CASCADE CHARTER TOWNSHIP

STORM WATER MANAGEMENT PLAN

PREPARED FOR:
CASCADE CHARTER TOWNSHIP, MI

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INTRODUCTION

This Storm Water Management Plan (SWMP) was prepared for Cascade Charter Township (Township) located in Kent County, Michigan, with financial participation from the Kent County Drain Commissioner (KCDC) as part of the county-wide storm water management strategy adopted in 2003. Under this program, townships are required to develop and update their individual SWMPs every ten years. The KCDC requires SWMPs to address the following general elements:

1. Identify existing drainage patterns in the Township.

2. Conduct an analysis of each delineated watershed, including culvert analysis and other techniques, to locate problem areas in the Township and determine which management practices will be used.

3. Define and delineate three storm water management zones in the Township.

4. Develop recommendations based on the analysis. Provide detailed construction costs of necessary management practices for each district.

5. Implement an action plan to address problem areas.

The SWMPs provide a means for local community input on regional storm water management. The SWMPs also create a regional management tool which allows for collaboration between the Township, the KCDC, and the Kent County Road Commission (KCRC) for storm water control. This collaboration assists in site plan reviews and identification of critical or problem areas that require management of multiple types of waterways, such as private drainage ways, existing water courses, and county drains.

The Cascade Charter Township SWMP provides the Township with:

1. An atlas of township hydrology
2. A prioritized inventory of existing drainage deficiencies
3. A storm water management zone map as a basis for appropriate storm water strategies for future development and opportunities for regional storm water management

Figure 11 provides a graphical reference for the locations of watercourses and road culverts recommended for improvements. Descriptions of the recommended improvements is provided in the narrative of the report and construction cost estimates are provided in Appendix 3. The proposed improvements should be reviewed with the KCDC and the KCRC to develop an overall improvement master plan and schedule.

Figure 12 provides the graphical reference for the proposed storm water management zones in the Township. Table H provides general recommendations, by drainage district, for recommended best management practices (BMP). It is important to note that the zone map and BMP recommendations are intended as guidelines for use in the storm water management review of a development. Individual and unique characteristics in a given development may require that more stringent storm water management criteria and controls to be applied.

TOWNSHIP HYDROLOGY

This section provides background hydrologic information for Cascade Charter Township (Township). The primary influences are watersheds, drainage patterns, wetlands, and hydrologic soil types.

WATERSHEDS

The three major watersheds in the Township are illustrated in Figure 1. These watersheds drain to either Plaster Creek on the western side of the Township, the Thornapple River in the central portion of the Township, or the Grand River in the north eastern quadrant of the Township. The following is a short description of each of these three watersheds.

PLASTER CREEK WATERSHED

This watershed is comprised of the western 15% (3,315 acres) of the Township. Storm water flow in the northern segment of this watershed originates both from within the Township and from neighboring Ada Township. North of I-96, these storm water flows move southward through the Martin and Beak Drain and into the City of Kentwood just south of I-96. South of I-96, storm water originates within the Township and flows eastward into the City of Kentwood at various locations. All of the water from this watershed flows through the City of Kentwood and into Plaster Creek.

THORNAPPLE RIVER WATERSHED

This watershed is comprised of the central 73% (16,243 acres) of the Township. A portion of the storm water near the south and east boundaries of the Township originates in neighboring townships. All other storm water in this watershed originates within the Township boundaries. All these storm flows discharge to the Thornapple River which flows northward, into Ada Township and eventually into the Grand River.

GRAND RIVER WATERSHED

This watershed is comprised of the northeast 12% (2,756 acres) of the Township. All storm water runoff in this watershed originates in the Township and discharge directly to the Grand River.

DRAINAGE DISTRICTS

A total of 37 drainage districts were defined within the three watersheds in the Township. The drainage districts vary from 99 to 2,496 acres in size with an average of size of 600 acres.

Figure 2 identifies each drainage district and the primary drainage path. Table A provides a listing of the identified drainage districts and their size in acres.

Table A - Drainage Districts

Plaster Creek Watershed		**Thornapple River Watershed**		**Grand River Watershed**	
Drainage District	*Acreage*	*Drainage District*	*Acreage*	*Drainage District*	*Acreage*
60th Street	292	Alaska	99	Cascade East	293
Cascade West	1,716	GRFIA Northeast	316	Crestwood Hills	725
GRFIA Northwest	303	Cascade Road	930	Grand River One	345
GRFIA Southwest	434	Cascade Southeast	2,496	Grand River Two	272
Kendrick	117	Cascade Woods	383	Highgrove	516
Meadowbrooke	453	Forest Creek	180	Platinum Falls	167
		Burger 1	188	Shadlow Trail	276
		Burger 2	1,468	Thornapple Club	162
		GRFIA Southeast	1,580		
		Hidden Hills	268		
		M-6 Interchange	204		
		Maracaibo Shores	773		
		Middle Thornapple	800		
		North Thornapple	1,496		
		Quiggle Lake	762		
		Ridgewood Creek	284		
		Schoolhouse Creek	2,179		
		Sentinel Pointe	267		
		South M-6	180		
		South Thornapple	523		
		Sturbridge	524		
		Tammarron North	230		
		Tannon	113		
TOTALS	**3,315**		**16,243**		**2,756**

