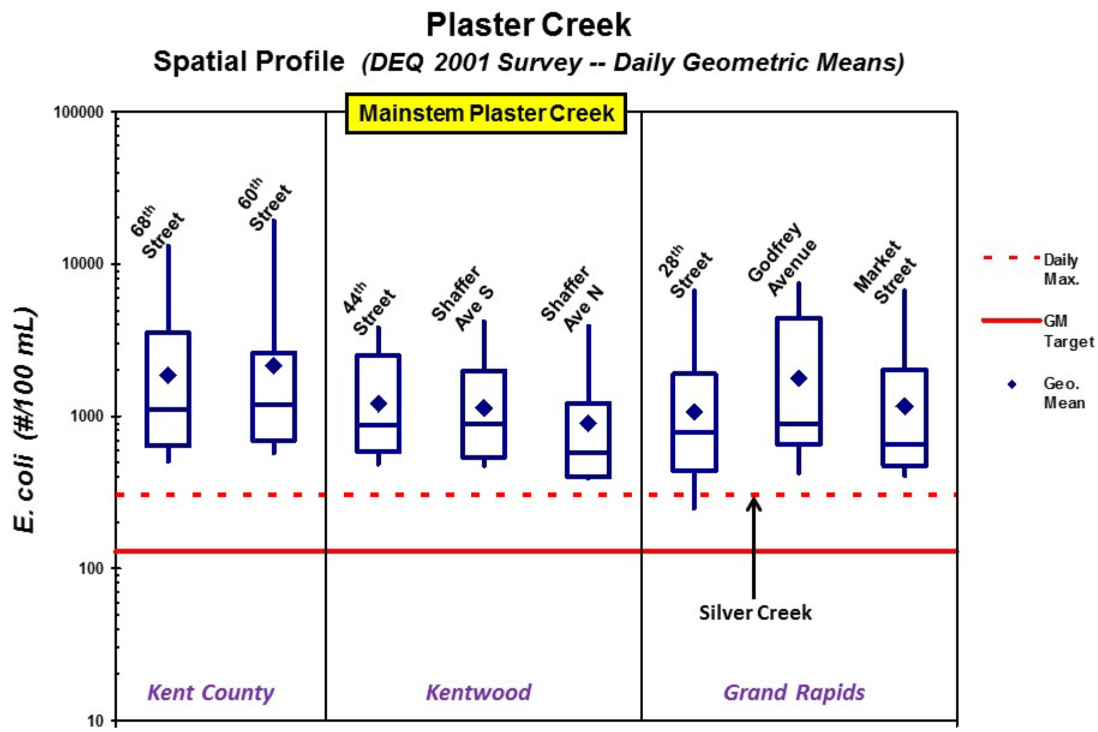

Figure 17 Spatial Distribution of Plaster Creek Bacteria Concentrations

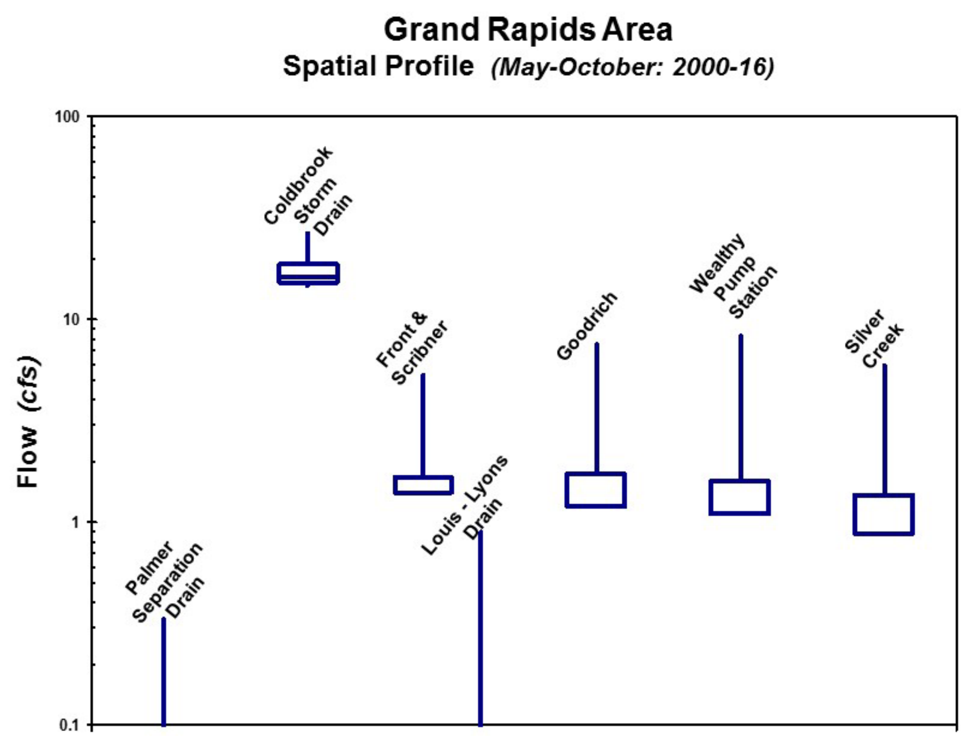

Figure 18 Key Outfall SWMM Flow Summary

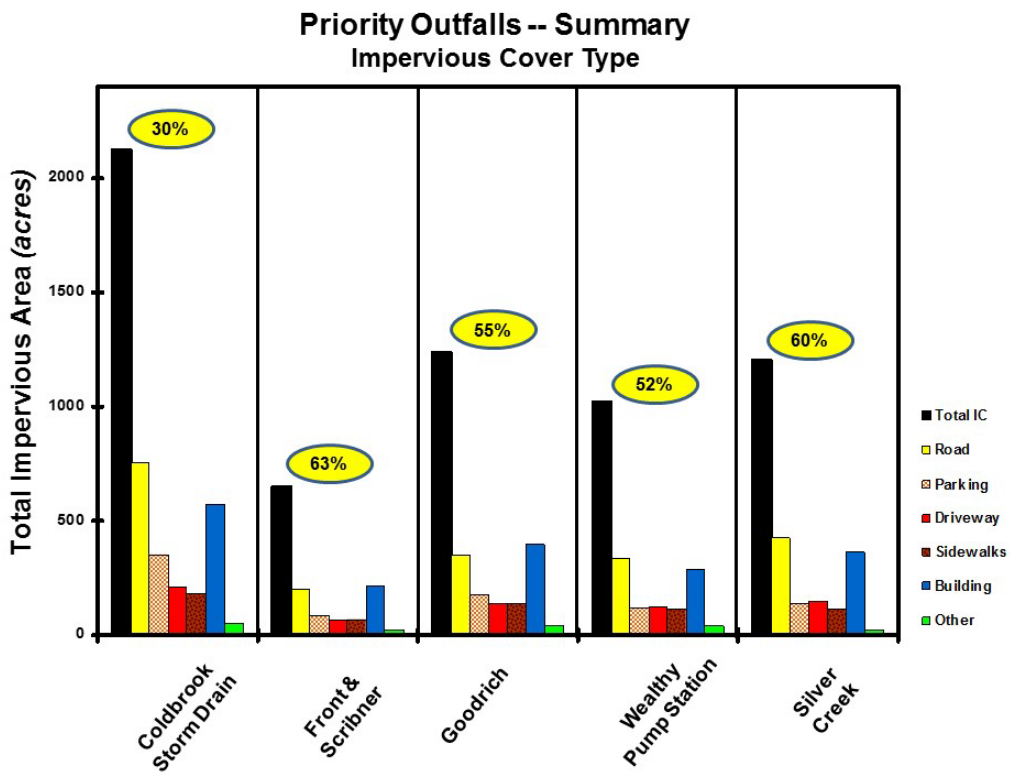

Figure 19 Impervious Surface Composition for Priority Outfalls

2.4 SUMMARY

A lot of water quality information and data analysis was presented. The purpose of this section is to summarize the take home message.

