4. Water Quality

> "People tend not to realize the impact of their actions until long after damage has been done."
> - Unknown Author

The Relevance of Impervious Cover

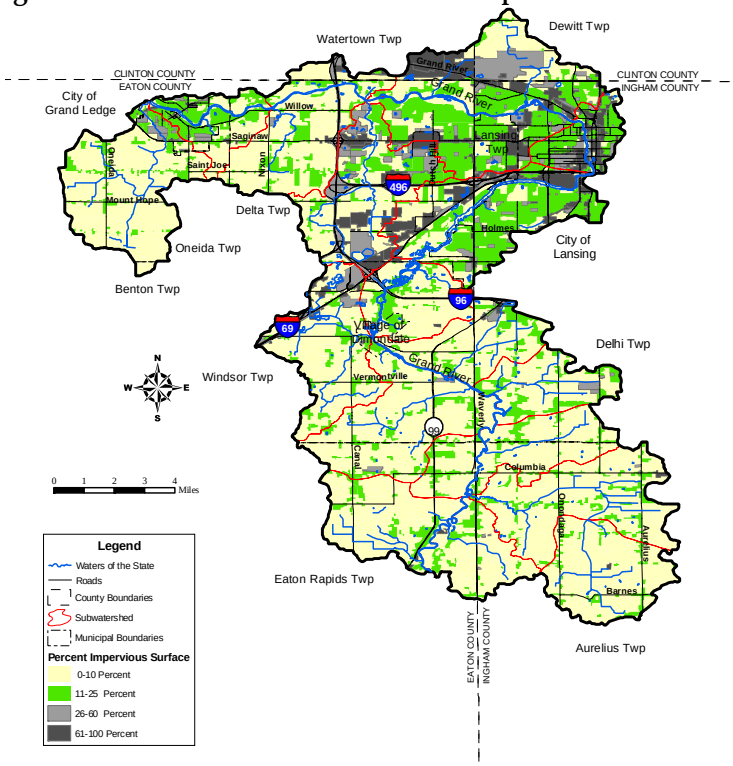
The physical, chemical, and biological integrity of a given stream system has been shown to be strongly correlated to the amount of impervious cover (the area covered by rooftops, streets, parking facilities, and other hard surfaces) in the subbasin or watershed (Schueler, 1994). Imperviousness appears to be one of the principal indicators of watershed "health." Analysis of stream systems across the country seems to indicate that there are thresholds at which watershed imperviousness results in degradation of water quality and physical stream processes.

The conversion of natural landscapes (i.e. farmland, forests, and wetlands) into urban landscapes creates a layer of impervious surface. Urbanization has a significant impact on hydrology, morphology, water quality and ecology of surface waters. The amount of impervious cover in a watershed can be used as an indicator to predict how severe differences are in character of urban watersheds and natural watersheds.

River Walk in Downtown Lansing, Courtesy of Tetra Tech, 2005.

In natural settings, there is very little runoff, with most of the rainfall being filtered by the soils, and supplying deep water aquifers. In urbanized areas, however, less and less rainfall is infiltrated, and as a result, less water is available to streams. Additional changes in urban streams due to increased impervious cover includes enlarged channels; upstream channel erosion contributing greater sediment load to the stream; in-stream habitat degradation; and declining water quality.

Figure 4-1 Grand River Watershed Percent Impervious



> *"Even small increases in impervious change stream morphology and degradation of aquatic habitat. The relationship between impervious cover and subwatershed quality can be predicted by a simple model, projecting current and future quality of streams and other water resources." (Center for Watershed Protection 2003)*

Research indicates that zones of stream quality exist, most noticeably beginning around 10% impervious cover with a second threshold appearing at around 25-30% impervious cover. These thresholds are powerfully modeled in the Impervious Cover Model, classifying streams into three categories; sensitive, impacted, and non-supporting. Watersheds with less than 10% imperviousness appear to exhibit natural chemical, physical, and biological quality. Between 10 and 25 percent imperviousness, river systems show signs of

degradation. Beyond 25 percent imperviousness; the damage to physical, chemical, and biological integrity may be irreversible. It is important to understand the Impervious Cover Model, although a powerful tool predicting quality of streams based on impervious cover change is not without its limitations. (Schueler, 1994).

Each land use type in the Grand River watershed was given an assumed percent impervious value. A geographic information system (GIS) was used to develop a composite of the impervious surfaces in the watershed. This method was designed to be utilized for urban area by determining the percent impervious of each subwatershed Table 4-1 and the percent impervious located in each municipal Table 4-2. Figure 4-1 shows the overall percent impervious within the Grand River Watershed.

Table 4-1 Percent Impervious Surfaces for the Grand River Watershed

Subwatershed	Average Weighted Percent Impervious
Carrier Creek Subwatershed	22%
Columbia Creek Subwatershed	5%
County Line Subwatershed	5%
Gilbert Drain Subwatershed	8%
Grand River A Subwatershed	5%
Grand River B Subwatershed	23%
Grand River C Subwatershed	36%
Grand River D Subwatershed	27%
Grand River E Subwatershed	13%
Grovenburg Drain Subwatershed	8%
John Earl Drain Subwatershed.	5%
Miller Creek Subwatershed	9%
Renyolds and Edwards Drain Subwatershed	29%
Silver Creek Subwatershed	10%
South Windsor Drain Subwatershed	5%
Upper West Aurelius Drain Subwatershed	4%
Willis Shaw and Fulton Drain Subwatershed	8%
Average Percent Impervious	**12%**

Habitat and Populations

The habitat and biota populations were identified by reviewing previously conducted and published studies conducted predominantly by the MDEQ and MDNR. These studies are summarized and presented below in discussions regarding the Grand River, Carrier Creek and Reynolds Drain. Figure 4-2 presents a visual summary of the data discussed in this section.

Table 4-2 Percent Municipal Impervious Surfaces for the Grand River Watershed

Municipal	Average Weighted Percent Impervious
Benton Twp	2.32%
Dimondale	9.94%
Lansing Twp	33.63%
Watertown Twp	44.09%
Dewitt Twp	21.94%
Grand Ledge	21.52%
Delhi Twp	7.64%
Oneida Twp	4.61%
Eaton Rapids Twp	5.40%
Lansing	29.57%
Aurelius Twp	4.11%
Windsor Twp	7.67%
Delta Twp	18.56%
Average Percent Impervious	**12.89%**

Grand River

Extensive research on the Grand River has been conducted by the State of Michigan and other groups since the 1950s. The data predominately cover macroinvertebrate and fish populations, habitat and Dissolved Oxygen (DO) concentrations. The presence or absence of specific macroinvertebrate and fish species indicates water quality of the stream. DO concentration and habitat are measured to ascertain whether the water body is able to support fish and other aquatic organisms. Michigan water quality standards (MWQS) require a minimum DO concentration of 5 to 7 mg/l depending on the designation of the water body.

In August 1955, Aquatic Biologist Eugene Surber conducted a biological survey of the Grand River in the Lansing area following reports of fish kills in the early mornings of July 16 and July 28, 1955. The fish kills were attributed to low flows in the Grand River in addition to very warm weather and pollution. The situation was additionally complicated by the two Lansing Board of Water and Light plants which use the river for cooling water and cause water temperatures up to 100°F (Surber 1995).

Nine sampling stations beginning at M-99 in Dimondale, through Lansing, to Charlotte Road near Portland were evaluated for DO, temperature, biological oxygen demand (BOD) and biological conditions. The stations upstream of Lansing contained an abundance of clean-water fauna indicating these sections were unpolluted.

Biota includes all of the plant and animal life in a particular region.

"One of the most valuable criteria of clean-water conditions is number of species. The greater the number of species, the cleaner and more productive is the habitat (Surber 1955)."

Grand River at Waverly Road south of Delta River Drive, Courtesy of Tetra Tech, 2005.

