5. Problem Assessment & Stressor Summary

What are stressors?

The term "stressor" refers to the pollutants and other undesirable factors that degrade water quality conditions. Stressors affecting a watershed might include pathogens, nutrients, trash and debris, sediment, and contaminated sediments. In addition to pollutants, other stressors might also come in the form of undesirable changes to the natural features of a watershed, such as changes to habitat and natural hydrology.

Purpose of this Chapter

This chapter is provided to meet the requirements of the Environmental Protection Agency's 319 grant funding program. The analyses and discussions presented herein are intended only to act as a part of a pollutant load reduction framework and are not meant to imply commitments towards the Phase II permit.

Introduction

Watershed management planning requires an understanding of the causes and sources of pollutants and other stressors (e.g., hydromodification) in the watershed, a quantifiable measurement of the pollutants and other stressors affecting the watershed, and a comparison of the current levels of pollutants and stressors against required water quality metrics (i.e., water quality standards). This information will indicate how much a pollutant or stressor must decrease to generate improvements in watershed conditions, as indicated by water quality standards and other types of water quality metrics.

This chapter presents significant information that is sometimes redundant with other chapters. This is because the analyses presented herein are best understood if all pertinent information is presented. Chapter 3 presented a detailed description of the causes and sources affecting conditions in the subwatershed, as well as the water quality metrics used to assess watershed conditions. Each of the causes and sources described in Chapter 3 result in one or more types of pollutants or stressors that adversely impact the watershed. This chapter provides a more detailed look at the primary pollutants and stressors generated by those causes and sources. This chapter also describes the analysis conducted to determine the percent reductions of specific pollutants and stressors necessary to improve water quality conditions, using water quality standards as the benchmark for measuring improvements.

It is important to note that the problem assessment and stressor summary for the subwatershed reflects the best sources of data available at the time of analysis. The analysis will change over time as a result of new data collected through the implementation of recent projects, such as the Clinton River Basin Watershed Initiative, and changes in the metrics used to assess water quality data, such as the adoption of new numeric nutrient criteria or improved indicators to assess pathogens. Watershed management planning is an iterative and dynamic process that requires the use of adaptive management, allowing strategies to evolve as new information becomes available. The analysis contained in this chapter will require regular re-assessment and re-evaluation as new data become available to ensure that strategies and priorities reflect the most accurate and most recent information.

Status of Water Quality

To determine the status of water quality in the subwatershed, it is necessary to have 1) water quality monitoring data and 2) the applicable water quality standards. Water quality standards are the measuring stick to determine if water quality is good, fair, or declining. Water quality standards consist of three components: designated uses, criteria, and an antidegradation policy. The first components, designated uses and criteria, are essential for measuring water quality in the subwatershed.

Where water quality does not support these designated uses, water quality is considered to be impaired. To determine if water quality supports the designated uses, it is necessary to compare water quality monitoring data from the subwatershed with numeric and narrative criteria — the second component of water quality standards.

As illustrated in the previous sections, a significant amount of water quality data and information have been collected at various locations since the early 1970s. Water quality has been sampled within the subwatershed at various locations since the early 1970s by a variety of agencies and organizations, including the Michigan Department of Environmental Quality (MDEQ) during their regular assessments of water quality throughout the State of Michigan. These monitoring data compared to water quality standards show that current water quality conditions in the subwatershed do not support designated uses. As a result, water quality in the subwatershed is impaired.

Status of Designated Uses

Based on the MDEQ-defined waterbody impairments and other information in Chapter 3, as well as the input summarized in Chapter 4, the designated uses that are threatened, those not being met, and those of indeterminate status have been identified and are presented in Table 5-1[1].

General Stressors

In addition to designated use impairments, the subwatershed also has beneficial use impairments that apply because it located in the overall Clinton River Area of Concern (AOC) in the Great Lakes basin. To address these beneficial use impairments, stakeholders within the Clinton River Watershed are working together to develop an updated Remedial Action Plan (RAP). The updated RAP will describe the activities underway to restore the impaired beneficial uses and include the restoration criteria necessary to demonstrate when the beneficial use has been adequately restored. Currently, eight beneficial uses are considered impaired including: restrictions on fish and wildlife consumption, degradation of fish and wildlife populations, degradation of benthos, restrictions on dredging activities, eutrophication or undesirable algae, beach closings, degradation of aesthetics and loss of fish and wildlife habitat. While restoration of these beneficial uses is an important goal for the subwatershed, the restoration criteria do not have the same regulatory significance as Michigan's water quality standards.

The Lake St. Clair Environmental Characterization defines a broad set of stressors that affect lands tributary to the lake. These stressors include:

- Land Development and Urban Expansion
    - Stormwater
    - Habitat Fragmentation and Destruction
    - Fire Suppression
    - Agriculture
    - Soil Erosion and Sedimentation
- Altered Hydrology
    - Water Level Changes
    - Draining of Wetlands
    - Filling Wetlands and Dredging Waterbodies
    - Diking and Breakwalls

Water Quality Classifications

Impaired
When water quality does not meet water quality standards, determined by comparing water quality monitoring data with numeric and narrative criteria that water quality must meet to support designated uses.