Bacteria (E. coli and fecal coliform)

- In the springtime during high flow conditions in the Grand River the loads appear to be elevated and quite variable at the Northland site which is the furthest upstream site along the river. This indicates that bacteria concentrations in the Grand River under high flow conditions are largely a function of sources upstream of Grand Rapids (but not suggesting the City has no effect either), Figure 10.
- Exceedances of Michigan's bacteria criteria have been observed in the Grand River throughout the recreation season (May to October) which is the focus of the TMDL. Monitoring data suggests bacteria is entering the river with runoff from the urban area.

Plaster Creek Biota

- Fish and macroinvertebrate communities were rated poor due to impaired habitat as affected by elevated siltation and sedimentation.
- Siltation and sedimentation were attributed to excessive erosion due to flashy flow conditions which are the result of runoff from the urban area.

Urban Runoff

- The water quality problems are due in large part to runoff from the urban areas.
- Runoff from urban areas is predominately due to the impervious surfaces.
- Hence from a hydrology perspective, the focus is on managing runoff from impervious surfaces for at least the water quality treatment volume (1-inch of rainfall) for bacteria and the channel protection (2-year) event for biota.

3.0 POLLUTANT SOURCES

The pollutant sources for the poor rated biota in Plaster Creek are due to urban hydrology. Runoff from urban areas is predominately due to the impervious surfaces. Bacteria is transported to the river from the urban runoff. A general list of potential bacteria sources is provided in Table 3 (adapted from UWRRC 2014).

Table 3 Potential Sources of Bacteria in Urbanized Areas

Category	Source/Activity
Municipal Sanitary infrastructure (piped)	Sanitary sewer overflows (SSOs), *not a significant source in Grand Rapids*
	Combined sewer overflows (CSOs), *not a significant source in Grand Rapids*
	Leaky sewer pipes (exfiltration)
	Illicit sanitary connections to MS4
	WWTPs (if inadequate treatment or upsets), *not a significant source in Grand Rapids*
Other Human Sanitary Sources (some also attract urban wildlife)	Leaky or failing septic systems
	Homeless encampments
	Porta-Potties
	Dumpsters (e.g. diapers, pet waste, urban wildlife)
	Trash cans
	Garbage trucks
Domestic Pets	Dogs, cats, etc.
Urban Wildlife (naturally-occurring and human attracted)	Rodents/vectors (rats, raccoons, squirrels, opossums)
	Birds (gulls, pigeons, swallows, etc.)
	Open space (foxes, beavers, feral cats, etc.)
Other Urban Sources (including areas that attract vectors)	Landfills
	Food processing facilities
	Outdoor dining
	Restaurant grease bins
	Bars/stairwells (washdown areas)
	Piers/docks
Urban non-stormwater Discharges (potentially mobilizing surface-deposited bacteria)	Power washing
	Excessive irrigation/overspray
	Car washing
	Pools/hot tubs
	Reclaimed water/graywater if not properly managed)
MS4 Infrastructure *the infrastructure is also the primary conveyance mechanism for most sources*	Illegal dumping
	Illicit sanitary connection to MS4 (also listed above)
	Leaky sewer pipes (exfiltration) (also listed above)
	Biofilms/regrowth
	Decaying plant matter, litter and sediment in the storm drain system
Recreational Sources	Bathers and/or boaters
	RVs (mobile)
Natural open Space/Forested Areas	Wildlife populations
	Grazing

4.0 REMEDIAL MEASURES

As discussed in Section 3.0, there are many different potential sources of bacteria. It is recommended to approach the potential sources of bacteria in the following priority ranking order.

Rank 1. Prioritize human sanitary sources of bacteria first given the greater public health risks they may present. Examples of these sources include leaky sewer pipes, sanitary sewer connections, homeless encampments, waste dumping (e.g. RV discharges), and septic systems.

Rank 2. The second priority is to control non-human anthropogenic sources of bacteria. Examples of these sources include pet waste, fertilizers, trash, and leakage from dumpsters and garbage trucks.