WETLANDS

Figure 3 illustrates the wetlands in the Township as identified in the National Wetlands Inventory performed by the U.S. Fish and Wildlife Service. The following categories of wetlands are identified:

- Aquatic bed wetlands - Wetlands and deepwater habitats dominated by plants that grow principally on or below the surface of the water for most of the growing season in most years.
- Emergent wetlands - Characterized by erect, rooted, herbaceous hydrophytes, excluding mosses and lichens. The vegetation is present most of the growing seasons.
- Forested wetlands - Characterized by woody vegetation that is 18 feet tall or taller.
- Scrub-scrub wetlands - Areas dominated by woody vegetation less than 18 feet tall. The species may include shrubs, young trees, and trees stunted because of environmental conditions.
- Unconsolidated bottom and unconsolidated shore wetlands - Characterized by the lack of large stable surfaces for plant and animal attachment.

Wetlands can provide some measure of storm water quality treatment through plant uptake of various nutrients and substances. However, wetlands must be protected from high velocity flows and from sedimentation.

HYDROLOGIC SOIL TYPES

The National Resource Conservation Service (NRCS) of the U.S. Department of Agriculture prepares and maintains soils data for every county in the United States. The soil surveys are published on a county-wide basis and provide a wealth of information about the soils that are present. Figures 4 and 5 illustrate the different soils that have been identified in the Township. The different soils are identified by name and can be viewed at the parcel scale using the Kent County Geographic Information System (GIS).

It is necessary to determine the hydrologic characteristics of the soils in an area to calculate the potential storm water runoff from an area and the potential for flooding. Sandy soils infiltrate a larger fraction of the rainfall resulting in a smaller volume of runoff and lower flood discharge rates. Clayey soils infiltrate less rainfall resulting in larger runoff volumes and higher flood discharges. The NRCS characterizes the runoff potential of a given soil using the Hydrologic Soil Group (HSG) classification. Soils are classified as A, B, C, or D. The HSG data, shown in Figures 6 and 7, is from the NRCS Soil Survey Geographic (SSURGO) database. This is the highest resolution soils database maintained by the NRCS.

The HSG classification is based on the water infiltration capacity of the soil after wetting from long-duration storms and opportunity for swelling. In the definitions to follow, the infiltration rate is the rate at which water enters the soil and the transmission rate is the rate at which the water moves through the soil. The hydrologic soil groups are described below.

- Hydrologic Soil Group A. Soils having high infiltration and transmission rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels.

- Hydrologic Soil Group B. Soils having moderate infiltration and transmission rates when thoroughly wetted and consisting of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.

- Hydrologic Soil Group C. Soils having slow infiltration and transmission rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes the downward movement of water or soils with moderately fine to fine texture.

- Hydrologic Soil Group D. Soils having very slow infiltration and transmission rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material.

Some soils have a dual designation. A soil designated as A/D, for example, is a soil that behaves like an A or D soil depending on artificial drainage. If the soil is saturated with water (i.e. in the presence of a high water table) then the drainage characteristics are more like a D soil. If the soil is artificially drained (i.e. using agricultural field drains) then it may have the characteristics of an A soil. Additionally, soils in highly developed areas are not always classified due to significant amounts of impervious surfaces.

In the Township, there are some general soil patterns which are identifiable in Figures 6 and 7. Type B soils are predominate directly adjacent to the rivers. Sandy Type A soils are generally found along the higher river bank areas with a mixture of B and C soils in the upland areas. The southeastern quarter of the Township is primarily Type C soils. Clayey Type D soils are present in isolated pockets throughout the Township. The soils in the area surrounding the Gerald R. Ford International Airport and in the developed areas along 28th Street have not been classified by NRCS due to the high level impermeable pavement surface coverage.

The high percentage of Type A and B soils in the Township can provide significant opportunity for infiltration basins and reduction in runoff from development. However, the predominance of these soils in the lower sections of the drainage districts creates a high potential for erosion due to the inherently low cohesion properties of these soil types. This erosion potential is evident in several of the Thornapple River drainage districts and in one of the Grand River Drainage districts.