Downstream at the Shiawassee Street Bridge in Lansing, tubificids (indicator species of polluted areas) were found in great abundance along the right bank, confirming pollution due to the Red Cedar River confluence on that side. Further downstream of the Shiawassee Street Bridge and the Lansing Wastewater Treatment Plant (WWTP), tubificids became increasingly abundant with few other organisms present, verifying the existing pollution or severe environmental conditions. The sharp reduction in the number of species below the Lansing WWTP strongly supported evidence that the Lansing sewage contained wastes toxic to virtually all species other than tubificids. Considerable biological recovery did take place in the Grand River further downstream near Charlotte Road where samples were collected (Surber 1955).

A separate study was conducted by the Michigan Water Resource Commission on August 23, 1963 in response to a telephone call concerning "thousands of dead carp" in the Grand River in the vicinity of Waverly Road-Delta Mills Bridge in Lansing. Investigators found 250 dead fish corresponding with a flow decrease to 40 cubic feet per second (cfs), sewage composing 1/3 of the flow, and low oxygen conditions (Carr 1963). Three years later in December of 1966, Carlos Fetterold prepared comments on the effects of heated discharge. The study found that low DO levels in the Grand River combined with the added thermal load from the Lansing Board of Water and Light effluent limit the production of warm-water fish.

Macroinvertebrates

Animals that are visible to the naked eye, but do not have backbones. Typical macroinvertebrates include insects (may flies, black flies, caddisflys and stone flys), aquatic worms, crustaceans, snails, and worms.

Source: Cheo and Murdoch , 2001.

Two additional studies conducted in 1970 as part of the water quality assurance and fish habitat study at the Lansing WWTP on the Grand River recorded the conditions upstream and downstream of the treatment plant. Both of these studies rated the waste discharges from the WWTP and the nearby Oldsmobile Plant #3 (jet plant) as severely limiting the fish populations for over four miles downstream of the WWTP (Wuerthele Jan. 9-22, 1970, Wuerthele Jan. 19-20, 1970)

In 1977 the East Lansing and Lansing WWTPs were identified as the primary sources of water quality impairments in the Grand River. By July 1, 1977 the Lansing WWTP was required to meet final effluent limitations of the Michigan Water Quality Standards (MDNR 1977). A more recent study (Butler 1995) shows that the implementation of final effluent limitations has significantly improved the water quality in the Grand River, Lansing vicinity.

Carrier Creek at Saginaw Hwy. (Jan. 2005)

A July 1999 investigation of water quality was conducted by staff from the Michigan Department of Environmental Quality (MDEQ) in the Grand River at three sampling locations following a report of dead fish. Temperature and DO were measured at two locations upstream of the Ottawa Street dam and at one location downstream of the dam (Brunsen 2000). The DO concentrations at the two locations upstream of the dam, Kalamazoo Avenue and River Front Park, were 2.54 mg/l and 2.57 mg/l, respectively. These levels do not meet the daily minimum standards of 5 mg/l. However, the DO concentration rebounded to 5.28 mg/l

downstream of the dam at the Grand River Avenue sample location, supporting evidence that the dam provides sufficient re-aeration to meet the minimum daily standards (Brunsen 2000).

Carrier Creek

The Michigan Department of Natural Resources (MDNR) and MDEQ conducted a series of biological and habitat quality assessments for Carrier Creek in Eaton County.

An initial study was requested by Lansing MDNR staff in July 1989 due to concerns about non-point source pollution impacts from agricultural run off, urban run off, and soil erosion (Goble and Masterson 1990). Data were collected at three stations along the Carrier Creek, at I-496, St. Joe Highway, and the Old River Trail, stations 1, 2 and 3, respectively. At Station 1, I-496, heavy sedimentation (likely due to road construction on I-496) appeared to produce a moderate overall macroinvertebrate habitat quality. Fish habitat quality was considered low with green sunfish and bluegill fish dominating the area. Downstream at station 2, St. Joe Highway, the macroinvertebrate habitat quality remained unchanged at moderate quality while fish diversity was low. Further downstream at the Old River Trail, Station 3, macroinvertebrate habitat and fish habitat quality were both low. Sand and gravel substrates dominated all three stations.

A follow-up study was performed in July of 1996 to evaluate point source and non-point source pollutants in the watershed (Hanshue 1999). The most downstream station, station 1 (station 3 in study conducted in 1989) was located just before the Grand River confluence. Although the overall abundance of macroinvertebrate and fish biomass was high, the samples were dominated by tolerant, low quality species thus were given an overall moderate quality. The upstream Carrier Creek sampling locations were significantly impaired by historical drainage and construction site erosion. At station 2, St. Joe Highway, the Creek flows through a golf course where channelization, clearing of vegetation and removal of in-stream coverage compounded previously documented impairments to the fish and macroinvertebrate communities. Due to the new impairments combined with the unchanged conditions from the previous surveys, sampling in 1996 was not conducted. Further upstream at station 3, Saginaw Hwy, (I-496 station in 1989 study) a development project cleared land with failure to implement adequate storm water control measures causing significant erosion to fill in the stream channel. Because samples could not be taken, the survey was discontinued. These findings put Carrier Creek as a threatened water body on the 1998 303(d) list and led the Great Lakes and Environmental Assessment Section (GLEAS) staff to evaluate the watershed to make Total Maximum Daily Load (TMDL) recommendations and a TMDL date of 2002 (Cooper 2002).

In August 2000, a Watershed Management Plan (WMP) was completed for Carrier Creek which addresses a number of existing and future problems within the watershed. The need for a WMP was based on environmental assessments and it focuses on re-establishing and enhancing the warm water fishery, indigenous aquatic life and wildlife, and the recreational potential of total body contact (Wetland and Coastal Resources, Fitzgerald Henne & Associates 2000).

Measurements

The common measurement for testing parameters is milligram per liter. This measurement is approximately one unit in one million units. Examples of this finite measurement are as follows:

- One fluid ounce of chocolate in a railroad tank car of milk.
- One minute in two years.
- One inch in sixteen miles.
- The weight of one postage stamp to the weight of a man.

Carp
NOAA, 2004

Watershed.org, 2004

Caddis Fly Larvae in Case

Watershed.org, 2004

Stone Fly

In 2001, staff from the MDEQ conducted a study to assess the current quality of the macroinvertebrate community following development of the WMP and the listing in Michigan's Year 2000 Section 303(d) report. The 303(d) report lists Carrier Creek as having impaired macroinvertebrate communities from excessive sedimentation (Wuycheck 2002). Biological survey results for macroinvertebrate communities indicated acceptable quality at all three sampling locations. The MDEQ found that the substantial soil deposition found in the 1996 study at I-496 was rehabilitated and stabilized in addition to the removal, dispersal and/or stabilization of in-stream snags and deadfalls that were previously observed. Additionally, an upland coffer dam was built for collection and redirection of runoff from a development site to Carrier Creek via an enclosed drain.

Reynolds Drain

Brown Bullhead
NOAA, 2004

A study was conducted by the MDNR in July 1991 on the Reynolds Drain and an unnamed tributary in Ingham County to assess whether Capitol City Airport operations were adversely affecting conditions in the area (Scott, 1992). Three sampling locations were assessed, two located in Reynolds Drain and one on an unnamed tributary just south of the Airport. The study found poor physical habitat conditions at all three sampling stations attributed to improper land use practices and channelization. The macroinvertebrate community was found to be poor at the culvert on the tarmack in the unnamed tributary. Extremely low water levels were also observed. No chemicals were found at concentrations above the MWQS in any of the samples.

Volunteer Monitoring

Project GREEN

Project Global Rivers Environmental Education Network (GREEN) is an interdisciplinary, watershed-based education program providing hands-on opportunities to high school students. Students gain science, math, and social skills outside the classroom primarily through dealing with local water quality problems. Table 4-3 identifies the monitoring location in the watershed.