Threatened
When water quality currently meets water quality standards, but current conditions exhibit a declining trend that could result in a water quality impairment without corrective action.

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[1] The assessments presented herein are subject to change. New pollution sources, additional data, and updated water quality standards all might affect the status of the designated uses.

Table 5-1. Status of designated uses.

Designated Use	Waterbody / Reach	Status	Stressor
Agricultural Water Supply	Indeterminate	In-determinate*	Elevated PCB levels; *unknown distribution of agricultural uses (assumed to be none)
Industrial Water Supply	Indeterminate	In-determinate*	Elevated PCB levels; *unknown distribution of industrial uses
Public Water Supply	All in the subwatershed near public water supplies	Threatened	Elevated PCB levels; cross contamination concerns between surface and groundwater
Other Aquatic Life / Wildlife	Red Run Drain / Gibson Drain / Spencer Drain	Impaired	Habitat Modification - Channelization
Other Aquatic Life / Wildlife	All other inland lakes, reservoirs, impoundments	Threatened	Mercury in fish tissue (implied impacts to other aquatic life)
Other Aquatic Life / Wildlife	All waterbodies	Threatened	Elevated PCB levels
Warm-water Fishery	All waterbodies	Impaired	Sediment
Warm-water Fishery	All waterbodies	Threatened	Low dissolved oxygen (due to algae from nutrient elevation)
Warm-water Fishery	All waterbodies	Threatened	Hydrology (flow variability)
Warm-water Fishery	All waterbodies	Threatened	Elevated PCB levels
Total Body Contact	Red Run Drain, Bear Creek, and all tributaries in Warren, Center Line, Madison Heights, Troy, and Clawson	Impaired	Pathogens
Total Body Contact	All waterbodies	Threatened	Presence of algae from nutrient elevation
Partial Body Contact	Red Run Drain, Bear Creek, and all tributaries in Warren, Center Line, Madison Heights, Troy, and Clawson	Impaired	Pathogens
Partial Body Contact	All waterbodies	Threatened	Presence of algae from nutrient elevation

- Contaminants
    - Nutrient Loading
    - Toxic Contamination
    - Sediment Contamination
- Shoreline Modification, Shipping, and Boating
    - Vegetation Removal
    - Shoreline Hardening
    - Vessel Activity and Marina Development
- Invasive Species
    - Aquatic and Wetland Invasives
    - Terrestrial Invasives
    - Potential Invasives
- Natural Disturbances
    - Ice Storms
    - Windthrow

Obviously, not all of these stressors impact the subwatershed, nor are they necessarily at a scale appropriate for subwatershed planning. However, defining this framework allows one to see how this WMP fits into the bigger picture.

Determining Significant Stressors

A wide range of data and information are available on the Clinton River watershed. Review and analysis of recent data from studies and reports, also summarized in Chapter 3, helped to determine the most significant pollutants and stressors specifically in the subwatershed. Data and reports containing information on stressors used in this analysis include the following:

- Federal and state water quality monitoring data;
- Michigan Department of Environmental Quality's 2006 Sections 303(d) and 305(b) Integrated Report containing the Water Quality Standards Nonattaiment List for Water Bodies Requiring TMDLs;
- State biological monitoring data for fish and macroinvertebrates;
- Development of Restoration Criteria in the Clinton River Area of Concern (Draft Final 2005);
- Lake St. Clair Environmental Characterization (2004); and
- Clinton River Assessment (DRAFT 2005).

Based on all of the data analyzed, the status of designated uses and related stressors, and the general stressor list, it has been determined that the most significant stressors in the subwatershed (and the most appropriate to address at this scale) include the following:

- Sediment;
- Phosphorus;
- Pathogens;
- Flow alterations;
- Contaminated sediments; and
- Habitat alterations.

Based on this list, the Subwatershed Advisory Group (SWAG) identified **sediment**, **phosphorus**, **pathogens**, and **flow alterations** as the top priorities to address in this plan, especially with respect to developing loading estimates and reduction targets.

Steps in the Load Duration Curve Approach

A load duration curve approach helps to identify the issues surrounding the impairment and to differentiate between pollutant sources. Steps for this approach are as follows:

1. Develop a flow duration curve for the stream by generating a flow frequency table and plotting the data points.
2. Translate the flow curve into a load duration curve. To accomplish this, multiply each flow value by the water quality target and by a conversion factor. Graph the resulting points.
3. Convert each water quality sample to a load by multiplying the water quality target concentration by the average daily flow corresponding to the day of sample collection and a conversion factor. Plot the individual loads on the graph..
4. Anaylze location of data points with respect to the load duration curve. Points plotting above the curve represent deviations from the water quality target and the daily target load. Those plotting below the curve represent compliance with targets and the daily target load.
5. Interpret the final curves. The area beneath the load duration curve is interpreted as the loading capacity of the stream. The difference between this area and the area representing the current loading conditions is the load that must be reduced to meet water quality targets.