CONDITION INVENTORY AND ANALYSIS

DRAINAGE DISTRICT EVALUATION

PROBLEM AREAS

The Township has received reports of flooding or erosion problems in 8 of the 37 defined drainage districts. Those districts are listed below and are illustrated in Figure 8.

- Cascade West
- Sentinel Pointe
- Burger 1
- Burger 2
- Forest Creek
- Hidden Hills
- Quiggle Lake
- Cascade Road

All of the districts with reported problems were field investigated along with 6 other districts with significant development potential. All of the field investigated districts are identified in Figure 8. Storm water modeling was performed on these 14 districts to evaluate the hydraulic performance of the major culvert crossings.

DISTRICT DEVELOPMENT POTENTIAL

Proactive storm water management policies are an important part of controlled development. Each of the drainage districts were reviewed to gauge the relative development potential. This potential was based on two main factors:

OPEN AREA

Each district was reviewed to determine the acreage of open space which was not encumbered by poor soils (Type D or C/D), steep slopes, wetlands, or waterways.

UTILITY AVAILABILITY

Each district was evaluated to determine the acreage of open area which was within the current Urban Utility Service Boundary (UUSB). The UUSB represents the approved limit of future City of Grand Rapids water and sewer service and can be generally described as the area from the western Township line to the first half section line east of Buttrick Avenue (ca 2007). Development density within the UUSB is generally higher than outside of the boundary line as additional lot space is not needed for septic system and water supply well installation. Higher development density can result in higher runoff coefficients and therefore increased storm water runoff.

Approximately 1,700 acres of open areas were identified to be within the UUSB. Of the 37 districts identified in the Township, 8 of them represent over 50% of the area with high development potential.

Table B - Drainage Districts with Highest Development Potential

District	Acreage
Schoolhouse Creek	218
60th Street	204
Quiggle Lake	160
GRFIA Northeast	158
Highgrove	139
Cascade Road	112
Cascade Southeast	10
Cascade West	86

FIELD INVESTIGATION

Development can often have a negative impact on water ways. Larger volumes of runoff along with higher discharge rates can cause erosion and flooding. As indicated in Figure 8, a total of 14 drainage districts were selected for field investigation; 8 with known problems and 6 others based on the open acreage development potential noted above. Investigations involved walking the primary drainage routes through each district and noting the existing condition of the stream channel and stream corridor. Narratives, graphics, and photographic documentation for each of the investigated districts are included in Appendix 1.

CULVERT EVALUATION

Culverts are hydraulic structures that can provide crossings over open channels, allow significant grade changes in short segments, and provide stream bed stability where flow velocities may be high. Culverts that are undersized may impede storm water flows. Impeded flows can lead to increased upstream flooding and increased downstream erosion due to excessively high exit velocities, or overtopping of the roadway. Culverts that are too short or that don't have proper entrance and exit treatments may cause bank scour and erosion. Sediment erosion leads to downstream sediment deposition which is a primary pollutant in many Michigan waterways. Significant sediment deposition can result in loss of downstream conveyance capacity and loss of fish habitat.

CULVERT IDENTIFICATION

Culverts were located using three primary resources:

- REGIS database - REGIS is the Regional Geographic Information System. It is a spatial database of community information covering about two thirds of Kent County. The REGIS database includes information about many of the culvert crossings in the Township. REGIS was used to identify approximately 199 culvert locations along the public road system.

- GIS mapping - GIS aerial photographic mapping was used to identify an additional 74 culvert locations where roads crossed streams or drains.

- Field investigation - Field investigation of the 14 selected drainage districts resulted in identification of an additional 25 culverts.

These three resources identified a total of 298 culverts within the Township, which are illustrated in Figure 9. Most of these culverts are located at public road crossings of the waterways.

CULVERT INVESTIGATION

Of the 298 identified culverts, 66 culverts lie within the 14 drainage districts selected for visual inspection. The information gathered for each of the 66 culverts includes:

- Location
- Size
- Type
- Length
- Sediment depth
- Water level
- Vegetation present at both upstream and downstream end
- Flow condition at downstream end
- Photographs of upstream and downstream ends

The visual inspections identified 40 road crossing culverts within the investigated districts which appeared to have potential capacity problems or physical degradation. The following surveyed information was gathered for these 40 culverts to allow hydraulic evaluation of the culverts:

- Upstream and downstream invert elevations
- Roadway elevations
- Downstream channel cross section

Figure 10 indicates the locations of both the visually inspected culverts as well as those surveyed. Summary information and photographic documentation for each of the investigated culverts is included in Appendix 2.