Table 4-3 Project GREEN Education Programs

Location Description	Volunteer Group conducting water testing:
At the aluminum bridge where the Hunter Drain meets the Grand River (on Woldumar Nature Center property, at the lagoon) southwest of Lansing, MI	Woldumar Nature Center Data collected during Spring and/or Fall of 2002 - 2004
Grand River at Sweeney Boat launch, immediately north of I-496 in Lansing, MI	Everett High School students Data collected during Spring and/or Fall of 1996,1997,1999-2002
Grand River at the angular dock in Riverfront Park, downtown Lansing, MI	Lansing Eastern High School students Data collected during Spring and/or Fall of 2000-2005

Mid-Michigan Environmental Action Council

Mid-Michigan Environmental Action Council (Mid-MEAC) is a non-profit and volunteer based environmental organization dedicated to improving the environment and quality of life by raising environmental consciousness and activism. Data collection was provided in the Michigan Clean Water Corps grant application, which required testing of each site and includes past monitoring data. Monitoring sites are located on Table 4-4.

Table 4-4 Mid-MEAC Monitoring Data

River Name	Road Location	County	Macro Rating	Location Assessment	Surrounding Areas	Reason to Monitor	Year
Grand River	Columbia Road (near Kingland)	Ingham County	Fair	High recreational and tourism activities	wetlands, shrubs/old fields, forest, residential lawns/parks and impervious surface	Provides a representation of the river upstream of impacts from East Lansing, Lansing and Grand Ledge	2004
Sandstone Creek	Fitzgerald Park in Grand Ledge	Eaton County	Fair	Turbidity present, moderate highway/road/bridge maintenance, moderate urban runoff.	forest, residential lawns/parks	Historically, fertilizers and storm water run-off have been impacted by sedimentation and siltation. Volunteer monitoring data would be used by MDEQ, consultants, and local governments to assess the current condition of the stream.	2004

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Figure 4-2 Water Quality Data Summary

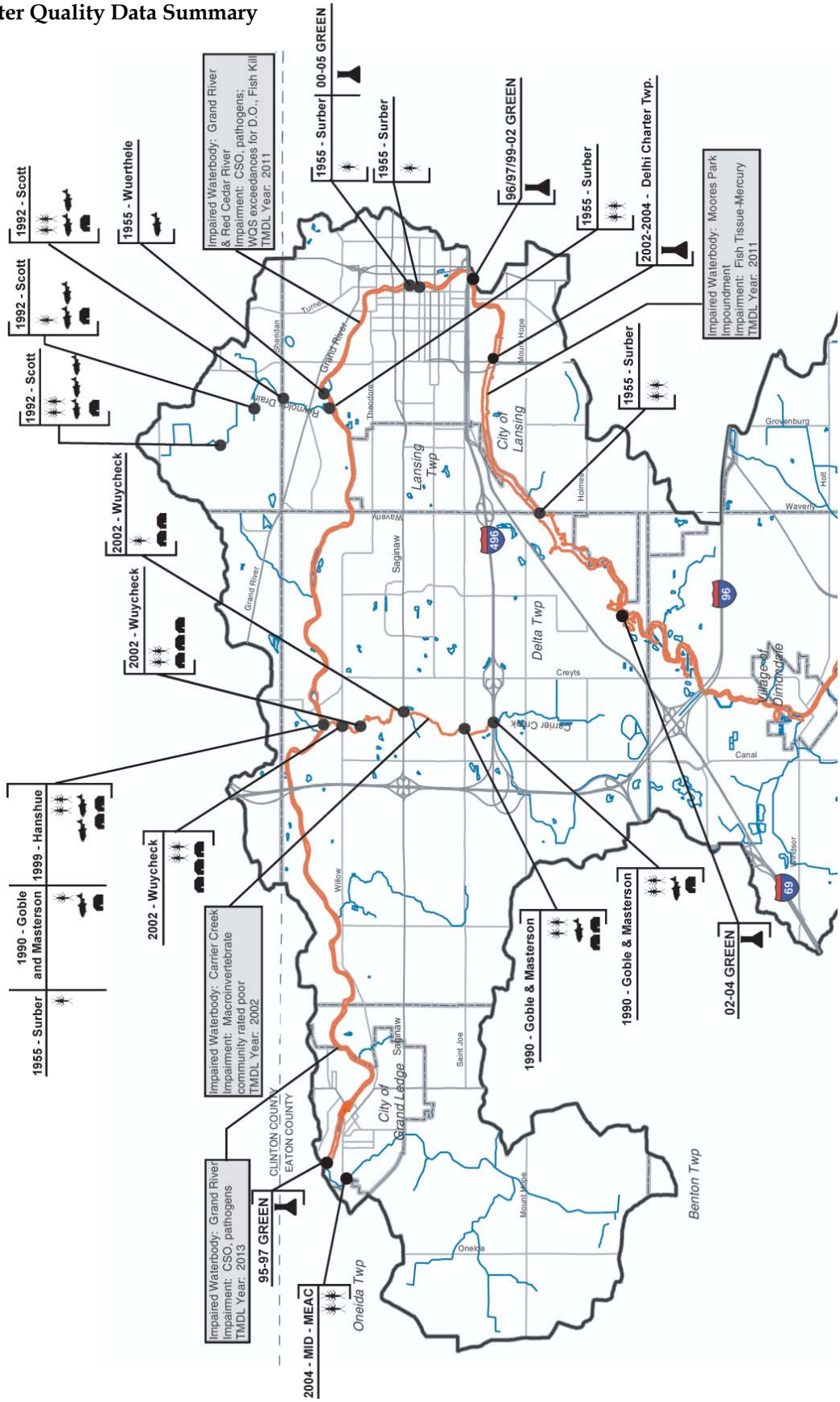
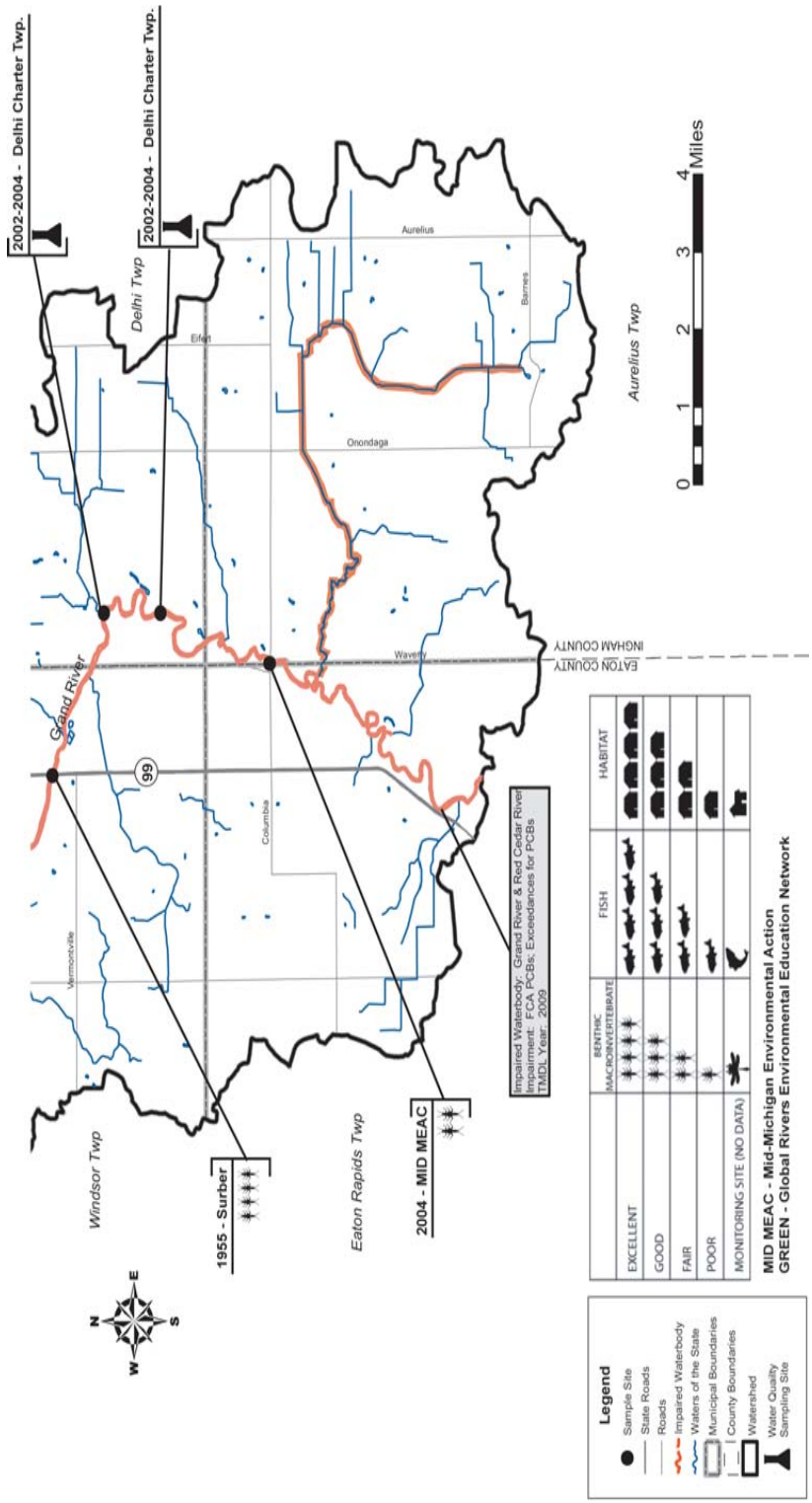


