4. Water Quality

The Relevance of Impervious Cover

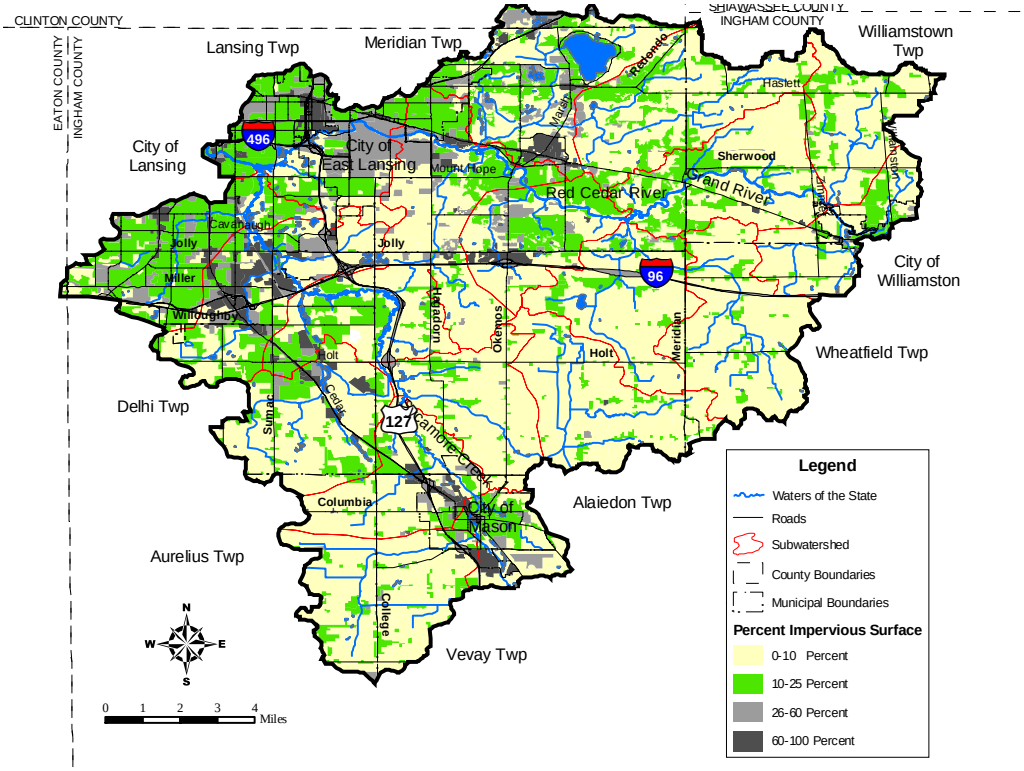
The physical, chemical, and biological integrity of a given stream system has been shown to be strongly correlated to the amount of impervious cover (the area covered by rooftops, streets, parking facilities, and other hard surfaces) in the sub basin or watershed (Schueler, 1994). Imperviousness appears 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.

Downtown East Lansing, (MRP, 2005).

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.

In natural settings, there is very little runoff, with most of the rainfall being filtered by the soils, and eventually supplying deep water aquifers. In urbanized areas, however, less and less rainfall is infiltrated, and as a result, less water is available to streams via groundwater.

Figure 4-1 Red Cedar Watershed Percent Impervious



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 structure degradation; and declining water quality.

> *"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 Red Cedar 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 areas, so impervious cover estimates for rural or agricultural areas will not be presented here. Within the Red Cedar watershed there are several areas of impervious cover which exceed 60 percent of the land area. The larger of these areas are located in the following locations:

- US-127 and Grand River Avenue (Frandor shopping area)
- Downtown East Lansing and northern part of MSU campus
- I-96 and Okemos Road
- Area around Marsh Road and Grand River Avenue (Meridian Mall)
- Areas in the vicinity of US-127 and Mason

Areas greater than 25 percent impervious are predominately located in the areas north of I-96 and West of US-127, including parts of Meridian Township, East Lansing, Lansing, Lansing Township, Delhi Township, Aurelius Township, Vevay Township, and Mason. Areas less than 25 percent imperiousness are scattered throughout these areas and would include rural and agricultural landscapes. Table 4-1 and the percent of impervious located in each municipal Table 4-2. Figure 4-1 shows the overall percent impervious within the Red Cedar Watershed.

Habitat and Populations

Habitat and population information is summarized narratively in the following paragraphs. Figure 4-2 provides a visual depiction for the watershed of the habitat information.

Table 4-1 Impervious Surface for the Red Cedar Watershed

Subwatershed	Average Weighted Percent Impervious
Sycamore Creek A Subwatershed	17.91%
Red Cedar A Subwatershed	6.99%
Cook Creek Subwatershed	5.30%
Smith Drain Subwatershed	15.47%
Sycamore Creek B Subwatershed	12.53%
Mud Creek Subwatershed	4.32%
Aurelius-Vevay Drain Subwatershed	10.89%
Button Drain Subwatershed	5.74%
Holmes Drain Subwatershed	22.50%
Cook and Thorburn Subwatershed	9.73%
Branch Mud Creek Subwatershed	3.63%
Mud Lake Drain Subwatershed	25.08%
Red Cedar B Subwatershed	6.93%
Red Cedar C Subwatershed	24.71%
Mud Lake Outlet Drain Subwatershed	6.64%
Willow Creek Subwatershed	5.69%
Sloan Creek Subwatershed	4.34%
Herron Creek Subwatershed	13.08%
Lake Lansing Subwatershed	16.45%
Average Percent Impervious	**11.52%**

Table 4-2 Percent Municipal Impervious Surfaces for the Red Cedar Watershed

Municipal	Average Weighted Percent Impervious
Windsor Twp	18.63%
Locke Twp	1.94%
Williamston	12.81%
Bath Twp	26.36%
Lansing Twp	18.93%
Mason	21.19%
East Lansing	23.45%
Aurelius Twp	4.50%
Vevay Twp	7.17%
Wheatfield Twp	4.30%
Delhi Twp	13.19%
Lansing	27.32%
Williamstown Twp	5.62%
Meridian Twp	12.43%
Alaiedon Twp	6.08%
Average Percent Impervious	**7.28%**

Table 4-3. Fish in the Red Cedar River.