CULVERT HYDROLOGIC AND HYDRAULIC CALCULATIONS

Hydrologic and hydraulic calculations were performed on the 40 surveyed road crossing culverts. Hydrologic calculations were used to determine the peak discharge expected through the culverts for the 10-year, 25-year, and 100-year rainfall events, which respectively consist of 3.52, 4.45, and 6.15 inches of rain in a 24-hour period. The hydrologic analysis was performed using the methods outlined in the Michigan Department of Environmental Quality (MDEQ) document "Computing Flood Discharges for Small Ungaged Watersheds." The following assumptions were used in this analysis:

- HSG ratings (as shown in Figures 6 and 7) were averaged over each drainage district.
- Land use distributions were determined for the contributing area upstream of each culvert based on aerial photographs.
- Rainfall Runoff Curve Numbers (CN) were determined assuming district-wide distribution of soil types for each culvert area. This resulted in some less conservative discharge estimates in the upland areas where the soil types tend to be heavier than the average for the entire watershed.
- Waterway flow concentration times were determined based on flow path slopes and lengths indicated on U.S. Geological Survey (U.S.G.S.) topographic maps. A minimum 200-foot length was assumed for sheet flow. This conservative assumption (effective in the upland areas) counteracted the potential effects of the CN assumptions described above.
- Haestead Methods Culvert Master computer program was used to perform the hydraulic culvert calculations.

The computer program provided data for the headwater elevation of the culvert for each of the modeled rain events. The headwater elevation is the potential water surface elevation on the upstream side of the culvert. Detailed culvert and hydraulic output data is provided in Appendix 2. Table C provides a summary of the computed headwater elevations as compared to the road crossing surface elevation. Highlighted head water elevations indicate levels above the road surface.

Table C - Culvert Headwater Elevations

District	Crossing Location	Road Elevation	Headwater Elevations		
			10-yr	25-yr	100-yr
Cascade Road	Quiggle Avenue	102.53	99.50	101.00	102.70
	Cascade Road (west of Quiggle Avenue)	108.46	103.20	105.20	108.60
	Cherry Lane (45th Street)	102.52	99.40	102.40	103.00
	Cascade Road (850 feet east of Buttrick Avenue)	97.90	98.00	98.20	98.50
	Cascade Road (375 feet east of Buttrick Avenue)	109.95	104.60	106.80	110.20
	Buttrick Avenue	107.99	103.80	105.40	108.40
	Whitneyville Avenue	118.52	102.50	104.20	106.30
Highgrove	Bolt Drive	102.91	100.00	102.30	103.20
	Driveway: 1659 Sterling Oaks Blvd.	102.82	98.80	100.60	103.00
	Grand River Drive	102.20	97.40	98.30	100.20
	Railroad tracks	100.23	96.10	97.60	100.30
GRFIA Southeast	Thornapple River Drive	108.12	96.40	97.30	99.10
Hidden Hills	Vinewood Avenue	106.46	101.50	102.40	104.30
	Cascade Road	115.39	101.50	102.70	105.50
Cascade West	Patterson Avenue	101.90	95.30	96.00	97.60
Burger 1	Forest Valley Drive	105.92	102.80	106.00	106.10
	Woodbrook Drive	100.00	75.50	76.40	78.30
	Burger Drive	102.03	98.80	101.00	102.40
60th Street	60th Street	102.87	101.00	102.80	103.30
Sentinel Pointe	Thornhills Avenue	100.00	72.00	75.00	89.50
	Thornapple River Drive	105.54	105.70	105.80	106.10
	Driveway: 3082 Thornapple River Drive	113.25	106.00	112.40	114.00
Quiggle Lake	36th Street	103.52	103.60	103.70	103.90
	Buttrick Avenue	110.35	103.70	109.00	110.60
	Oak Apple Drive	107.88	103.30	104.50	107.80
	Cascade Road	115.01	103.10	104.50	107.70
Cascade Southeast	Whitneyville Avenue	101.90	96.60	97.70	99.80
	52nd Street	110.43	102.50	103.50	105.50
	Buttrick Avenue	103.92	97.90	99.50	102.80
	Thornapple Bayou Drive	101.16	96.80	98.70	101.50

Table C - Culvert Headwater Elevations

District	Crossing Location	Road Elevation	Headwater Elevations		
			10-yr	25-yr	100-yr
Schoolhouse Creek	Cascade Road (near Burton Street)	103.57	100.10	102.40	103.90
	Burton Street	102.27	100.60	102.40	102.70
	Driveway: 6629 Cascade Road	100.35	100.40	100.90	101.70
	Driveway: Cascade Fellowship Church	102.34	100.30	102.70	103.40
	Oakbrook Street (west)	104.00	99.20	101.00	104.50
	Oakbrook Street (east)	103.65	98.60	100.50	104.00
	Thornapple River Drive	107.17	95.10	96.40	99.20
Burger 2	Meadowood Drive	110.29	103.90	105.30	107.50
	Thornapple River Drive	108.64	106.00	108.00	109.10
	Tricklewood Drive	110.18	109.80	105.20	107.60

IMPROVEMENT RECOMMENDATIONS

STREAM RECOMMENDATIONS

Recommendations for improvements includes stabilization of sections of streambank and removal of accumulated sediment, in both the waterway channels (channel clean-out) and in existing sediment trap areas. Table D provides an estimate of the amount of work needed in each watershed. Appendix 3 provides construction cost estimates for the work.