Figure 4-2 Water Quality Data Summary (continued)



Frog and Toad Survey

Wood Frog

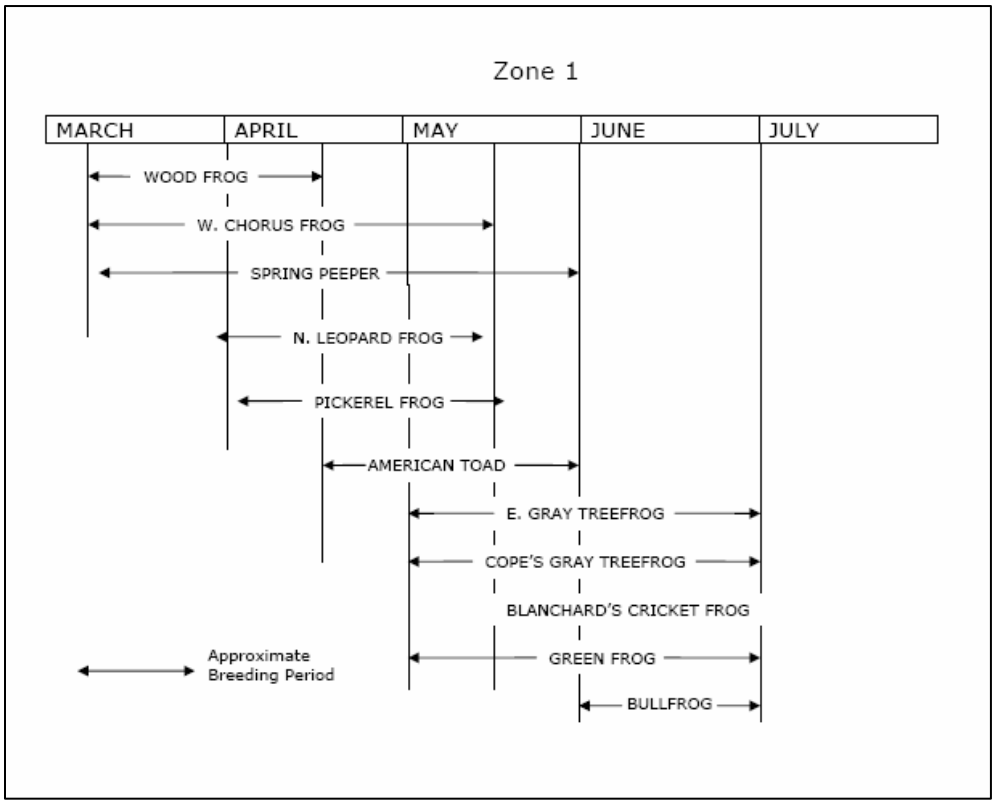
Michigan is home to 13 native species of anurans (frogs and toads). In recent years, observers have noticed a decline in population of several anuran species in Michigan. Frogs and toads are sensitive to changes in water quality and urbanization. Therefore, their populations serve as an index to environmental quality.

The State of Michigan is concerned about the decline of anurans. Michigan initiated a volunteer based frog and toad survey program in 1988 to increase the knowledge of anuran distribution and to monitor population over the long-term. Wetland sites are visited in early spring, late spring and summer for monitoring.

Volunteers identify the species based on their breeding season call or songs and determine the abundance of each species using a call index of 1 (1-5 individuals), 2 (6-12 individuals) & 3 (unable to count individuals).

In the Tri-County area, anuran species include the Wood Frog, Western Chorus Frog, Spring Peeper, Northern Leopard Frog, American Toad, Gray Tree Frog, and Green Frog. Volunteers are unable to observe the other species shown in Figure 4-3 because they are primarily found along the lake shore, in the Upper Peninsula, or their population is declining in Michigan. Tri-County area data from the frog and toad surveys are available from the MDNR going back to 1996.

Figure 4-3 Calling Calendar for Frogs and Toads in Michigan



Water Chemistry

From September 8 through September 14, 1995, a study was conducted to assess the chronic toxicity of the Lansing WWTP Outfall 001 effluent in Lansing, Michigan. *Ceriodaphnia dubia* survival and reproduction tests were performed on a composite sample from the Lansing WWTP effluent and indicated that the effluent was not acutely or chronically toxic to the species (Butler 1995). *Ceriodaphnia dubia* is an indicator organism used by the Environmental Protection Association (EPA) for testing adverse effects of effluent. The Lansing WWTP effluent met the aquatic toxicity requirements and no toxic chemicals were detected at or above the MWQS detection limit.

Watershed Fish Consumption

The Michigan Department of Community Health (MDCH) uses fish contaminant data collected by the MDEQ to develop the annual Michigan Fish Advisory. Presently, there is no particular fish consumption advisory (FCA) in effect for any water bodies within the Grand River Watershed, although, all inland lakes, reservoirs, and impoundments within the watershed are under a general statewide fish advisory for mercury contamination. This advisory applies to all inland lakes in Michigan since not all inland lakes, reservoirs, and impoundments have been tested or monitored. Table 4-5 lists the FCAs applicable to the watershed.

Table 4-5 Fish Consumption Advisory Information (2004 Michigan Family Fish Consumption Guide, MDCH).

Water body	Location	Fish Species	Restricted Population	Restriction
All inland lakes, reservoirs, and impoundments	Entire State	Bass	General Population	Any size: One meal per week
			Women and Children*	Any size: One meal per month
		Crappie	General Population	9+ inches: One meal per week
			Women and Children*	9+ inches: One meal per month
		Muskellunge	General Population	Any size: One meal per week
			Women and Children*	Any size: One meal per month
		Northern Pike	General Population	Any size: One meal per week
			Women and Children*	Any size: One meal per month
		Rock Bass	General Population	9+ inches: One meal per week
			Women and Children*	9+ inches: One meal per month
		Walleye	General Population	Any size: One meal per week
			Women and Children*	Any size: One meal per month
		Yellow Perch	General Population	9+ inches: One meal per week
			Women and Children*	9+ inches: One meal per month

* - Children are defined as those individuals under 15 years of age

Impaired Water Bodies

Based on the studies conducted by the MDEQ and the MDNR a MWQS violation has been identified in Carrier Creek within the watershed. A TMDL implementation date for Carrier Creek has been set for 2002 to develop a management strategy and ultimately restore the water quality. The details of the impairment, as outlined in the State of Michigan's 2002 Section 303 (d) are presented in Table 4-6.