Rank 3. Urban wildlife attracted due to anthropogenic impacts on the landscape and environment is the third priority. This includes example sources such as rodents attracted to trash and waterfowl attracted to open spaces.

Rank 4. The forth and lowest priority is to control non-anthropogenic sources. Examples of these sources include urban wildlife, plants, soils and decaying organic material.

Implement source controls first, then consider structural controls if the source controls are unsuccessful. Source controls related to correcting human sanitary sources are particularly important.

4.1 BACTERIA REDUCTION STRATEGIES

Provided in Table 4 are general strategies to reduce bacteria loads as a part of stormwater control measures. The City is already implementing many of these strategies. The City's Stormwater Management Plan (SWMP) prepared by GVMC (2019) includes a list of proposed BMPs to achieve the pollutant load reduction requirements. The plan also assigned a priority of based on the anticipated impact. The *status* column of Table 4 provides information cross referencing the general strategies with the SWMP. Refer to the SWMP for additional information.

Table 4 Sources and Strategies for Bacteria Reduction

Rank	Source	General Stormwater Control/Management Strategies	Status
1	Illicit Connections to MS4s	Implement an IDEP program to identify and remove illicit connections	Ongoing implementation. Addressed in SWMP Table 10
1	Leaking Sanitary Sewer Lines/Aging Sanitary Infrastructure	Conduct investigations to identify leaking sanitary sewer line sources and implement repairs	Implemented with IDEP program and with asset management program
1	Homeless Populations	Support of city shelters and services to reduce homelessness	
		Periodic cleanup of homeless camps near streams	
		Providing public restrooms	
		Partnering with non-governmental organizations to address homelessness	
1-2	Illegal Dumping	Implement a reporting hotline for illegal dumping and educate the public/industries that dumping to storm sewer systems is illegal	Ongoing implementation. Addressed in SWMP Table 7 (ERP), Table 9 (PEP) and Table 10 (IDEP)
1-3	Storm Sewer System and Stormwater Quality BMPs	Catch basin cleaning	Ongoing implementation. Addressed in SWMP Table 13 and 17
		Street Sweeping	Ongoing implementation. Addressed in SWMP Table 13 and 18
		O&M stormwater structural controls	Ongoing implementation. Addressed in SWMP Table 13 and 16.

Rank	Source	General Stormwater Control/Management Strategies	Status
1-3	Stormwater Runoff from Urban Areas	Minimize directly connected impervious areas and manage stormwater runoff for at least the water quality treatment volume *Managing runoff from urban areas also addresses many of the problems associated with domestic pets, dry weather flow, and urban wildlife.*	Ongoing implementation. Private development projects are addressed in SWMP Table 12. Municipal projects are addressed through the Vital Streets program.
2	Domestic Pets (dogs and cats)	Adopt and enforce pet waste ordinances	Implemented through several ordinances
		Provide signage to pick up dog waste, providing pet waste bags and disposal containers	Ongoing implementation. Addressed in SWMP Table 9 (PEP)
		Place dog parks away from environmentally sensitive areas and provide water quality treatment for the runoff from dog parks and kennels	
2-3	Dry Weather Urban Flows (irrigation, car washing, power washing, etc.)	Implement public education programs to reduce dry weather flows from storm sewers related to lawn/park irrigation practices, car washing, power washing and other non-stormwater flows	Ongoing implementation. Addressed in SWMP Table 9 (PEP)
		Inspection of commercial trash areas, grease traps, washdown practices, along with enforcement of ordinances	Ongoing implementation with IDEP, PEP, and County Health Department.
3	Urban Wildlife (rats, bats, raccoons)	Reduce food sources accessible to urban wildlife (e.g. manage restaurant dumpsters/grease traps, residential garbage, feed pets indoors)	Ongoing implementation with IDEP, PEP, and County Health Department.
3-4	Birds (e.g. Canada geese, gulls, pigeons)	Identify areas with high bird populations and evaluate deterrents, population controls, habitat modifications and other measures that may reduce bird-associated bacterial loading	
3-4	Wildlife: (raccoons, beavers, deer, foxes, rats, mice)	Consult with state wildlife offices on strategies to reduce food, shelter and habitat for overpopulated urban wildlife	
		Implement and enforce urban trash management practices	

As indicated in Table 4 managing runoff from urban areas by minimizing directly connected impervious surfaces and providing water quality volume treatment addresses many of the problems associated with domestic pets, dry weather flow, and urban wildlife. This is one of the reasons why significant emphasis is placed on impervious surfaces.