Table D - Recommended Stream Improvements

District	Streambank Stabilization	Channel Clean-out	Sediment Trap Cleanout
Cascade Road	5,000 LF	2,500 LF	
Burger 1	2,500 LF	500 LF	
Sentinel Pointe	250 LF	250 LF	Upstream of gabions on Thornapple River Drive
Cascade Southeast	1,000 LF		
Quiggle Lake	5,000 LF	500 LF	
Hidden Hills	2,000 LF		
Highgrove	2,000 LF		
Schoolhouse Creek	500 LF		Upstream of the dam on Thornapple River Drive

CULVERT RECOMMENDATIONS

It is recommended that when road construction is performed, culverts unable to convey the 25-year rainfall event without roadway overtopping be considered for resizing. Prior to culvert replacement, more detailed hydrologic and hydraulic calculations should be performed to determine the most appropriate size. Upstream and downstream channel characteristics should be taken into account. Additional bank and channel improvements may be required. Table E indicates the public road crossing culverts which may create roadway overtopping and possible crossing failure during the 25-year storm event.

Table E - Probable Culvert Restrictions

Priority	District	Culvert Location
1	Cascade Road	Cascade Road 850 feet east of Buttrick Avenue
2	Sentinel Pointe	Thornapple River Drive
3	Quiggle Lake	36th Street
4	Schoolhouse Creek	Burton Street
5	Burger 1	Forest Valley Drive

It is also recommended that several culverts be cleaned of sediment deposition. The culverts listed in Table F are at least 10% plugged with sediment and should be targeted for sediment cleanout.

Table F - Culvert Sediment Removal Recommendations

Priority	District	Culvert Location
1	Cascade Road	I-96
2	GRFIA Northeast	48th Street
3	Highgrove	Grand River Drive
4	Sentinel Pointe	Heathmoor Court

LONG TERM MAINTENANCE RECOMMENDATIONS

Long term maintenance of open channel watercourses is a significant issue. Currently, there are three mechanisms for open channel maintenance:

- Maintenance by each individual property owner
- Maintenance through a private association of property owners
- Maintenance through establishment of a county drain

Open channel maintenance may involve improving the conveyance capacity, improving the water quality, and reducing streambank erosion and sedimentation. During the field reviews, several watercourses were identified which are not currently county drains and which could be improved with immediate maintenance. These watercourses are illustrated in Figure 11 along with existing county drains. Table G provides a relative ranking of the watercourses in most need of maintenance based on the field observations of the severity and magnitude of the degradation. Following Table G is a brief narrative describing the observed conditions in each district. Cost estimates for watercourse improvements in each district are compiled in Appendix 3.

Table G - Ranking of Watercourses for Maintenance

District	Rank (1=high priority)
Forest Creek	1
Cascade Road	2
Quiggle Lake	3
Burger 1	4
GRFIA Southeast	5
Hidden Hills	6
Highgrove	7
Cascade Southeast	8
Schoolhouse Creek	9
Sentinel Pointe	10

FOREST CREEK

Currently there is no county drain in this district. Severe streambank erosion and channel undercutting exists.

CASCADE ROAD

Currently there is no county drain in this district. The southern branch of this creek experiences moderate to severe erosion, resulting in severe sedimentation that is clogging culverts (culvert under I-96 is over half full of sediment).

QUIGGLE LAKE

This district is serviced by Humphrey County Drain at upstream end of reach (near Quiggle Lake). Streambank erosion is a common occurrence, especially towards the outlet where severe streambank erosion is evident.

BURGER 1

Currently there is no county drain in this district. The section from the Forest Valley Drive crossing downstream to the confluence with the main channel from the north (just upstream of Burger crossing) is experiencing major erosion problems. Old stabilization measures are not working.

GRFIA Southeast

Currently there is no county drain in this district. It is recommended that the reach from Thornapple River Drive to the Thornapple River be designated for maintenance. This section of the stream experiences moderate erosion with some major sloughing in spots.

Hidden Hills

This district is already serviced by the Apple Hills County Drain.