Table 4-6 Impaired Waterbodies

Water body	Location	Problem	TMDL date
Carrier Creek	Grand River confluence upstream to I-496.	Macroinvertebrate community rated poor.	2002
Grand River	Webster Road upstream to Moores River Dam	Pathogens (Rule 100); WQS exceedances for DO; Fish kills	2011
Grand River	Vicinity of Grand Ledge	CSO, Pathogens (Rule 100)	2013
Moores Park Impoundment (Grand River)	Vicinity of Lansing from the Moores Park Dam upstream to Waverly Road	Fish Tissue - Mercury	2011
Grand River	Lake Michigan confluence upstream to the vicinity of Jackson	FCA-PCBs; WQS exceedances for PCBs	2009
Columbia Creek (West Aurelius Drain)	Aurelius Twp. T2N, R2W, Sections 7, 8, 9, 10, 15, 16, 21, 28	Highly modified, Biological degradation	N/A

Cooper 2002

Pollutant Load Analysis

The intent of pollutant load analysis is to derive the potential pollutant contributions to a system for a given area to assist in prioritizing problem areas. Pollutant load analyses are often developed by extrapolating existing data or developing theoretical data from a model.

There is limited data on existing pollutant loads within this watershed. Therefore, it is practical to calculate the pollutant loadings by utilizing a model. The pollutant load analysis conducted for this watershed was modeled using the Environmental Protection Agency's Spreadsheet Tool for Estimating Pollutant Loads (STEPL). Phosphorus, 5-day Biological Oxygen Demand (BOD), and sediment loadings were all calculated on a subwatershed basis using this program. The methods used to calculate urban loadings of phosphorus, sediment, and BOD primarily utilized the runoff volume and land use specific pollutant concentrations for each subwatershed to provide an average annual loading. Agricultural sediment calculations utilized the universal soil loss equation (USLE), widely used to calculate average annual soil losses from sheet and rill erosion (EPA 2004). Phosphorus and BOD were calculated for agricultural areas by multiplying the soil load by a pollutant concentration for nutrients in the sediment.

Land Use Specific Pullutant Concentrations

Pollutant concentrations for the watershed were not available, therefore published concentrations from national studies were considered for their

applicability to this watershed. Table 4-7 presents the range of urban pollutant load concentrations found in a literature review.

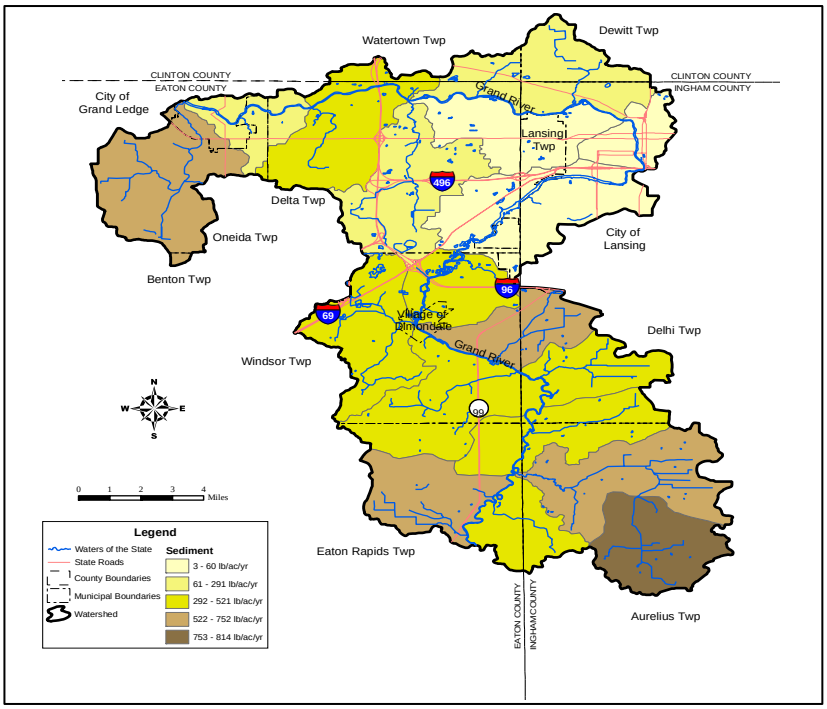
Table 4-7 Urban Pollutant Load Concentrations (mg/l)

Reference	Commercial			Industrial			Institutional			Transportation			Residential			Pasture Land			Forest		
	BOD	TP	TSS	BOD	TP	TSS	BOD	TP	TSS	BOD	TP	TSS	BOD	TP	TSS	BOD	TP	TSS	BOD	TP	TSS
EPA, 1983	9.3	0.2	69	--	--	--	--	--	--	--	--	--	10	0.38	101	--	--	--	--	--	--
EPA, 2004	9.3	0.2	75	9	0.4	120	7.8	0.3	67	9.3	0.5	150	10	0.4	100	13	0.3	--	0.5	0.1	--
MPS, 1992	16	0.26	30	23	0.36	142	--	--	--	--	--	--	43	0.57	205	--	--	--	--	--	--
Pitt, 2004	11	0.22	74	9	0.26	78	8.5	0.18	17	8	0.25	99	9	0.3	49	--	--	--	--	--	--

The data in Table 4-7 illustrate the diversity in land use specific pollutant load concentrations and the potential for error in the pollutant load estimates. For the purposes of this watershed; the concentrations identified in STEPL (EPA, 2004) were chosen for the pollutant load calculations.

These values were chosen with the understanding that the pollutant load analysis is a theoretical calculation of the loadings within the watershed and that the results would be used to draw conclusions and prioritize subwatersheds, in concert, with the published water quality data discussed previously.

Figure 4-4 Sediment Pollutant Load



Pollutant Load Results

The current unit pollutant loads (lbs/ac/yr) for sediment, phosphorus, and BOD are illustrated by subwatershed in Figure 4-4, Figure 4-5 and Figure 4-6, respectively. Tabular unit pollutant load data for each subwatershed is provided in Table 4-8. Locations and names of subwatersheds are provided in Figure 3-1.

In Table 4-8 the top five unit area loadings are highlighted in yellow with the subwatershed with the highest loading, Upper West Aurelius Drain, bolded. Locations and names of subwatersheds can be referenced in Table 4-1.

The model is showing that the highest unit loadings are occurring in the more rural or agricultural zones of the watershed. These results are not due to specific sites within the watershed, but are a result of the higher loadings associated with agricultural land uses. Best management practices existing within the watershed were not considered within this loading model.