Species	12/1979 – 5/1981[1]	6/2001 – 8/2002[2]
Brook Silverside		X
White Sucker, Catostomus commersoni	X	X
Northern Hog Sucker, Hypentelium nigricans	X	X
Spotted Sucker, Minytrema melanops	X	
Golden Redhorse, Monostoma ertybrurum	X	X
Silver Redhorse, Monostoma anusurrm	X	X
Shorthead Redhorse		X
Rock Bass, Ambloplites rupestris	X	X
Green Sunfish, Lepomis cyanellus	X	X
Pumpkin Seed, L. gibbosus	X	X
Warmouth, L. gulosus	X	
Bluegill, L. macrochirus	X	X
Smallmouth Bass, Micropterus dolomieui	X	X
Largemouth Bass, M. salmoides	X	X
Black Crappie, Pomoxis nigromaculatus	X	
Mottled Sculpin		X
Stoneroller, Campostoma anomalum	X	X
Carp, Cyprinus carpio	X	
Hornyhead Chub, Nocomis biguttatus	X	
Common Shiner, Notropis cornutus	X	X
Rosyface Shiner, N. rubellus	X	
Sand Shiner, N. stramineus	X	
Bluntnose Minnow, Pimephales notatus	X	X
Spotfin Shiner		X
River Chub		X
Blacknose Dace, Rhinichthys atratulus	X	X
Creek Chub, Semotilus atromaculatus	X	X
Northern Pike		X
Grass Pickerel, Esox americanus vermiculatus	X	
Brook Stickleback, Culaea inconstns	X	
Black Bullhead, Ictalurus melas	X	
Yellow Bullhead, I. natalis	X	X
Brown Bullhead, I. nubulosus	X	
Walleye		X
Johnny Darter		X
Greenside Darter		X
Rainbow Darter, Etheostoma caeruleum	X	X
Johnny Darter, E. nigrum	X	
Yellow Perch, Perca flavescens	X	
Blackside Darter, Percina maculata	X	X
Chestnut Lamprey		X
Northern Brook Lamprey		X
Rainbow Trout		X
Central Mudminnow, Umbra limi	X	X

1 – MSUE, 1997 (as collected by Patrick M. Muzzall, Zoology Department, Miichigan State University
2 – MSU-WATER, 2002

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

Red Cedar River

Research on the Red Cedar River has been conducted by the State of Michigan and other groups since the 1960s. The data predominately covers macroinvertebrate and fish populations, habitat, and Dissolved Oxygen (DO) levels.

A Michigan State University Extension (MSUE) publication describing the river notes highly variable habitat conditions depending on location in the river and flow conditions (MSUE, 1997). A list of fish present in the river between December 1979 and May 1981 can be seen in Table 4-3.

The MSU Watershed Action Through Education and Research (MSU-WATER) group conducted a fish sampling between June 2001 and August 2002 which indicated the presence of 19 of the 32 previously identified species and 12 additional species. These species are also presented in Table 4-3.

In a 1991 Michigan Department of Natural Resources (MDNR) study fish populations in the Red Cedar Watershed defined in this plan were found to be slightly impaired, but in good condition. An average of 11 species was identified from the three inventory locations with the largest number and diversity being identified where Okemos Road crosses the river. The least diverse and smallest number of species was identified near Kalamazoo Street in Lansing. Additional inventories outside of this watershed planning area indicate similar fish population and diversity conditions with only a few tributaries rated moderately impaired or fair (Scott, 1992).

In 2003 only two sites within the Red Cedar River were studied, 1) at Zimmer Road and 2) at Harrison Road. At Zimmer Road fish populations were found to be acceptable with approximately 15 species identified. At Harrison Road, 15 species were also identified, with the over all fish population rating being excellent (Rockafellow, 2003).

Tissue samples from select species indicated elevated levels of PCBs and mercury. This sampling was coordinated with the Michigan Department of Environmental Quality's (MDEQs) Fish Contaminant Monitoring Program, data which is used by the Michigan Department of Community Health to issue fish consumption advisories for waters of the state. A fish consumption advisory is in effect for the Red Cedar River (for PCBs in carp). Additionally, all inland lakes, reservoirs, and impoundments within the State of Michigan are also under a fish advisory for mercury contamination. The latter is a general advisory applied to all inland lakes in Michigan since not all inland lakes, reservoirs, and impoundments have been tested or monitored. Table 4-4 lists the fish consumption advisories applicable to the watershed.

Macroinvertebrate populations and diversity from Beeman Road downstream of the Williamston Waste Water Treatment Plant (WWTP) to Okemos Road were rated slightly impaired or in good condition by the MDNR in 1991 (Scott, 1992). The total number of species and the diversity of the species decreased slightly as the investigators moved downstream through this region. Within the urbanized regions of the watershed between Okemos Road and Kalamazoo Street in Lansing the population and diversity sampled decreased. The MDNR rated the macroinvertebrate populations near Kalamazoo Street moderately impaired or in fair condition. Upstream of this planning area the average condition over all of

Table 4-4 Fish Consumption Advisory Information.