Highgrove

Currently there is no county drain in this district. It is recommended that the segment from Bolt Drive to Grand River Drive be designated for maintenance. As the stream continues downstream closer to Grand River Drive, streambank erosion becomes more prevalent. This stream is not as severely eroded as those given above (lower priority).

Cascade Southeast

Currently there is no county drain in this district. It is recommended that the section from Whitneyville Road (south crossing) to Thornapple Bayou Drive be designated for maintenance. This section experiences moderate to severe streambank erosion and discharges significant flows to the Thornapple River.

Schoolhouse Creek

The upper reaches of the Schoolhouse Creek are designated as county drains (Walden Lake County Drain and Tobias/Walden County Drain). The Foremost County Drain is a tributary to Schoolhouse Creek. The upper sections of Schoolhouse Creek do not exhibit major streambank erosion, however residents towards the outlet into the Thornapple River have eliminated any buffer zones along the banks of the creek and significant bank erosion in the lower sections is occurring.

Sentinel Pointe

This district is already serviced by the Thornapple Hills County Drain.

DEVELOPMENT GUIDELINES

STORM WATER MANAGEMENT ZONES

Three storm water management zones have been defined to set minimum storm water control performance criteria for developments.

ZONE CHARACTERISTICS

ZONE A represents areas which require the most protective storm water management regulations. The goal of this zone is to preserve the natural condition of water bodies included in it, in whole or in part. Zone A has, in general, little impervious surface area and few storm water facilities. In this zone, when site conditions permit, infiltration of storm water runoff shall be required, rather than the directed flow of storm water runoff into water bodies. This storm water management practice provides greater protection for surface water quality, and also assists in augmenting stream base flow, reduction of flash storm flows and prevention of streambank erosion.

ZONE B represents developed areas that have significant impervious surfaces and storm water runoff facilities in place. The goal of Zone B is the control of storm water runoff in order to prevent further destabilizing of streams and other water bodies. In this zone, the use of detention ponds, the maintenance and enhancement of buffer strips and other measures to reduce directly-connected impervious areas are specified for the achieving of the storm water management standards applicable to Zone B. The management practices for this zone are intended to maintain existing water quality and to alleviate adverse downstream impact on water bodies.

ZONE C consists of highly urbanized areas, or areas where there has been significant modification of drainage ways. The amount of impervious surface area in Zone C is generally greater than 25%. Zone C is also the appropriate designation for stream reaches near a receiving water body large enough to provide detention storage (such as the Thornapple or Grand Rivers). Among the measures required in Zone C are the use of sediment basins, the maintenance and enhancement of buffer strips along water bodies and the reduction of impervious surface areas that are directly connected to water bodies. An important element of storm water management practice in Zone C is the control and prevention of sedimentation, in order to reduce pollution of water bodies.

PROPOSED STORM WATER MANAGEMENT ZONES

The proposed storm water management zones are indicated in Figure 12. The proposed zones are similar to the current Township Storm Zone Map with a few exceptions. The more restrictive Zone A was expanded to take into consideration the problems noted during the field investigations. The least restrictive Zone C was expanded along the Thornapple River to take into consideration the ability to direct discharge to the river without significantly impacting waterway stability or flow regimes.

BEST MANAGEMENT PRACTICES

A variety of best management practices (BMPs) are available to reduce the negative impact of development and to stabilize impacted streams. BMPs can be used to reduce peak discharge and runoff volume resulting from a storm event, to provide protection to streams and stream corridors, and to stabilize eroded and damaged streams.

RECOMMENDED BMP APPLICATION STRATEGIES

EXTENDED DETENTION BASINS

Extended detention basins are designed to receive and detain storm water runoff for a prolonged period of time, typically up to 48 hours. Extended detention is achieved by use of an outlet device regulating the flow from the basin at a rate which minimizes downstream erosion, reduces flooding, and provides for enhanced pollutant removal.

Extended detention basins may be designed as either single-stage or two-stage. Single-stage basins are normally used strictly for flood control and are not usually recommended where water quality benefits are needed. A two-stage basin contains water from small, frequent storms and the first flush of large storms in a lower second stage, with a normally dry upper stage for detention of larger storms for flood control. Managing a second stage as a shallow marsh increases the effectiveness of the basin to remove pollutants. All designs should be developed with multiple uses in mind.

REGION DETENTION/RETENTION BASINS

Most detention basins are designed at a development scale. Each development includes one or more basin designed to manage storm water only from that development. A regional detention basin performs the same function as an extended detention basin. The primary difference is that it services a larger area. Due to the large amount of storage needed regional detention basins often incorporate existing wetlands or lakes.