Method for Quantifying Stressors and Establishing Reduction Targets

Significant stressors identified in the subwatershed will require strategic actions to reduce their impact on water quality and overall watershed health. To enable the selection and implementation of effective actions, it is important to first undertake an analysis that quantifies the stressor, identifies a numeric target, and determines if a reduction in the stressor is necessary to achieve the target. Quantifying the stressor for pollutants such as sediment, phosphorus, and pathogens, requires a way to determine how much of the pollutant is coming from particular sources in the subwatershed. The amount contributed by sources is referred to as the current pollutant load. The amount that sources should not exceed to achieve the numeric target is referred to as the target load. The method used to estimate the current and target pollutant loads in the subwatershed is called a load duration curve approach.

Estimating Pollutant Loads: The Load Duration Curve

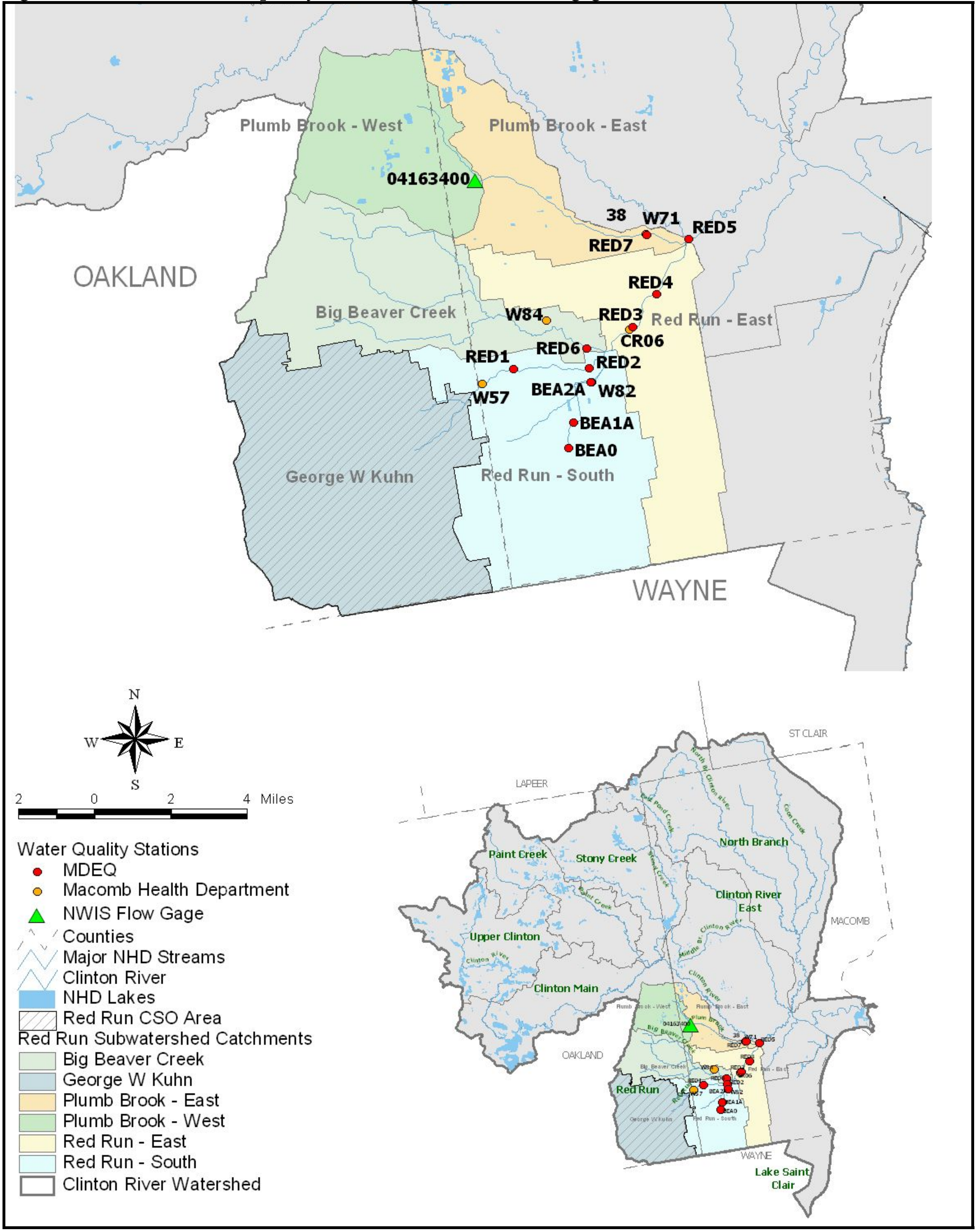
The load duration curve approach involves calculating the target loadings of a pollutant over the range of flow conditions expected to occur in the water body. The load reduction approach also considers critical conditions and seasonal variation. Because the approach establishes loads based on a representative flow regime, it inherently considers seasonal variations and critical conditions attributed to flow conditions. The flow regimes are categorized into the following five "hydrologic zones" (Cleland, 2005):

- High flow zone: flows that plot in the 0 to 10-percentile range, related to flood flows.
- Moist zone: flows in the 10 to 40-percentile range, related to wet weather conditions.
- Mid-range zone: flows in the 40 to 50 percentile range, median stream flow conditions;
- Dry zone: flows in the 60 to 90-percentile range, related to dry weather flows.
- Low flow zone: flows in the 90 to 100-percentile range, related to drought conditions.