Water body	Location	Fish Species	Restricted Population	Restriction
Red Cedar River	Entire River	Carp	Women and Children*	6-18 inches: One meal per week
				18+ inches: One meal per month
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*	Any size: 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*	Any size: 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*	Any size: One meal per month

* - Children are defined as those individuals under 15 years of age
Michigan Department of Community Health, 2004

the sites studied show that macroinvertebrate populations and diversity in slightly impaired or in fair condition (Scott, 1992).

Macroinvertebrate and fish communities are only as strong as the habitat available to them in the river corridor. Within the Red Cedar Watershed covered under this plan, the habitat ranged from excellent to poor. Immediately downstream of the Williamston waste water treatment plant the MDNR found excellent habitat in 1991. This habitat decreased slightly as the study progressed toward Okemos Road and decreased significantly by the time the river reached Kalamazoo Street. In the urbanized area heavy sedimentation deposition, urban debris, and high flow fluctuations were common, which was reflected in both the populations of fish and macroinvertebrates. Upstream of the planning area habitat in the Red Cedar River was significantly degraded and on average was rated poor. The MDNR identified impacts and clean-up activities at the Hoover Ball and Bering plant in Fowlerville and improper agricultural practices as the sources for the degraded habitat (Scott, 1992).

Recent, but limited data collected near MSU's campus indicate that macroinvertebrate communities tend towards poor in quality. This is evidenced by the water quality standard (WQS) violations for macroinvertebrate populations listed for the river (discussed in the following section). However, the presence of a rich mussel population, including several uncommon species is a positive indicator for habitat quality (MSU-WATER, 2002).

Historical Fish Species No Longer Encountered

Bowfin, Lake Chubsucker, Greater Redhorse, Longear Sunfish, Goldfish, Striped Shiner, Pearl Dace, Golden Shiner, Pubnose Shiner, Emerald Shiner, Northern Common Shiner, Blackchin Shiner, Blacknose Shiner, Spottail Shiner, Northern Weed Shiner, Mimic Shiner, Pugnose Minnow, Northern Redbelly Dace, Fathead Minnow, Blackstripe Topminnow, Tadpole Madtom, Common Eastern Madtom, Iowa Darter

Watershed.org, 2004

Crayfish

Sycamore Creek

A concise summary of the sampling results is taken from a MDEQ biological survey published in 2003 and is presented below:

> *Previous work has documented the negative impacts to Sycamore Creek caused by the discharge from the Mason WWTP (Mikula, 1974). More recently in 1996, a biological survey of Sycamore Creek was conducted upstream and downstream from the Mason WWTP outfall. The survey documented macroinvertebrate and fish communities that would be considered acceptable upstream from the outfall and considered poor downstream from the outfall (Thelen, 1999). The survey in 2001*

Watershed.org, 2004

Stone Fly

Mason WWTP Advancements

1977 – Expanded to tertiary treatment
1985 – Significant industrial user complied with industrial pretreatment standards.
1988 – Added fine bubble diffuser to improve oxygen transfer
1993 – Revised NPDES permit to decrease effluent limits for CBOD and ammonia nitrogen, increased DO limit and added limit for residual chlorine
1994 – Nominate by MDNR for an EPA award.
2001 – Replaced tertiary sand filters

indicated that the macroinvertebrate community upstream (Station 37) and downstream (Station 38) from the outfall would be considered acceptable. The fish community upstream from the outfall was considered poor, and the fish community downstream from the outfall was considered acceptable. However, the differences in the scores were very minimal. The habitat was rated as fair (moderately impaired) upstream and downstream from the outfall. Based upon these results, it does not appear that the discharge from the Mason WWTP is negatively impacting the biological communities in Sycamore Creek. (Rockafellow 2003)

The study conducted in 1996 identified embeddedness of the substrate and the lack of pools, riffles and runs is a major cause of the impaired biota. At Toles Road and Willow Creek, for example, 8-12 inches of silt was observed in the channel, which may be caused by the observed channelization and land use impacts within Willow Creek (Thelen, 1999). At least 70 percent of land use within the Sycamore Creek watershed is agricultural land (Supprick, 1999).

A study conducted between 1990 and 1997 (Supprick, 1999) showed that no till farming practices had increased from 4 to 67 percent in the Haines Drain, 0 to 75 percent in the Marshall Drain, and 4 to 35 percent in Willow Creek. A stream bank stabilization program was also implemented in the Willow Creek subwatershed. The study showed that total suspended solids and total phosphorus concentrations were reduced in Willow Creek, but no changes were observed in the Haines or Marshall Drains. The study suggests that changing land use practices alone will not improve the system, but that the system also needs to be stabilized to improve the biota impacts observed in the 1974 and 1996 studies.

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 4-5 and Figure 4-2 identifies the monitoring locations in the watershed.

Table 4-5 Project GREEN Education Programs

Location Description	Volunteer Group conducting water testing:
Red Cedar River on the Michigan State University Campus behind the Kellogg Center in East Lansing, MI	East Lansing High School students Data collected during Spring and/or Fall of 196, 1997, 2000-2005
West bank of Mud Lake, Haslett, MI	Haslett High School students Data collected during Spring and/or Fall of 1996-1999, 2002
Mud Drain just after it passes under Marsh Rd., Haslett, MI	Haslett High School students Data collected during Spring and/or Fall of 1996-1999, 2002
Red Cedar River on the east side of Aurelius Rd., Lansing, MI	Lansing Catholic Central High School Data collected during Spring and/or Fall of 1997, 1998, 2000, 2001-2003
Sycamore Creek at Austin Park in downtown Mason, MI	Mason High School students Data collected during Spring and/or Fall of 1999-2002, 2004
Red Cedar River at Ferguson Park, Okemos, MI	Okemos High School students Data collected during Spring and/or Fall of 1995-1999, 2001, 2002
Heron Creek just west of the Okemos High School campus, Okemos, MI	Okemos High School students Data collected during Spring and/or Fall of 1995-1999, 2001, 2002
Red Cedar River at McCormick Park, Williamston, MI	Williamston High School students Data collected during Spring and/or of 1999, 2001-2003

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, listed in Table 4-6, 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 Figure 4-2.