INFILTRATION BASINS

An infiltration basin is a water impoundment over permeable soils which receives storm water runoff and contains it until it infiltrates the soils. These basins remove fine sediment and the pollutants associated with them. Coarse sediment must be removed from the storm water by other methods prior to entering the basin. This BMP serves drainage areas up to 50 acres in size.

Although use of infiltration practices is encouraged, if not properly designed, constructed, and maintained, contamination of groundwater can occur. Infiltration basins should only be used as part of a "treatment train," where soluble organic substances, oils, and course sediment are removed by other management practices prior to storm water entering the infiltration basin. This practice should *not* be used in industrial parks, high density or heavy industrial areas, chemical or pesticide storage areas, or fueling stations.

Rain Gardens

A "rain garden" is a man-made depression in the ground that is used as a landscape tool to improve water quality. The rain garden forms a "bioretention area" by collecting water runoff and storing it, permitting it be filtered and slowly absorbed by the soil. The bioretention concept is based on the hydrologic function of forest habitat, in which the forest produces a spongy litter layer that soaks up water and allows it to slowly penetrate the soil layer. The site for the rain garden should be placed strategically to intercept water runoff. A nutrient removal or "filtering" process takes place as the water comes in contact with the soil and the roots of the trees, shrubs and vegetation. This process accounts for the improved water quality. The first flush of rain water is ponded in the depression of the rain garden, and contains the highest concentration of materials washed off impervious surfaces such as roofs, roads, and parking lots.

Vegetated Swales

A grassed swale is a natural or constructed watercourse consisting of vegetation and designed to accommodate concentrated flows without erosion. Grassed swales are capable of sustaining higher in-channel velocities than bare areas because the vegetation protects the soil by covering it and retarding water velocity.

Modular or Porous Pavement

Modular pavement comes in pre-formed modular pavers of brick and concrete. When the brick or concrete is laid on a permeable base, water will be allowed to infiltrate. Grass can be planted between the pavers, allowing structural support in infrequently used parking areas.

Porous asphalt pavement is a paved surface and subbase comprised of asphalt, gravel, and stone, formed in a manner resulting in a permeable surface. The various layers, called "courses," have the potential for storm water detention. Storm water which passes through the pavement may completely or partially infiltrate the underlying soil, the excess being collected and routed to an overflow facility through perforated underdrain pipes. The pavement may also be designed to receive off-site runoff.

INFILTRATION TRENCHES

An infiltration trench is a long, narrow, shallow excavation located over porous soils and back-filled with stone to form a subsurface reservoir to hold storm water and allow it to infiltrate the soil. It can be used on small sites up to five acres in size. Infiltration trenches remove fine sediment and the pollutants associated with them. Trenches may be "open" to the surface or enclosed below ground. Open trenches receive sheet flow of storm water from surrounding sources. The sheet flow enters the trench through a layer of vegetated porous soil on the top of the trench. Grass filter strips remove coarse sediments which would plug the spaces between the stones and make the trench ineffective.

Below-ground trenches may receive higher concentrations of flow than above-ground trenches. With below-ground trenches, storm water enters the basin through an inlet and pipe from the surface. The storm water entering the trench must be pre-treated using a combination of buffer strips and multi-chambered catch basins to remove coarse sediments and oils.

BUFFER/FILTER STRIPS

A buffer/filter strip is a vegetated area adjacent to a water body (i.e. river, stream, wetland, lake). The buffer/filter area may be natural, undeveloped land where the existing vegetation is left intact, or it may be land planted with vegetation. Its purpose is to protect streams and lakes from pollutants such as sediment, nutrients and organic matter, prevent erosion, provide shade, leaf litter, and woody debris. Buffer/filter strips often provide several benefits to wildlife, such as travel corridors, nesting sites and food sources.

For the purposes of this BMP, a buffer/filter strip is a combination of 1) a buffer of vegetation between human land use and a stream, and 2) a filter, to trap sediment and absorb sheet flow. The buffer is usually comprised of trees, the buffer provides shade, leaf litter, woody debris, erosion protection, and often serves as wildlife habitat. The filter strip is an area of dense grass at least 20 feet wide designed specifically to remove pollutants from storm water runoff from sheet flow off adjacent land, through filtering and infiltration. Although vegetative filters designed as specified in this BMP can be expected to provide significant pollutant removal, overall water quality will not be protected if a filter strip is not used in conjunction with a buffer along the stream corridor.

Sediment Basins

Sediment basins are man-made depressions in the ground where runoff water is collected and stored to allow suspended solids to settle out. They are used in conjunction with erosion control measures to prevent off-site sedimentation. They may consist of a dam, barrier or excavation, a principal and emergency outlet structure, and water storage space. Their primary purpose is to trap sediment and other course material. Secondary benefits can include runoff control and preserving the capacity of downstream reservoirs, ditches, canals, diversions, waterways and streams.