Attainment of the *E. coli* recreational standards (Table 1) by only implementing structural stormwater control measures is unlikely based on performance data from the International Stormwater BMP Database. However, stormwater controls have many other water quality benefits and may still reduce bacteria loads (especially through volume reductions), even if concentration-based limits are not consistently attainable. When selecting structural stormwater controls, both concentration and volume reduction benefits should be considered.

Management measures that reduce stormwater flows are the most effective at reducing bacteria. These include practices such as infiltration trenches and basins. Bioretention and porous pavement systems can also be effective but are dependent on the presence and configuration of an underdrain. Constructed wetlands and wet ponds are also effective at reducing bacteria based on the water retention and the exposure to solar radiation.

Enhanced filtration systems may also help remove bacteria. For example, iron enhanced filters and biochar amended filters have both been demonstrated to improve bacteria removal. Using fungi as a biological filter has also been shown to reduce bacteria runoff. The use of enhanced treatment systems may be appropriate for areas with high bacteria loads and where source control measures are unsuccessful, and infiltration is not practical.

4.2 PLASTER CREEK BIOTA STRATEGIES

With regards to the biota TMDL for Plaster Creek, as previously discussed the fundamental problem is the changes to hydrology due to the urbanization of the watershed. Runoff from urban areas is predominately due to the impervious surfaces. The primary strategy to address the problem is to minimize directly connected impervious areas and manage stormwater runoff for at least the channel protection criteria. Management measures that emphasize retaining runoff are the priority. Emphasis should also be placed on removing sediment from the urban runoff.

Since the fundamental problem is runoff from the impervious surfaces within the watershed, review and analysis of the impervious cover information can provide useful information for retrofit projects. For example, within the Silver Creek watershed, a tributary of Plaster Creek, Figure 21 shows an illustration of subcatchment areas, Figure 21 shows a column graph of impervious cover types and acreage, and Table 5 provides a tabular summary of the impervious coverage. This information shows, for example, that the Division-Buchanan subcatchment has the greatest quantity and highest density of impervious cover and therefore might be prioritized for implementation opportunities.

Catchment groups also provide a useful framework to organize asset management and vital streets information. For example, Figure 21 includes stormwater pipes greater than 30-inch diameter and roads located within each group. Other types of data can be incorporated into an integrated set of group attributes that could help guide project planning (e.g., individual parking lots to consider for green infrastructure, priority storm sewer lines for catch basin cleaning or treatment upgrades).