The Plum Brook at Utica, MI gage (USGS gage 04163400) was used to estimate flows in the watershed. Flow at other points in the watershed was estimated using a unit-area approach. Continuous stream flow data are available from the United States Geological Survey (USGS) National Water Information System (NWIS) online database.

Water quality monitoring data used to determine the current and target pollutant loads in the subwatershed originate from several water quality monitoring stations. Figure 5-1 shows the locations of water quality monitoring stations in the subwatershed. Water quality monitoring stations are not located throughout the subwatershed; therefore, specific water quality monitoring stations are identified and used as representative stations. Table 5-2 lists the catchments represented affecting water quality data at each water quality monitoring station.

Figure 5-1. Location of water quality monitoring and stream flow gages.



Distinguishing Between Sources and Causes of Impairment

Sources

Description of where pollutants or stressors are coming from. These sources of impairment are the activities, facilities, or conditions that generate the pollutants that keep waters from meeting the criteria adopted by the states to protect designated uses, such as municipal sewage treatment plants, storm sewers, and modification of hydrology.

Causes

The reason a particular source contributes pollutants or other stressors that cause water quality impairments. Causes help to define how an activity introduces a pollutant or other stressor into the watershed and highlights the type of management strategy necessary to address contributions from a particular source.

Table 5-2. Representative water quality monitoring stations and associated catchments.

Station ID	Primary Catchment	Other Catchments
RED1	Red Run - South	George W. Kuhn
RED2	Red Run - South	George W. Kuhn
RED3/ CR06	Red Run - East	Big Beaver Creek, Red Run River South, George W. Kuhn
RED4	Red Run - East	Big Beaver Creek, Red Run River South, George W. Kuhn
RED5	Red Run - East and Plum Brook - East	Plum Brook West, Big Beaver Creek, Red Run River South, George W. Kuhn
RED6	Big Beaver Creek	None
RED7/ W71	Plum Brook - East	Plum Brook West
W57	Red Run - South	George W. Kuhn
W82	Red Run - South	None
W84	Big Beaver Creek	None

It is important to note that the George W. Kuhn catchment represents a combined sewer area; all stormwater runoff and sanitary sewer wastewater goes to the Detroit Water and Sewerage Department (DWSD) WWTP. The combined sewer system in the George W. Kuhn catchment is associated with the George W. Kuhn (Twelve Towns) Retention and Treatment Facility (RTF) in Madison Heights. When flows in the system exceed the target discharge rate into the DWSD interceptor sewer, excess flow is stored in the facility. If the storage volume is exceeded, the overflow water is partially treated with chlorine before being discharged to the subwatershed. Recent improvements to the facility and tributary sewers have resulted in reduced wet weather flow, increased storage capacity, and improved treatment capabilities. Collectively, these improvements mean less frequent and less polluted discharges from the facility. Data used in this analysis for this catchment represent average overflow data from the combined sewer, referred to as combined sewer overflows (CSOs). Although direct management of combined sewer systems and CSOs is outside the scope of this watershed management plan, it is important to consider the impact that stormwater quantity and quality has on the combined sewer system in the subwatershed. As a result, this catchment is included in this analysis.

The remainder of this chapter examines the significant stressors subwatershed – sediment, phosphorus, pathogens, and hydrologic flow. Information provided for each significant stressor provides a summary of the sources, impacts, impairments, indicators, water quality standards, available data, pollutant load estimates and target reductions, critical areas, how to monitor progress and ideas for improvement.

Sediment

Sediment in urban watersheds is an important pollutant; causing problems and negative impacts while also transporting other pollutants that bind to sediment particles, including phosphorus. 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 generated by human activity has caused enormous damage to streams throughout North America (Waters, T.F. 1995).

Sediment transported by moving water is described by the terms "suspended load" and "bedload." The suspended load is comprised by the fraction of material that is mixed intimately with the flowing water and tends to make the water appear muddy. The suspended load may be further segregated to include the suspended solids and the dissolved solids. Suspended solids will settle through the water based on their own density given an opportunity; however, solids are often sporadically and repeatedly caught in local turbulent eddies and remain suspended. The bedload is comprised of the larger particles too heavy to be suspended, but rather pushed along near the streambed (Leopold, 1994).

All streams require a degree of bedload transport to maintain their pools, riffles, and meanders. Some substrate movement is beneficial because it allows fine sediment to be flushed out of the spaces between larger particles and ultimately downstream. However, if there is too much substrate movement, the channel may be too unstable to support healthy fish and invertebrate populations.