Table 4-6 Mid-MEAC Monitoring Data

River Name	Road Location	County	Macro Rating	Location Assessment	Surrounding Areas	Reason to Monitor	Year
Red Cedar River	Okemos Road	Ingham County	Good	Filamentous algae & foam present, highway/bridge/road maintenance & runoff, high channelization, moderate erosion, moderate urban runoff	forest, residential lawns/parks	To assist in documenting changes in the Red Cedar River over time.	2004
Sycamore Creek	Scott Woods Park	Ingham County	Fair	Turbidity present, trash present, moderate removal of riparian vegetation, bank/shoreline erosion, and natural sources	forest, residential lawns/parks	To assess current condition of Sycamore Creek, which is a non-attainment waterbody for dioxin exceedances	2004

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Figure 4-2 Water Quality Data Summary

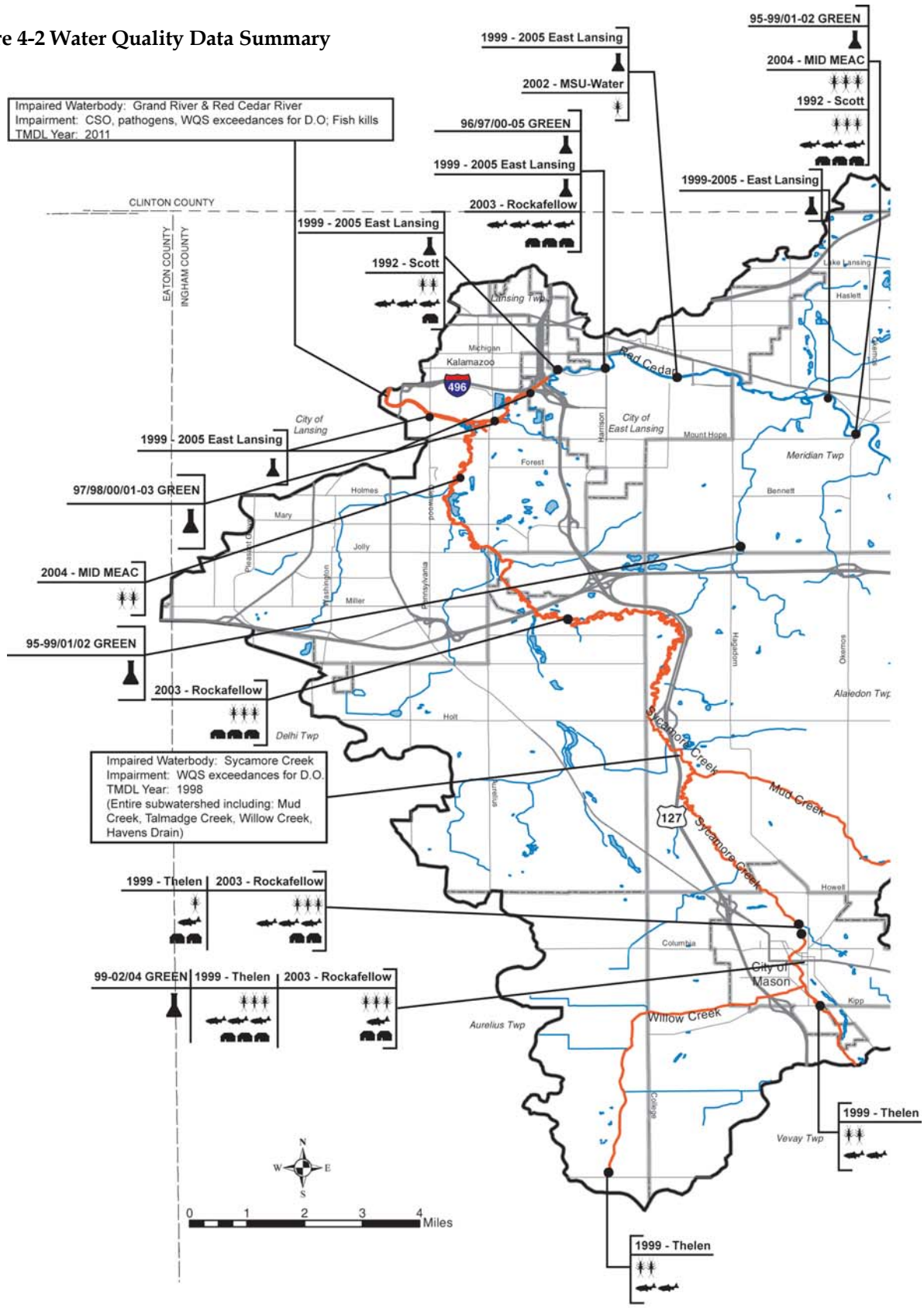
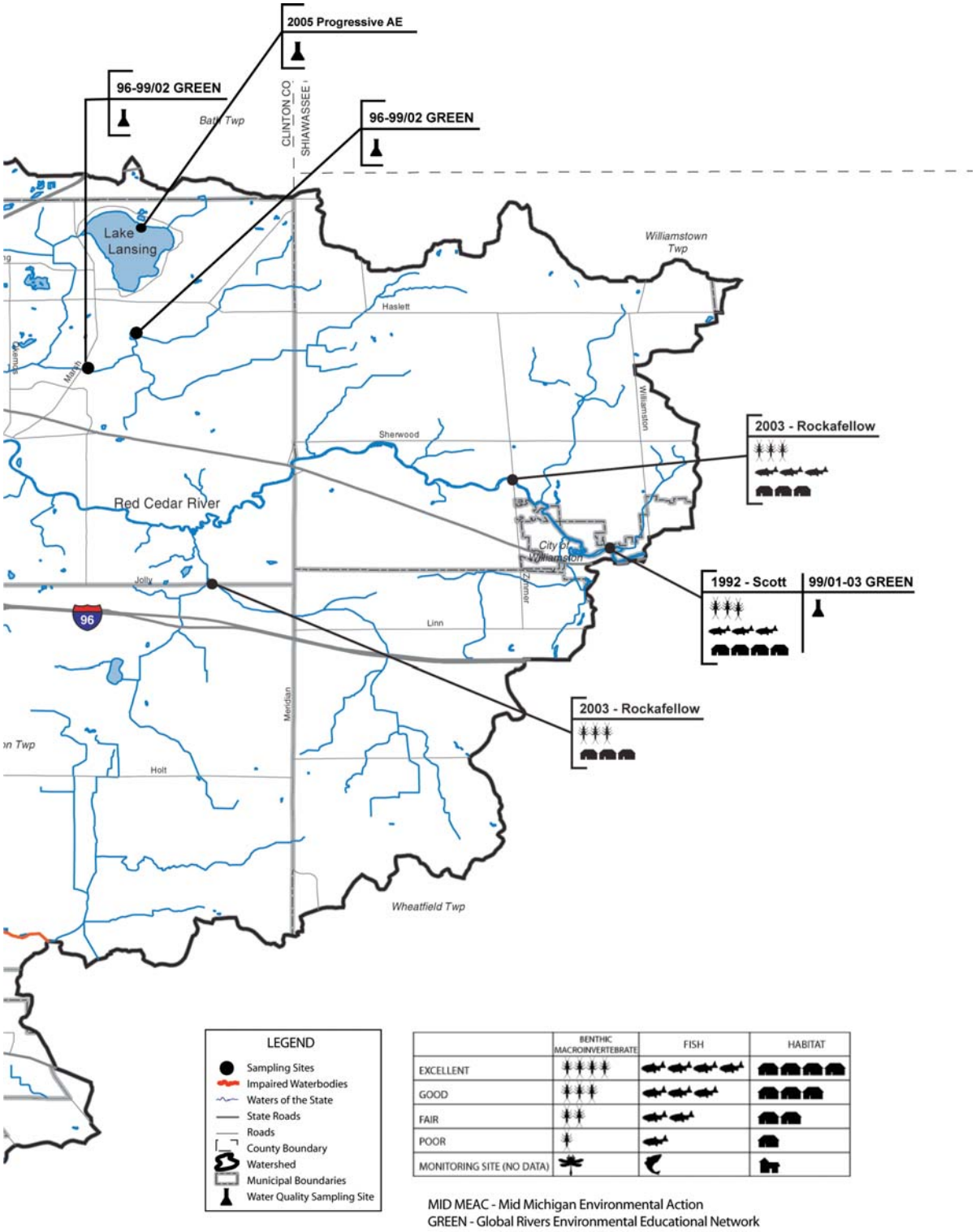