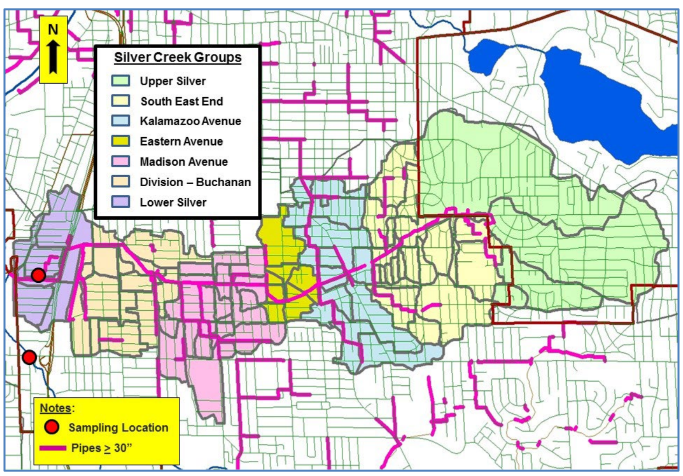

Figure 21 Silver Creek Subcatchments

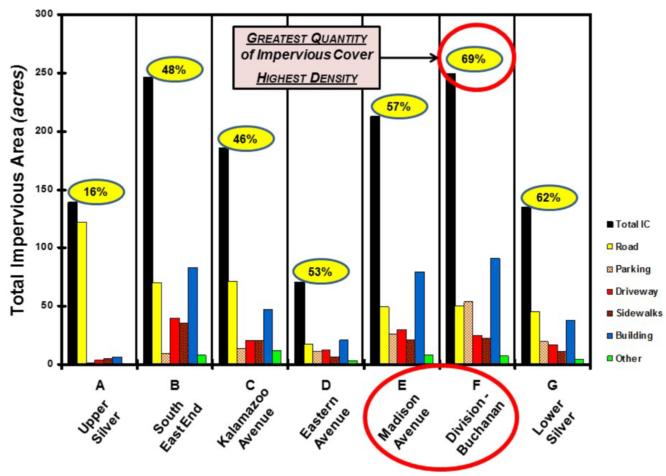

Figure 21 Silver Creek Impervious Cover

Table 5 Silver Creek Impervious Cover Types

Group	Impervious (acres)[1]							Pervious[2] (acres)	Total (acres)
	Road	Parking	Driveway	Sidewalks	Building	Other	Total[2]		
A. Upper Silver[3]	122.1 (88%)	1.3 (1%)	3.3 (2%)	4.9 (4%)	6.4 (5%)	0.5 (0%)	139 (16%)	748 (84%)	886
B. South East End	70 (28%)	9.5 (4%)	40 (16%)	35.8 (15%)	82.5 (34%)	8.3 (3%)	246 (48%)	271 (52%)	517
C. Kalamazoo Ave.	71.3 (38%)	14.1 (8%)	20.2 (11%)	20.3 (11%)	47.4 (26%)	11.9 (6%)	185 (46%)	219 (54%)	404
D. Eastern Ave.	17.4 (25%)	11.2 (16%)	12.5 (18%)	6.2 (9%)	20.7 (29%)	2.8 (4%)	71 (53%)	64 (47%)	134
E. Madison Ave.	49.1 (23%)	26 (12%)	29.9 (14%)	20.7 (10%)	79.2 (37%)	8.1 (4%)	213 (57%)	163 (43%)	376
F. Division–Buchanan	50.2 (20%)	53.9 (22%)	24.4 (10%)	22.7 (9%)	90.5 (36%)	7.1 (3%)	249 (69%)	112 (31%)	361
G. Lower Silver	45.4 (34%)	19.6 (15%)	16.5 (12%)	11.1 (8%)	37.5 (28%)	4.2 (3%)	134 (62%)	82 (38%)	216
Total	**425.5 (34%)**	**135.6 (11%)**	**146.8 (12%)**	**121.7 (10%)**	**364.2 (29%)**	**42.9 (3%)**	**1,237 (43%)**	**1,658 (57%)**	**2,895**

1. Percentage shown for roads, parking, driveway, sidewalks, building and other are expressed as a percentage of the total impervious area.
2. Percentage shown for total impervious and pervious are expressed as a percentage of the total area.
3. Impervious cover analysis was not completed for areas outside of Grand Rapids city limits and may affect the data presented.

5.0 EVALUATING EFFECTIVENESS

Various metrics will be tracked for evaluating the effectiveness of the BMPs implemented. Individual program metrics for illicit discharge source identification, public education and good housekeeping practices are discussed with information specific to those programs.

The City monitors water quality at 15 locations in the Grand Rapids area; six on the mainstem Grand River and nine tributary sites (Figure 3). In-stream monitoring of *E. coli* and sediment are planned to continue. The Data Information and Procedures (DIP) committee of the Lower Grand River Organization of Watersheds (LGROW) developed a *Monitoring Manual for NPDES MS4 TMDL Waterbodies in the Lower Grand River Watershed* (2015). This manual will be used to guide the monitoring procedures including the sampling locations, data quality, and sampling procedures and frequency. The instream monitoring data will be the primary mechanism to evaluate the effectiveness of meeting the TMDL requirements.

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