Sources

The main sources of sediment are the erosion of uplands, lateral movement of channels into streambanks, and down cutting of streambeds. Natural erosion is present almost everywhere and results from wind and water passing over land surfaces. Table 5-3 identifies some general sources and causes of sediment based on human activities.

Table 5-3. General sources of sediment.

Sources	Causes
Streambanks	Flow Fluctuations (see Hydrologic Flow) Human Access
Construction Site Runoff	Inadequate Soil Erosion and Sedimentation Controls
Road-Stream Crossings	Poor Maintenance Poor Construction Poor Design Human Access
Drainage Ditches	Ditch Cleanout without Soil Stabilization Flow Fluctuations (see Hydrologic Flow) Human Access
Sand for 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

In the subwatershed, the likely predominant sources of sediment are related to stormwater runoff from urbanized areas. Suspected sources include streambank erosion, construction activities, and hydrological impacts to specific locations along the approximately 54 miles of open channel waterways and number of small lakes / ponds that exist in the subwatershed.

Chapter 3 of this WMP presents information gathered through the visual assessment process on subwatershed conditions that could contribute to sediment loads. The road-stream crossing survey results presented in Table 3-3 show that all assessment sites lack a 100-foot riparian buffer along all waterbodies. The unified stream assessment conducted at three locations in the subwatershed revealed severe bank erosion in Big Beaver Creek, with five locations recommended for bank stabilization. In 2005, the MCPWO and volunteers collected field data on streambank conditions in the subwatershed. MCPWO and volunteers documented poor conditions at one location on the Big Beaver Creek, three locations on the Plum Brook, and one location on the Nelson Drain. They also documented fair conditions at three downstream locations on the Red Run Drain. Figure 3-6 in this WMP illustrates streambank conditions and locations requiring attention throughout the subwatershed. As discussed in Chapter 3, other sources and causes of sedimentation in the subwatershed include flow obstructions, such as dams, that cause sediment deposition in upstream areas, and road crossings due to altered flow paths to accommodate man-made features.

As part of the visual assessment process, volunteers conducted Unified Subwatershed and Site Reconnaissance (USSR) surveys that examined potential pollutant sources in neighborhoods, streets, and storm drains. The USSR surveys also examined hot spots and pervious areas. Chapter 3 presents the overall results of the USSR surveys. The neighborhood source assessment and the street and storm drain survey examined 15 locations in the subwatershed. Of those with curb and gutter, only 21% of the neighborhoods were assessed as having 'clean and dry' curb and gutter. Sediment and organic material, such as leaves and lawn clippings had the largest pollution source potential in the curb and gutter. The street and storm drain survey revealed cracked roads at 27% of the locations. This condition may allow more sediment to be introduced into runoff as a result of the deteriorating concrete. On-street parking is permitted on 50% of the street areas, which requires more impervious area than streets without parking and also may interfere with street sweeping efforts, resulting in increased sediment loads in runoff. Of the five areas included in the pervious area assessment, one site was predominantly covered by bare soil and, therefore, has increased erosion and sediment pollution potential.

Impact and Impairment

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. Embeddedness refers to the extent to which gravel and cobbles are surrounded or covered by fine sediment. Decay of deposited organic sediments can also negatively affect in-stream dissolved oxygen concentrations. This is known as the sediment oxygen demand (SOD).

Indicators

Direct measurement of the amount of sediment moving in the watercourse may be measured as the total suspended solids (TSS), total dissolved solids (TDS) and the bedload. Turbidity indirectly measures the amount of sediment by considering the amount of light passable through the water column. Conductivity may also be used to indirectly measure the dissolved solids.

In addition, indicators such as the embeddedness and fish and benthic macroinvertebrate population and diversity may also be used as indicators of sediment.

Water Quality Standards

The water quality standards in Michigan pertaining to sediment do not include any numeric values to serve as a benchmark for assessing the amount of sediment in a water body. As a result, it is necessary to develop a numeric target for sediment. For purposes of this watershed management plan, a preliminary numeric target for sediment was selected by evaluating data from Ohio reference sites within the same ecoregion as the Clinton River watershed (OEPA, 1999). This preliminary numeric target uses TSS as the indicator because suspended solids provide an estimate of the potential magnitude of sediment as a stressor and the primary sediment sources. The Clinton River watershed is located in the Huron-Erie Lake Plain ecoregion and the 90th percentile TSS values of reference sites within this ecoregion are approximately:

- Headwaters (< 20 square miles): 50 mg/L
- Wadeable (20 < 200 square miles): 65 mg/L
- Small Rivers (200 < 1000 square miles): 75 mg/L

The TSS value for small rivers applies to the subwatershed and is used as the benchmark to determine if current sediment loads meet water quality standards.