Figure 4-2 Water Quality Data Summary (continued)



Frog and Toad Survey

Wood Frog

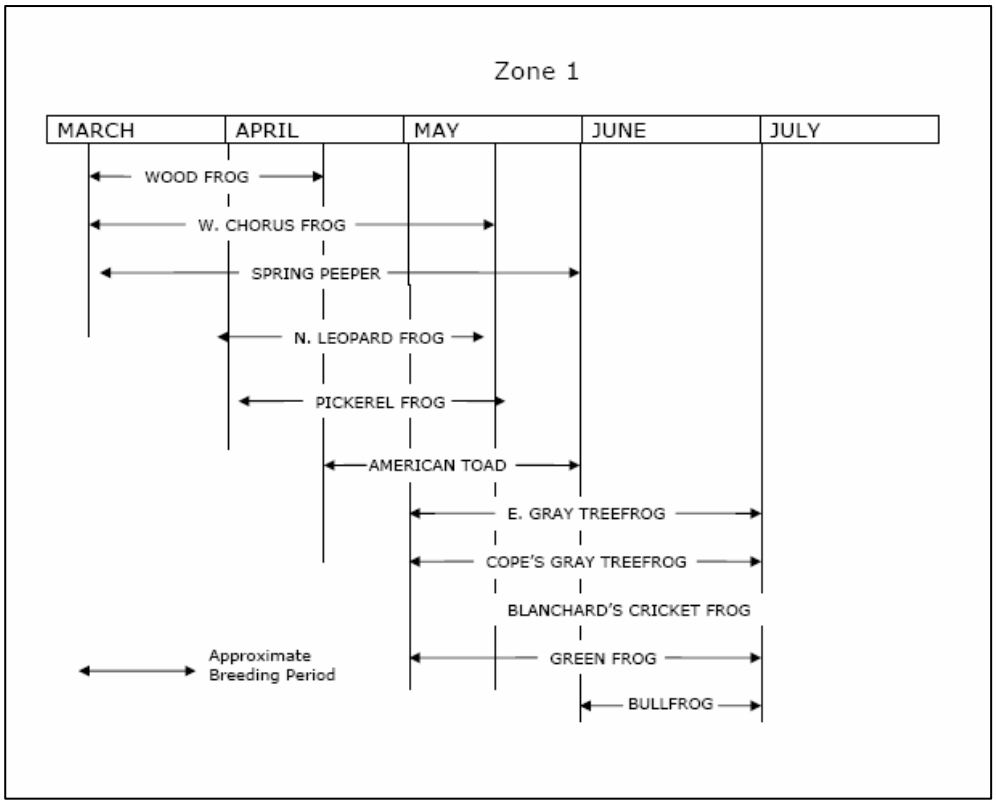
Michigan is home to 13 native species of anurans (frogs and toads). In recent years, observers have noticed a decline in population of several anuran species in Michigan. Frogs and toads are sensitive to changes in water quality and urbanization. Therefore, their populations serve as an index to environmental 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. Volunteers monitored the frogs and toads primarily in Watertown Township and Meridian Township. Approximately 13 sections within the Looking Glass River Watershed were surveyed by 30 volunteers. 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 and Hydrology Studies