Table 4-8 Unit Area Storm Water Loading Data

	Current		
Subwatershed	**Phosphorus (lbs/ac/yr)**	**BOD (lbs/ac/yr)**	**Sediment (lbs /ac/yr)**
Aurelius-Delhi Drain	0.60	6.9	505.69
Carrier Creek	0.23	3.54	166.53
Columbia Creek	0.75	7.46	650.20
County Line	0.57	7.39	486.33
Gilbert Drain	0.60	6.71	525.23
Grand River A	0.72	7.83	629.45
Grand River B	0.08	2.10	42.60
Grand River C	0.01	0.29	3.61
Grand River D	0.04	1.11	23.08
Grand River E	0.27	3.64	233.63
Grovenburg Drain	0.51	6.05	444.65
John Earl Drain	0.74	7.06	636.46
Miller Creek	0.61	6.72	511.78
Renyolds & Edwards	0.24	2.91	198.59
Silver Creek	0.58	7.10	478.55
South Windsor Creek	0.59	7.50	477.52
Upper West Aurelius	**0.90**	**8.41**	**814.88**
Willis Shaw & Fulton	0.57	7.76	483.97

Figure 4-5 Phosphorous Pollutant Load

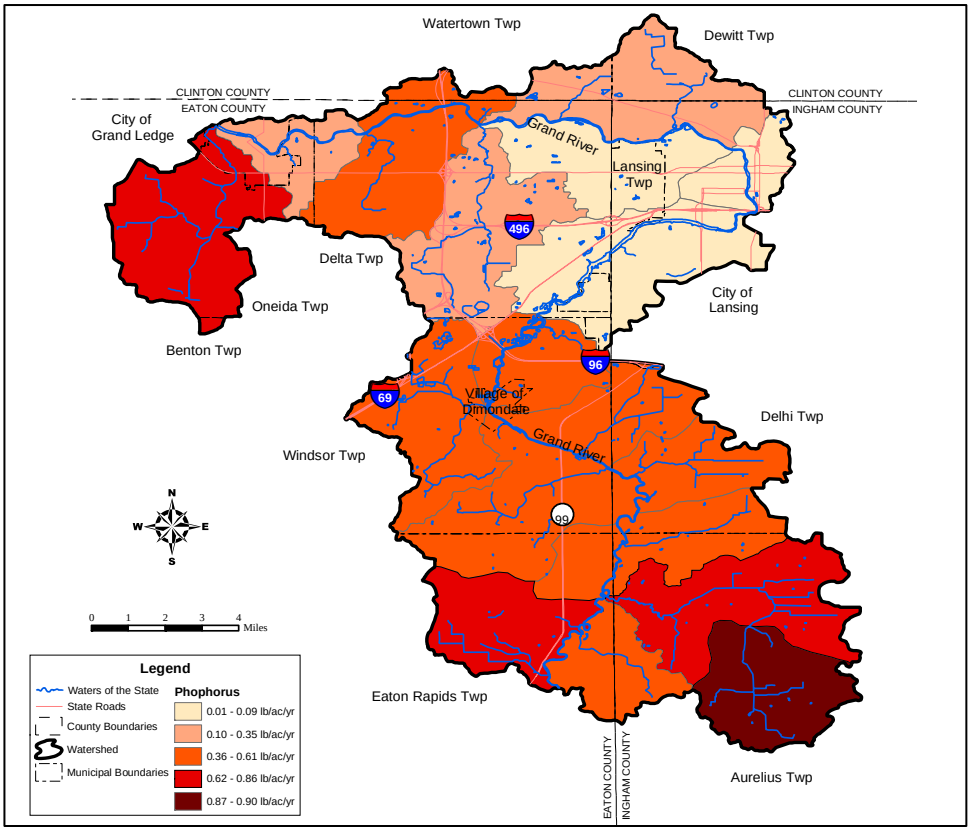
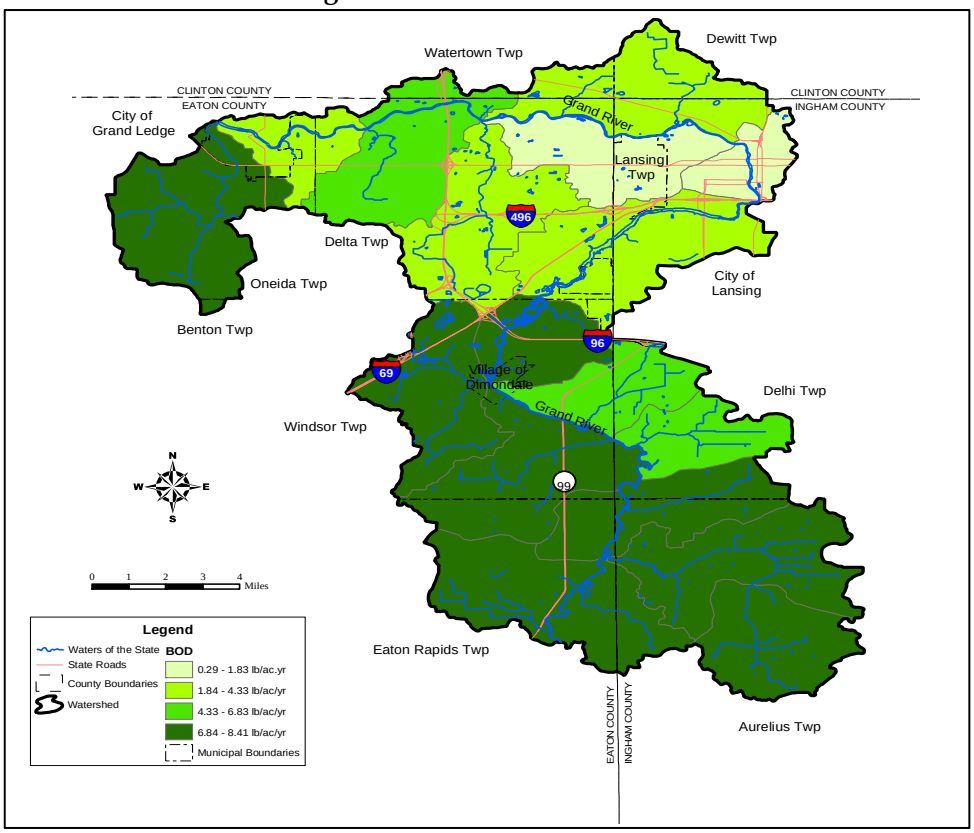


Figure 4-6 BOD Pollutant Load



Pollutant Load Summary

Overall, the loadings calculated may provide an accurate representation of the loadings occurring in the watershed. In many instances agricultural landscapes have the highest loads of sediment, phosphorous, and BOD, although urban areas should not be underestimated in their loading contributions. Much of the urban sediments which may not be accounted for through the pollutant load calculations may be originating from construction sites, poor maintenance of roads and catch basins, and altered urban waterways.

The MDEQ and MDNR found the greatest impact to macroinvertebrates, fish and habitat in the Grand River to be occurring in the downstream areas within the urbanized zone and downstream of the WWTPs. Sediments may be carried from the upstream reach of the urbanized zone where water velocities are slower and the sediment is able to be deposited.

The published data support the pollutant load calculations produced in the STEPL program for most of the watershed, but suggest that the program is underestimating the urbanized subwatersheds.

Sources and Causes of Pollutants

A list of pollutants, their sources and causes was developed for the Watershed. Each pollutant is grouped into one of five categories of pollutants below; oxygen-depleting, physical, toxic, thermal or `other' followed by a description of the pollutant and possible sources and causes.

Oxygen-Depleting Pollutants

Oxygen-depleting pollutants generally are, or cause, organic materials that require a large amount of oxygen for decomposition. Many organisms living in water systems require the presence of oxygen (aerobic organisms) for survival, such as fish and zooplankton, and will suffocate in oxygen-deficient systems. Common oxygen-depleting pollutants of concern in the Grand River watershed are listed below.

Detergents are becoming a serious threat of contamination to storm water. Detergents are the soaps people use to wash their cars, which are carried to waterbodies through storm drains. Once detergents enter a water body they cause excessive algae growth. As the algae begin to decompose, it creates an oxygen-deficient environment. Detergents/soaps also alter the aquatic environment and destroy the mucus layer in fish that protects them from parasites. Washing vehicles on lawns or other pervious surfaces will help reduce the rate at which detergents enter the storm drain.