Current and Target Load Estimates to Calculate Load Reduction Percentages

The TSS target value presented above serves as the numeric goal for suspended solids in the subwatershed. To determine if the current amount of sediment entering the subwatershed will meet or exceed the TSS target value, it is necessary to estimate the current amount of sediment entering the subwatershed from a variety of sources. This amount is referred to as the current sediment load. In addition to determining the current load, it is also necessary to identify the target load – the amount of sediment that sources can contribute without exceeding the TSS target value for the subwatershed. If the current load is greater than the target load, management activities are necessary to reduce the sediment load entering the subwatershed.

This section presents the estimated current and target sediment load at each representative water quality monitoring station and the associated percent reduction in sediment loads necessary to meet the TSS target value in the subwatershed.

The load duration curve approach estimated current and target sediment loads using monitoring data for total suspended solids and a combination of recent and extrapolated flow data. Available total suspended solids sampling data originate from U.S. Geological Survey's (USGS) National

Water Information System (NWIS) and the Macomb County Health Department. Table 5-4 presents the available TSS data used to estimate current and target loads. Although other TSS data are available, the analysis focused on the most recent data with the most samples in the period of record.

Table 5-4. TSS data used to estimate current and target loads.

Station ID	Period of Record	Count	Avg. (mg/L)	Min. (mg/L)	Max. (mg/L)
CR06	9/20/2004 - 11/2/2005	26	74	1	730

Table 5-5 presents the existing and target annual TSS load (metric tons per year) for the in-stream sampling locations in the subwatershed. In addition, Table 5-5 states the percent annual load reduction necessary to achieve the TSS target value of 75 mg/L.

Table 5-5. Estimated existing annual loads and associated reductions by representative monitoring station.

Station ID	Existing Load (t/yr)	Target Load (t/yr)	Load Reduction (t/yr)
CR06	1,737	857	880 (-51%)

The load duration curve approach to estimate TSS loads in the subwatershed indicates that two areas require significant TSS load reductions to achieve the 75 mg/L TSS target value. At this location, the existing load was most likely to exceed the target load during high flow conditions.

Data from water quality monitoring station CR06 show that the existing TSS loads from all catchments, except East and West Plum Brook, require a 51 percent reduction to achieve the target load that will meet the TSS target value. Due to a lack of information for East and West Plum Brook, the 51 percent reduction will be applied to the existing loads in these two catchments.

Load Reduction Goals by Catchment

To calculate the sediment load reduction goals by catchment, it is necessary to have an estimate of the sediment loading from the sources in each catchment. Using readily available information such as land use and precipitation data, the Spreadsheet Tool for the Estimation of Pollutant Load (STEPL) is able to provide an estimated sediment load for each catchment. It is important to keep in mind that the STEPL model does not estimate sediment loads from streambank erosion or account for upstream sediment load contributions (Tetra Tech 2004); therefore, the estimated loads are likely to be less than the actual sediment load from each catchment – particularly those experiencing streambank erosion or significant contributions from upstream sources.

The total estimated sediment load for each catchment and the applicable percent load reduction provide the total estimated load reduction for each catchment. Given that the STEPL model does not account for streambank erosion, an additional 10 percent is added on to the estimated load. The additional 10 percent is an arbitrary number and may be higher or lower than the amount contributed by actual streambank erosion. This percentage will be update if and when better data on contributions from streambank erosion become available. Table 5-6 presents the estimated total sediment load from each catchment, including the additional 10 percent of the original estimated load to account for streambank erosion. Table 5-7 presents the estimated load reduction by catchment.

Table 5-6. Estimated annual TSS load and additional load to account for streambank erosion by catchment

Catchment	Estimated Sediment Load (ton/year)	Additional Load to Account for Streambank Erosion (10%)	Total Estimated Sediment Load (ton/year)
Red Run - South	1,083	108	1,191
Big Beaver Creek	884	88	972
Plum Brook - West	273	27	300
Plum Brook - East	373	37	410
Red Run - East	994	99	1,093
George W. Kuhn	86	0	86

Table 5-7. Estimated TSS load reduction needed by catchment

Catchment	Estimated Sediment Load Reduction Needed (tons/year)	
Red Run - South	608	51% reduction estimated at CR06 applied to total estimated sediment load of 1,191 t/yr
Big Beaver Creek	496	51% reduction estimated at CR06 applied to total estimated load of 972 t/yr
Plum Brook - West	153	51% reduction estimated at CR06 applied to total estimated load of 300 t/yr
Plum Brook - East	209	51% reduction estimated at CR06 applied to total estimated load of 410 t/yr
Red Run - East	557	51% reduction estimated at CR06 applied to total estimated load of 1,093 t/yr
George W. Kuhn	44	51% reduction estimated at CR06 applied to total estimated load of 86 t/yr