Based on the studies conducted by the MDEQ and the MDNR, a number of WQS violations have been identified in the watershed. These impaired waterbodies are assigned a date to implement a Total Maximum Daily Load (TMDL) management strategy to address the violation and ultimately restore the water quality. The impaired waterbodies and the TMDL dates are presented in Table 4-7.

Table 4-7 Impaired Waterbodies.

Water body	Location	Problem	TMDL date
Red Cedar River	From the Grand River confluence upstream to Kalamazoo Street.	CSO, pathogens (Rule 100); WQS exceedances for D.O.; Fish kills.	2011
Sycamore Creek (entire subwatershed including: Mud Creek, Talmadge Creek, Willow Creek, and Havens Drain)	Grand River confluence upstream to headwaters and to included Mud Creek, Talmadge Creek, Willow Creek, and Havens Drain.	WQS exceedances for D.O.	1998

MDEQ, 2004

Red Cedar River

Dissolved Oxygen issues within the Red Cedar Watershed have been documented as far back as the 1960's. In a survey conducted by the Michigan Water Resources Commission, low levels of dissolved oxygen were identified downstream of the East Lansing WWTP and near Potter Park Zoo (Fishbeck, 1960).

In studies conducted from 1968 to 1970, sediments below the East Lansing WWTP were combined with significant amounts of organic sludge and were identified as having a sewage odor. Additionally, phosphorus became three times more concentrated between the WWTP and the mouth of the river (Jackson, 1974). The East Lansing WWTP was upgraded in the mid-1970 to include tertiary treatment, which would assist in removing additional organics. Additionally, the phosphorus levels would likely have been reduced as a result of the phosphorus ban implemented in the early 1970s.

In 1982, a study stated algae, microphytes, and sediments were determined to have the greatest impact to DO levels within the last three quarters of a mile of the river, where DO levels were the lowest (Allen, 1982). Recent studies show low levels of DO upstream of the weir at the Michigan State University campus and near River Point Park in Lansing. Both locations have slower velocities and therefore less opportunity for aeration within the water column (Sunday, 2003). These conditions, combined with accelerated deposition of oxygen depleting sediments and organic materials, increase the demand for oxygen and decrease the DO (Allen, 1982, Sunday, 2003).

Sycamore Creek

Sediment is the primary pollutant causing reduced levels of DO by introducing elevated levels of nutrients, which increase aquatic plant coverage and therefore respiration (Supprick, 1996). The TMDL developed calls for the Mason WWTP to maintain a stable effluent of 4 mg/l or less for BOD and 0.5 mg/l of ammonia. The plan also calls for a reduction of sediment oxygen demand of 52 percent. The major contributors of the sediment oxygen demand include eroding stream banks, agricultural land, and urban sediments (Supprick, 1996).

Lake Lansing

Water quality monitoring was conducted in Lake Lansing during the spring and summer seasons of 1999, 2000, 2003, and 2004 (Progressive AE 2005). Based on the compilation of these studies, Lake Lansing is considered borderline between mesotrophic and eutrophic. Phosphorus levels are moderate to high with dense rooted plant growth and moderate to low algae growth. Water clarity was moderate to good, and pH and alkalinity were normal. Dissolved oxygen (DO) levels were depleted near the bottom of the lake in late summer indicating the decay of abundant plant and animal life; otherwise, DO levels were generally high.

Additional information on water quality issues in Lake Lansing is included in the Lake Lansing Watershed Advisory Committee Watershed Management Plan Executive Summary, April 2002.

Oligotrophic
- Clear water, low productivity
- Very desirable fishery of large fish

Mesotrophic
- Increased production
- Accumulated organic matter
- Occasional algal bloom
- Good fishery

Eutrophic
- Very productive
- May experience oxygen depletion
- Rough fish common

http://dnr.wi.gov/org/water/fhp/lakes/selfhelp/trophic.htm. Last accessed May 25, 2005

Pollutant Load Analysis

The intent of a 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 utilizing 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), which is used widely 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 sediment.

Land Use Specific Pollutant Concentrations

Pollutant concentrations for the watershed were not available, therefore published concentrations from national studies were considered for their applicability to this watershed. Table 4-8 presents the range of urban pollutant load concentrations found in a literature review.