Streambank Stabilization

There are numerous methods available to stabilize streambanks. Four common stabilization methods vary widely in the principals used to provide erosion protection.

- Riprap is one of the more commonly used streambank stabilization techniques. It is a permanent cover of rock used to stabilize streambanks, provide in-stream channel stability, and provide a stabilized outlet below concentrated flows. It is generally used on streambanks at the toe (bottom) of the slope, with other structures placed up-slope to prevent soil movement. It is often a component of many soil bioengineering techniques.

- Soil bioengineering is a method of using vegetation to stabilize a site with or without structural controls. Some refer to bioengineering as softening the traditional rock-the-bank approach because non-invasive vegetation is used to blend the site into its surrounding landscape. Bioengineering techniques may be as simple as using stop-logs to form terraces, then seeding exposed soil to help prevent soil movement. Techniques also include using fascines (long bundles of willow or dogwood), with layers of brush, along with individual plantings.

- In-stream deflectors use artificial or natural elements to deflect erosive flows away from critical streambanks. This technique is most commonly used at stream meanders to either prevent bank erosion or to allow sediment deposition on the downstream side of the deflectors for bank aggregation. These techniques include the use of J-hooks, pile vanes, and tree revetments.

- In-stream grade control techniques are most commonly used to prevent stream bed erosion and subsequent bank sloughing/erosion. These techniques can be used to provide channel bottom armoring or to create in stream dams which slow the water velocity near the channel bottom. Techniques include the use of rock riffles, cross vanes, and check dams.

RECOMMENDED BMPS BY DRAINAGE DISTRICT

BMP recommendations vary by watershed. Table H provides a summary of the recommended BMPs for each district. The reasoning used to determine the type or types of BMPs recommended is as follows:

- All infiltration BMPs (lot level, development level, and regional). This should be the BMP of choice for all new developments in watersheds with significant areas in Storm Water Management Zone A.

- Extended detention/retention basins. This BMP is recommended for all new developments where infiltration is not possible. It is recommended in watersheds with significant area in Storm Water Management Zone B.

- Regional detention/retention basins: Regional detention is storm water detention on a regional scale instead of a development scale. This is recommended only if suitable sites are identified. The criteria for suitable regional detention sites are as follows:
  - Must be "high" enough in the watershed to have a positive impact on the receiving stream.
  - Must be "low" enough in the watershed to be able to accept drainage from several developments.
  - Must be in parts of the Township with a high development potential.

Figure 13 shows sites that have been identified as potential regional detention sites.

- Buffer/filter strips along streams. These are recommended in all watersheds.

- Sediment basins. These are recommended in watersheds with significant area in Storm Water Management Zone C.

- Streambank stabilization. These are recommended in watersheds where field investigation noted eroding or damaged streambanks.

Table H - District BMP Recommendations

Drainage District	Infiltration	Extended Detention or Retention	Regional Detention	Buffer or filter strips	Sediment basin	Streambank stabilization
60th Street		✓		✓		
Alaska	✓			✓	✓	
GRFIA Northeast	✓			✓		
Cascade Road	✓		✓	✓		✓
Cascade East	✓			✓		
Cascade Southeast	✓			✓		✓
Cascade West	✓	✓	✓	✓		
Cascade Woods	✓	✓		✓		
Crestwood Hills	✓			✓		
Forest Creek	✓			✓		✓
Grand River One	✓			✓	✓	
Grand River Two	✓			✓	✓	
Burger 1	✓			✓		✓
Burger 2	✓	✓		✓		
GRFIA Northwest		✓		✓		
GRFIA Southeast	✓	✓	✓	✓		
GRFIA Southwest		✓		✓		
Hidden Hills	✓			✓		✓
Highgrove	✓	✓		✓		✓
Kendrick		✓		✓		
M-6 Interchange	✓			✓		
Maracaibo Shores				✓	✓	
Meadowbrooke		✓	✓	✓		
Middle Thornapple	✓	✓		✓	✓	

Drainage District	Infiltration	Extended Detention or Retention	Regional Detention	Buffer or filter strips	Sediment basin	Streambank stabilization
North Thornapple	✓	✓		✓	✓	
Platinum Falls	✓	✓		✓		
Quiggle Lake	✓		✓	✓	✓	✓
Ridgewood Creek	✓			✓	✓	
Schoolhouse Creek	✓		✓	✓		✓
Sentinel Pointe	✓			✓		✓
Shadlow Trail	✓			✓		
South M-6	✓			✓		
South Thornapple				✓	✓	
Sturbridge	✓	✓		✓		
Tammarron North	✓	✓	✓	✓		
Tannon	✓			✓	✓	
Thornapple Club				✓	✓	