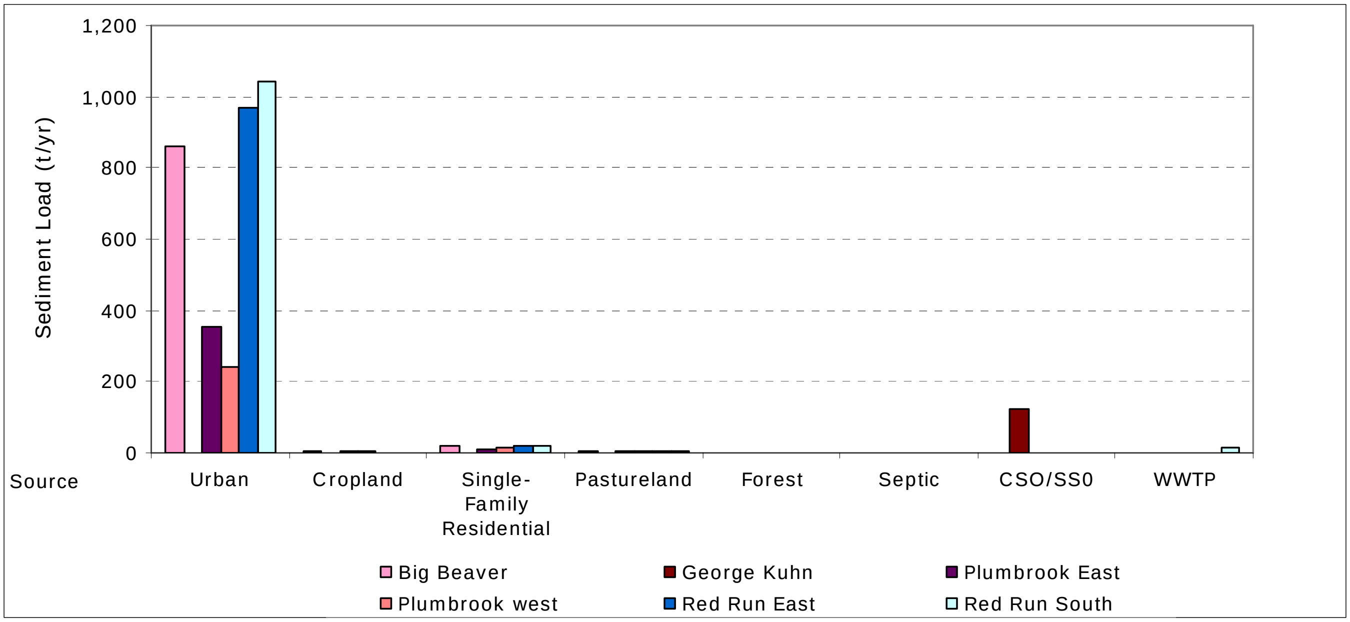
Critical Areas

Critical areas are the geographic portions of a watershed that contribute the greatest amount of a pollutant and have the most significant impact on the watershed. Identifying critical areas is an important step when determining how to achieve the TSS load reductions necessary to meet the TSS target value. The most significant sources of sediment loading in the subwatershed are stormwater runoff from urban land uses (e.g., commercial, industrial, institutional, transportation, multi-family dwellings, vacant developed land, and open space) according to the analysis conducted using the STEPL model. Figure 5-2 presents a comparison of the relative contributions of sediment loading from different sources by catchment.

What is a critical area?

A critical area is the geographic portion of the watershed that is contributing a majority of the pollutants and is having a significant impact on the waterbody (MDEQ 2000).

Figure 5-2. Estimated sediment load by source and catchment.



Although the STEPL model results provide only an estimate, the information is helpful in understanding the relative contributions of sediment loading from sources within the subwatershed and how to prioritize these sources when selecting management practices to achieve load reductions.

Within the urbanized areas, sediment picked up by the surface runoff is readily conveyed to a gutter (an impervious channelized flow path) which runs along most streets and washes into a traditional storm sewer drainage system, which quickly discharges the sediment to the nearby water courses. The traditional catch basin sumps offer some limited opportunity to remove sediment.