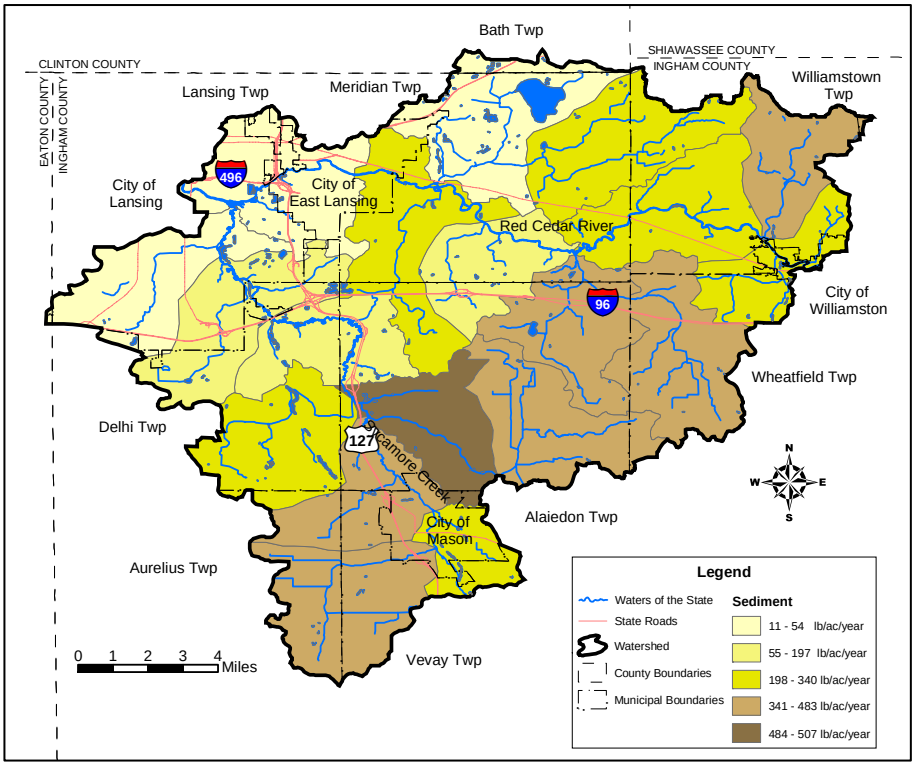
Table 4-8. Urban Pollutant Load Concentrations (mg/l)

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 4-8 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. Unit Area Loadings -Sediments.



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 4-9. Locations and names of subwatersheds are provided in Figure 3-1.