Photo Courtesy of Tetra Tech, 2005

Table 4-9 Detergents: Sources and Causes

Sources	Cause
Residential Car Washing	Lack of Buffer
Commercial Car Washing	Poor Construction
	Poor Maintenance
	Lack of Ordinance
	Lack of Enforcement
Cleaning Agents Used Outside	Lack of Buffer
	Poor Construction
	Poor Maintenance
	Lack of Ordinance
	Lack of Enforcement

Nitrogen and phosphorus nutrients are crucial elements for aquatic systems when they exist in low concentrations. When concentrations are found in excess, negative impacts are exerted on receiving waters, such as excessive plant growth. Excessive plant growth leads to increased plant decomposition as the plants start to die off. The decomposition process consumes oxygen. Thus increased nutrients lends to oxygen depletion. Nutrient concentrations are found to be directly connected to land use, with urban and agricultural land uses introducing the highest loads and annual rainfall amounts. More annual rainfall results in a greater magnitude of nutrient concentrations. Nitrogen is reported in four concentration forms. Nitrate (NO_3), nitrite (NO_2), total nitrogen (Total N), and total Kjeldhal nitrogen (TKN). Phosphorus is measured using either total phosphorus (Total P) or soluble phosphorus (phosphates) (CWP, March 2003).

Table 4-10 Nutrients: Sources and Causes

Sources	Cause
Livestock	Unrestricted Access Lack of Buffer
Manure Storage	Poor Design Poor Construction Poor Maintenance
Animal Waste (Non-Agricultural)	Pet Owners Not Picking Up Waste Wildlife Lack of Buffer
Failing Septic Systems	Poor Design Poor Construction Poor Maintenance
Leaky Sanitary Sewer	Poor Design Poor Construction Poor Maintenance
Combined Sewer Overflows (CSOs)	Function of Design Criteria Increased Development Unnecessary Inflow
Sanitary Sewer Overflows (SSOs)	Excessive Infiltration Storm Water Inflow Increased Development
Fertilizer Use (Non-Agricultural)	Fertilizer Application Lack of Buffer
Atmospheric Deposition	Causes Not Appropriate for this Plan but Education Needed
Agricultural Runoff	Poor Nutrient Management Lack of Buffer
Increase in Naturally Occurring Sources	Loss of Wetlands
Residential Yard Waste	Poor Maintenance Poor Design of Facility
Dumpsters	Poor Construction Poor Maintenance
Golf Courses	Fertilizer Application Lack of Buffer
Publicly Owned Treatment Works (POTWs)	Plant Effluent Limits Poor Design Poor Maintenance

Physical Pollutants

Physical pollutants include rubbish and sediments from erosion. These pollutants cover and suffocate plant and animal life, reduce light availability for aquatic plant and micro-algae growth, and may cause a decline in the biological diversity of an ecosystem when they are deposited into streams. The physical pollutants of concern in the Grand River watershed are briefly described below.

Sediment in urban watersheds is an important pollutant; causing problems and negative impacts while furthermore transporting other pollutants that

Photo Courtesy of Tetra Tech, 2004.

bind to sediment particles. Quantitatively, sediment has been labeled the most important single pollutant in U.S. streams and rivers. Inorganic fine sediments are naturally present to some extent in all streams. However, in the last half century, excessive sediment of anthropogenic origin has caused enormous damage to streams throughout North America (Waters, T.F. 1995). Suspended sediment, through turbidity, reduces light penetration through the water thus reducing photosynthesis. Fish in nature avoid streams or stream reaches with high suspended sediment levels creating environments just as devoid of fish as if they had been killed. Deposited sediment increase the level of embeddedness of the stream bed (termed habitat reduction) resulting in a decrease of invertebrate populations and consequently in food available to fish. Sediment can be measured by Total Suspended Solids (TSS), Total Dissolved Solids (TDS) and turbidity (CWP, March 2003).

Table 4-11 Sediments: Sources and Causes

Sources	Cause
Livestock in Stream	Unrestricted Access
Agricultural Runoff	Over Grazing of Livestock
	Lack of Buffer
	Poor Conservation Practices
Road-Stream Crossings	Poor Design
	Poor Construction
	Poor Maintenance
	Human Access
Stream Banks	Flow Fluctuations (see Hydrologic Flow)
	Livestock Access
	Human Access
Drainage Ditches	Ditch Cleanout without Soil Stabilization
	Flow Fluctuations (see Hydrologic Flow)
	Livestock Access
	Human Access
Construction Site Runoff	Inadequate Soil Erosion and Sedimentation Controls
Sand Used on Winter Road	Application Practices
	Lack of Buffer
	Poor Clean Up Practices
Gravel Roads, Parking Lots and Driveways	Lack of Buffer
	Poor Maintenance
Loss of Material Around Storm Sewer System	Poor Construction
	Poor Maintenance
Off-Road Vehicles	Unrestricted Access
	Lack of Buffer
Mining Operations/Gravel Pits	Inadequate Soil Erosion and Sedimentation Controls

Photo Courtesy of Tetra Tech, 2004.

Trash & Debris can impact the biota and stability of a waterway. It is also an issue with the aesthetic appeal and perception of a river. Common sources of trash and debris include storm water, combined sewer overflows, beachgoers and other non-point sources, boats, solid waste

disposal and landfills, industrial activities, and illegal dumping or littering (EPA, 2004).

Table 4-12 Trash and Debris: Sources and Causes

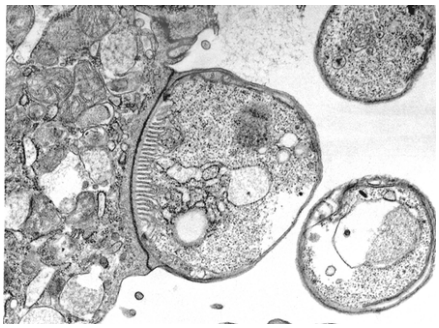
Sources	Cause
Dumping	Lack of Convenient Disposal Facilities
Animal Scavenging	Lack of Secure Disposal Facilities

Hydrologic Flow is not a pollutant in the terms of heavy metals or pesticides, but does affect biota and stability of streams and rivers. Changes in hydrologic flow typically increase the volume, frequency, and peak discharges of the stream. These changes can cause stream bank erosion, sedimentation, and poor conditions for plants, fish and macroinvertebrates. Increasing impervious surfaces within the watershed, channelization, and removal of riparian vegetation are common causes for changes in hydrologic flow.

Source: Great Swamp Water Association Conservation Area, 2005

Table 4-13 Hydrologic Flow: Sources and Causes

Sources	Cause
Increased Channelization	Impervious Surfaces
	Lack of Buffer
	More Hydraulically Efficient Drainage Systems
	Additional Drainage Systems
	Development with Poor Storm Water Planning
Loss of Infiltration	Impervious Surfaces
	Turf Grass
	Compacted Soils
	Lack of Buffer
	Loss of Natural Areas
	Development with Poor Storm Water Planning
Loss of Storage	Loss of Wetlands
	Loss of Low Areas Acceptable for Flooding
	Loss of Floodplain
	Development with Poor Storm Water Planning



Source: The University of Florida, 2005

Toxic Pollutants

Toxic pollutants are non-biodegradable compounds including heavy metals and organic compounds. Toxic pollutants are deadly to organisms because the organism's natural biological processes are disrupted; usually with very low pollutant concentrations. The major toxic pollutants of alarm for the watershed are listed below.

A **Pathogen** is a microbe that under certain conditions will cause disease. Because many pathogens are not easily identified in water, an indicator organism such as *Escherichia coli* is commonly used as an estimation of pathogenic organisms. *Cryptosporidium parvum* and *Giardia lambia*, two protozoa, are the most common waterborne pathogens in the U.S. These protozoa, originating from human sewage and animal feces, are waterborne parasites that cause intestinal problems when ingested by creating a cyst that attaches to a host (i.e. cattle host, and then transferred to humans). Elevated levels of both pathogens were detected in a study of urban storm water runoff causing concern over drinking water supplies (CWP, March 2003).