Figure 4-5. Unit Area Loadings – Phosphorus

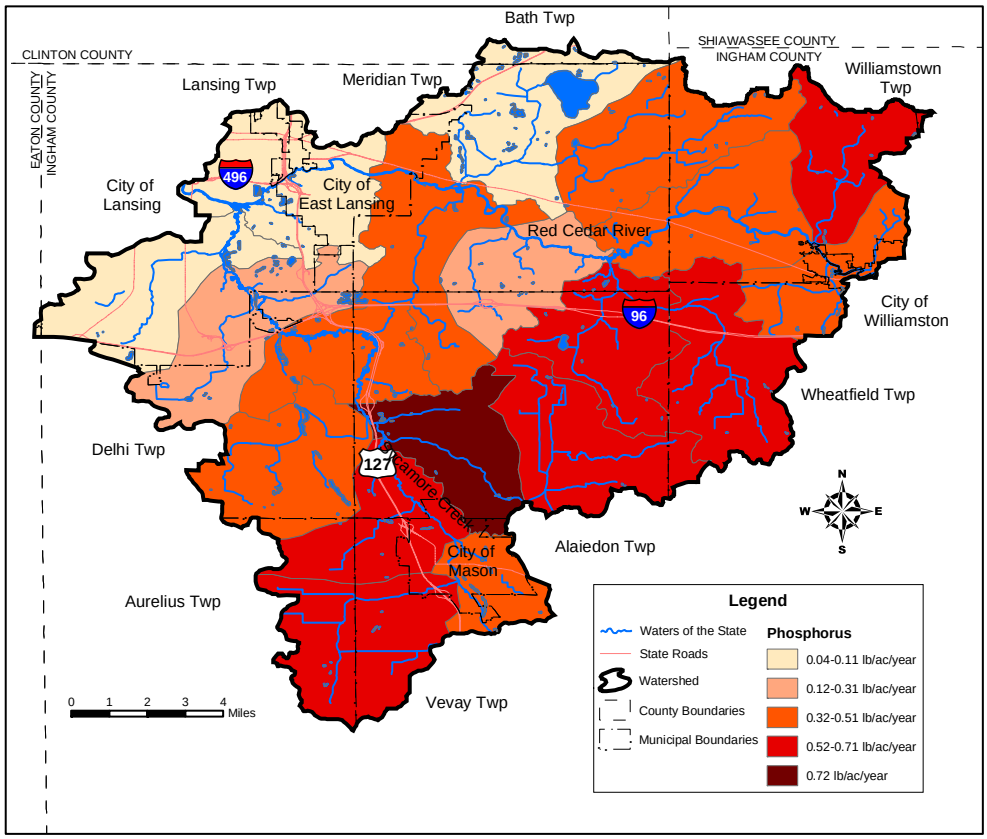


Figure 4-6. Unit Area Loadings - BOD

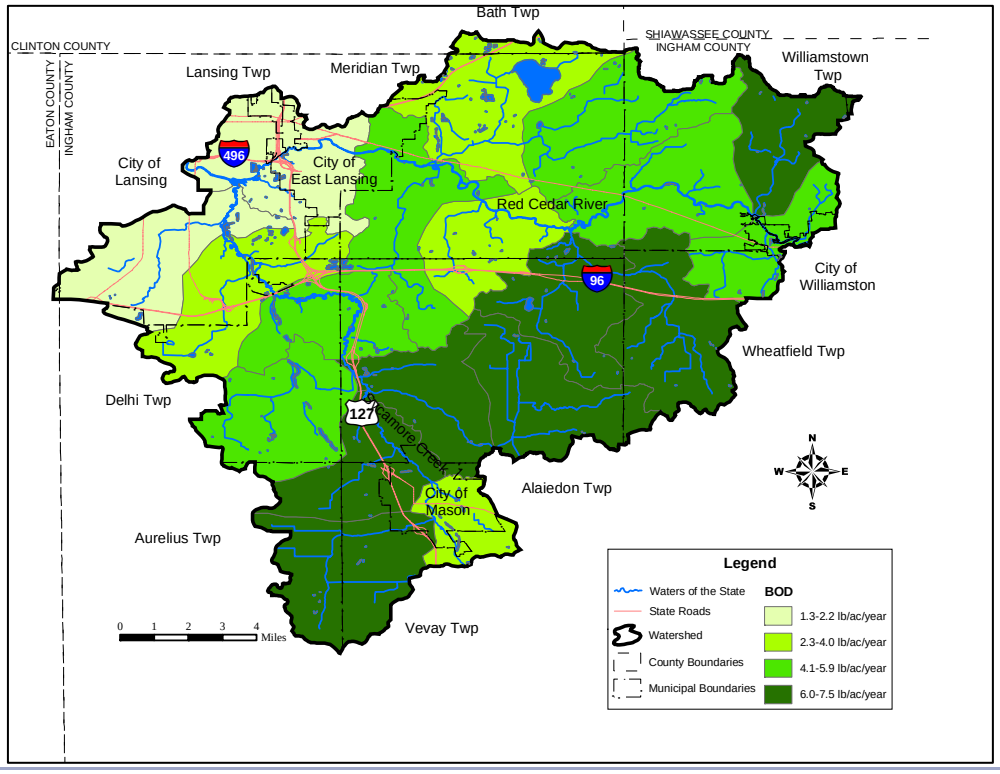


Table 4-9 Unit Area Storm Water Loading Data.

Subwatershed	Phosphorus (lbs/ac/yr)	BOD (lbs/ac/yr)	Sediment (lbs /ac/yr)
Aurelius-Vevay Drain	0.51	5.9	350
Branch Mud Creek	0.66	7.3	440
Button Drain	0.59	6.6	400
Cook and Thorburn Drain	0.43	5.4	270
Cook Creek	0.51	6.1	350
Herron Creek	0.37	4.2	240
Holmes Drain	0.04	1.3	11.2
Lake Lansing	0.09	2.6	33.8
Mud Creek	**0.72**	**7.5**	**510**
Mud Lake Drain	0.21	4	110
Mud Lake Outlet Drain	0.38	5.4	240
Red Cedar A	0.49	5.7	340
Red Cedar B	0.45	5.7	290
Red Cedar C	0.09	1.3	52
Sloan Creek	0.64	6.9	430
Smith Drain	0.26	3.6	170
Sycamore Creek A	0.34	3.8	250
Sycamore Creek B	0.31	4.5	190
Willow Creek	0.65	7.2	440

In Table 4-9 the top five unit area loadings are highlighted with the number one loading, Mud Creek, bolded.

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.

Pollutant Loading 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, phosphorus, 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 Red Cedar to be occurring in the downstream areas within the urbanized zone. Sediments may be carried from the upstream reach to the urbanized zone where water velocities are slower and the sediment is able to be deposited. The MDEQ identified oxygen-depleting sediments as one component of the decrease in DO near MSU and the mouth of the Red Cedar. The other two major contributors to low DO within the last three quarters of a mile of the river include algae and microphytes (Allen, 1982). Under the same circumstances, the slower water near the mouth of the river may contain dissolved phosphorus and other nutrients, discharged upstream, which enhance the growth and respiration of plants in an environment of limited aeration.

The primary DO sink in Sycamore Creek is attributed to sediment oxygen and demand, which increase aquatic plant coverage and therefore respiration (Suppnick, 1996). The pollutant load calculations identified Willow Creek, Sycamore Creek A, Aurelius-Vevay and Mud Creek subwatersheds as having the highest loadings within the Sycamore Creek watershed for all three parameters. The observations made by Thelen (1999) and Suppnick (1999) support much of the results of the pollutant load calculations.

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, including: Red Cedar C and Holmes Drain.

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 Red Cedar 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.

Table 4-10 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).

Photo Courtesy of Tetra Tech, 2005

Table 4-11 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 Red Cedar 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 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).

Photo Courtesy of Tetra Tech, 2004.

Table 4-12 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 4-13 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.

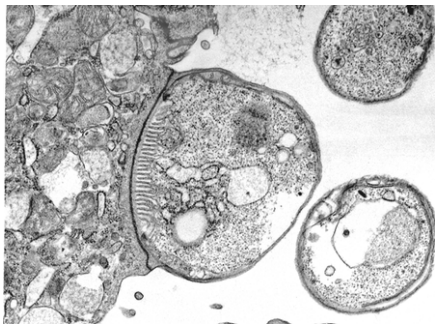
Source: Great Swamp Water Association Conservation Area, 2005

Table 4-14 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

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.



Source: The University of Florida, 2005

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 4-15 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

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).

Source: Morton Salt, 2005

Table 4-16 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 4-17 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 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).

Source: King County Government, 2005

Table 4-18 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 4-19 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 4-20 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

Source: DHI Water and Environment, 2005

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).

Table 4-21 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, and an increase in metabolic activity producing greater disease and parasite susceptibility (CWP, March 2003).

Table 4-22 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)	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 4-23 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

Photo Courtesy of Tetra Tech, 2005.

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