Table 4-14 Pathogens: Sources and Cause

Sources	Cause
Livestock	Unrestricted Access
	Lack of Buffer
Manure Storage	Poor Design
	Poor Construction
	Poor Maintenance
Animal Waste (Non-Agricultural)	Pet Owners Not Picking Up Waste
	Wildlife
	Lack of Buffer
Illicit Connections	Poor Construction Practices
Failed Septic Systems	Poor Design
	Poor Construction
	Poor Maintenance
Leaky Sanitary Sewer	Poor Design
	Poor Construction
	Poor Maintenance
Combined Sewer Overflows (CSOs)	Function of Design Criteria Increased Development with Poor Storm Water Planning Unnecessary Inflow (e.g. connected downspouts and footing drains)
Sanitary Sewer Overflows (SSOs)	Excessive Infiltration
	Storm Water Inflow Increased Development with Poor Storm Water Planning
Dumping	Lack of Adequate Disposal Facilities

Source: Morton Salt, 2005

Salt (Deicer) is often used to melt snow and ice on roads and sidewalks. Extremely high concentrations, in the range of 2,000-5,000 mg/l, are typical in snowmelt and storm water runoff particularly in colder regions. However, chloride becomes toxic to organisms at concentrations of 500-

1,000 mg/l and may additionally affect soil permeability, drinking water and small streams (CWP, March 2003).

Table 4-15 Salt: Sources and Causes

Sources	Cause
Roadways	Application Practices
	Lack of Buffer
Water Softeners	Poor Design
	Poor Maintenance
	Poor Construction

Oil and grease are often referred to as "hydrocarbons," or petroleum-based substances. Hydrocarbons travel attached to sediment and are frequently found in storm water and accumulate in bottom sediments. Little is known about the direct impacts of hydrocarbons on waterways, however, bioaccumulation and toxicity in aquatic organisms is a large concern. "Hotspots" for high concentrations of hydrocarbons are gas stations, convenience stores, commuter and residential parking areas and streets (CWP, March 2003).

Source: Rouge Valley Council of Governments, 2005

Table 4-16 Oil and Grease: Sources and Causes

Sources	Cause
Automobiles	Poor Maintenance
	Lack of Convenient Disposal Facilities
	Inadequate Disposal Facilities
Dumping from Food Preparation Facilities	Poor Maintenance
	Lack of Convenient Disposal Facilities
Dumpsters	Poor Design
	Poor Construction
	Poor Maintenance
Maintenance/Storage Yards	Poor Maintenance
	Poor Construction
	Lack of Oil/Grease Separator
	Lack of Buffer
Junk Yard	Poor Maintenance
	Lack of Oil/Grease Separator
	Lack of Buffer
Gas Stations	Poor Maintenance
	Poor Design
	Poor Construction
	Lack of Oil/Grease Separator

According to the EPA, as much as 100 pounds of **Household Hazardous Waste (HHW)** is generated per home/garage annually. HHW includes paints, solvents, used motor oil, excess pesticides and cleaning products. Although the exact fraction of HHW that is illegally dumped into the storm

Source: King County Government, 2005

drain is unknown, it is apparent that during most outdoor rinsing of pesticide applicators and outdoor painting cleanup the waste enters the storm drain system creating potential toxins to aquatic life (CWP, March 2003).

Table 4-17 HHW: Sources and Causes

Sources	Cause
Paint	Lack of Convenient Disposal Facilities
Batteries	Lack of Convenient Disposal Facilities
Solvents	Lack of Convenient Disposal Facilities
Medicines/Antibiotics	Lack of Convenient Disposal Facilities
	Not Removed By POTW

Heavy Metals, specifically zinc, copper, lead, cadmium, and chromium, have been consistently found in urban storm water at levels of concern. EPA studies found that 75% of the time, concentrations of lead, zinc and copper exceed chronic toxicity limits in storm water samples. These metals result from the use of motor vehicles, metals and paint weathering, burning and atmospheric deposition of fossil fuels and have the potential, from bioaccumulation, to be highly toxic to aquatic organisms (CWP, March 2003).

Table 4-18 Heavy Metals: Sources and Causes

Sources	Cause
Automobiles	Normal Result of Usage
	Poor Maintenance
Metal Roofs	Normal Result of Usage
	Lack of Buffer
Soil Leachate	Contaminated Soil from Historic Industrial Practices
	Normal Background Level Present in Soil
Maintenance/Storage Yards	Poor Maintenance
	Poor Construction
	Lack of Buffer
Junk Yard	Poor Maintenance
	Lack of Buffer
Dumping	Lack of Education
	Lack of Convenient Disposal Facilities
Publicly Owned Treatment Works (POTWs)	Plant Effluent Limits
	Poor Design
	Poor Maintenance
Atmospheric Deposition	Causes Not Appropriate for this Plan but Education Needed
Medical Establishments	Lack of Convenient Disposal Facilities
	Poor Management

Polychlorinated Biphenyls (PCBs) were commonly used in industrial and commercial equipment including heat transfer systems and televisions as well as in paints, plastic and rubber products, pigments, dyes and

carbonless copy paper until PCBs were banned in 1976. According to the EPA, PCBs are known to cause cancer in animals, cause problems in human immune, reproductive, nervous and endocrine systems and affect intellectual development of children and adults (EPA, 2005).

Table 4-19 PCBs: Sources and Causes

Sources	Cause
Stream Bottom Sediment	Plant Discharges
	Lack of Convenient Disposal Facilities
	Permitted Usage
Brownfield Runoff and Subsurface Leaching	Plant Discharges
	Lack of Convenient Disposal Facilities
	Permitted Usage

Pesticides are used to control unwanted pests in the urban environment and vary in mobility, persistence, and potential aquatic impacts. Pesticide detection has been found to proportionally increase with the amount of urban land. Studies have found that high concentrations of pesticides, specifically diazinon, have adverse effects on ecology and human health. The Center for Watershed Protection (CWP) studies identify 100 percent of urban stream fish contain detectable pesticide levels in their tissues (CWP March 2003).

Source: DHI Water and Environment, 2005

Table 4-20 Pesticide: Sources and Causes

Sources	Cause
Agricultural Lands	Pesticide Application
	Lack of Buffer
Residential Gardens	Pesticide Application
	Lack of Buffer
Drainage Ditches/Retention Basins	Pesticide Application to Reduce Maintenance
Golf Courses	Pesticide Application
	Lack of Buffer
Mosquito Treatment	Pesticide Application
	Lack of Buffer
Lake Management	Pesticide Application
	Lack of Buffer

Thermal Pollutants

Thermal pollution is waste heat generated from industrial processes which use water for cooling. The water is returned back into the water system at a significantly higher temperature, decreasing the dissolved oxygen and increasing the biological demand for oxygen from organisms.

Changes in **temperature**, even slight changes, will cause stress to urban streams and aquatic life. Specifically, increases in temperature result in changes in migration patterns, increased sensitivity and mortality in fish,

Photo Courtesy of Tetra Tech, 2005.

and an increase in metabolic activity producing greater disease and parasite susceptibility (CWP, March 2003).

Table 4-21 Temperature: Sources and Causes

Sources	Cause
Urban Runoff	Impervious Surfaces Lack of Shade over Drainage and Storage Facilities
Lack of Riparian Buffer	Lack of Shade over Watercourse
Publicly Owned Treatment Works (POTWs) and Industrial Discharges	Plant Effluent Limits Poor Design Poor Maintenance

Photo Courtesy of Tetra Tech, 2005.

Other Potential Problems

While **woody debris** is not technically a pollutant, large amounts of it hinder recreation such as canoeing in rivers and streams and may indicate bank erosion problems. Woody debris can also increase the flood stage and increase flooding on private property. However, woody debris is generally beneficial to the environment since it provides habitat for fish and macroinvertebrates which is critical for maintaining a healthy fishery.

Table 4-22 Woody Debris: Sources and Causes

Sources	Cause
Dead Fall	Natural Causes Flow Fluctuations (see Hydrologic Flow) Clearing by Property Owners (view of river)
Yard Waste Dumping	Lack of Convenient Disposal Facilities
Wildlife Habitat	Natural Causes

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