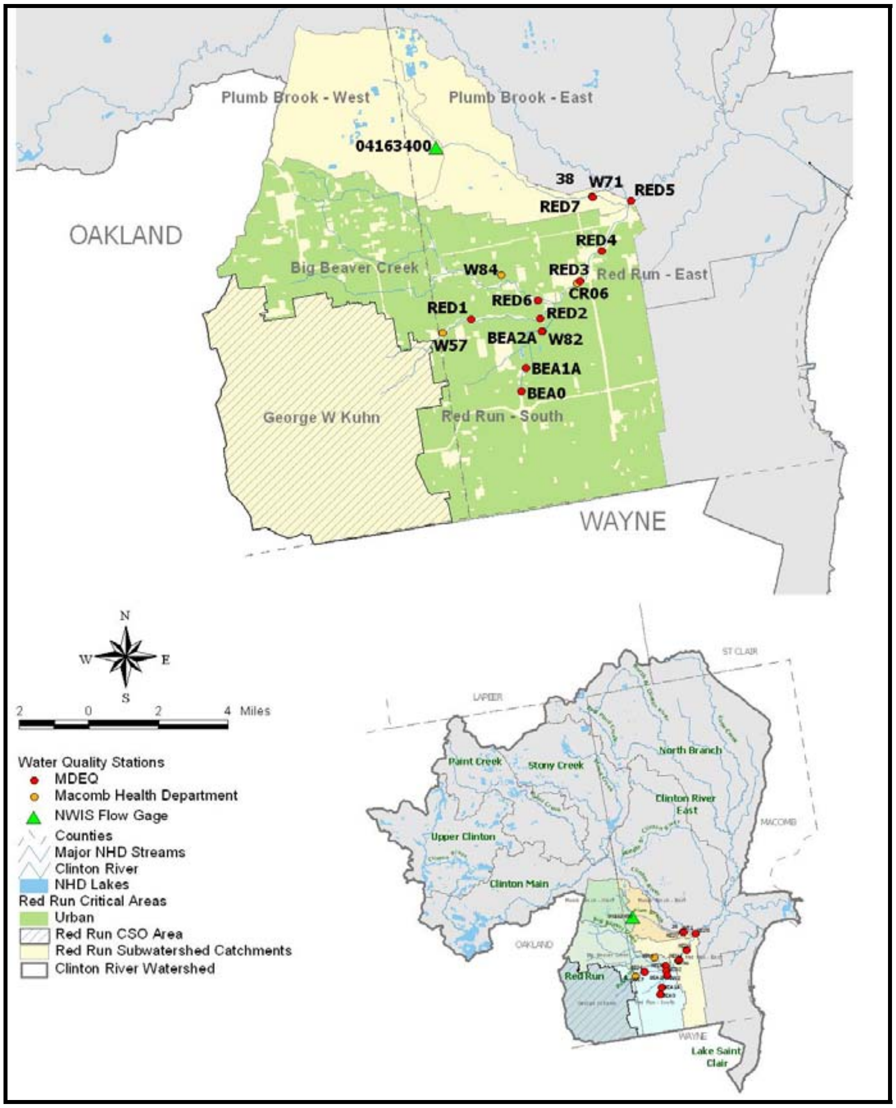
Defining critical areas for sediment in the subwatershed requires consideration of the results from both the load duration curve analysis approach and the STEPL model. These results represent both measured and estimated data. Based on TSS load reductions and estimated source contributions of the sediment load, the critical areas to address in the subwatershed include those described below.

Those sources include those which contribute to the sediment loads that were estimated using monitoring data from the water quality monitoring stations that indicate the need for an annual TSS load reduction.

1 Urban Sources in Big Beaver Creek, Red Run – East, and Red Run - South

Results from STEPL clearly indicate that urban runoff is estimated to be the most significant source of sediment load in the subwatershed. The three catchments estimated to contribute the greatest sediment load are Big Beaver Creek, East Red Run and South Red Run. These catchments also have the greatest sediment load reductions to achieve the numeric TSS target value. Figure 5-3 shows the location of the urban areas in each of these catchments.

Figure 5-3. Urban land uses in the Big Beaver Creek, Red Run – East, and Red Run – South catchments identified as critical areas for sediment load reductions.



Detailed information from the USSR surveys, particularly the neighborhood assessment and the street and storm drain surveys, will provide detailed locations of how to prioritize efforts in these catchments. Similar assessments in other areas of these catchments are likely needed to determine the potential for sediment pollution from curb and gutter, cracked streets, and other related urban land uses.

2 Known Areas of Exposed Soil

Field data collected through the visual assessments show that sources of sediment other than those accounted for in STEPL exist in the subwatershed. The unified stream assessment conducted at three locations in the subwatershed revealed severe bank erosion in Big Beaver Creek, with five locations recommended for bank stabilization. MCPWO and volunteers documented poor streambank conditions at one location on the Big Beaver Creek, three locations on the Plum Brook, and one location on the Nelson Drain. They also documented fair conditions at three downstream locations on the Red Run Drain. This type of information should help to further pinpoint critical areas related to streambank erosion and allow for prioritization of streambank restoration activities to reduce sediment loading.

3 Soil Erosion from Construction Related Activities

These areas are problems particularly when immediately adjacent to a water course or in an urbanized area with direct access to a storm sewer system. Although these areas were not considered in the STEPL model, it is well documented that soil erosion from construction related activities is a severe problem in rapidly developing areas and contributes significant sediment loads to the waterways. Although most of the subwatershed is built out, there are opportunities for limited new development and redevelopment. As mentioned in Chapter 2, portions of the subwatershed are projected to have increase in residential land use ranging from 2 to 13 percent. Open space is projected to decline from 9 to 5 percent. It is important to note that construction-related soil erosion control is addressed through a permitting program discussed in more detail in Chapter 7, and does not fall under the scope of this plan.

Monitoring Progress

Monitoring the reductions in the sediment load requires continued monitoring of TSS, as well as other indicators of sediment (e.g., turbidity, conductivity, benthic macroinvertebrates, pebble counts). The Macomb County Health Department conducts ongoing monitoring through its Surface Water Sampling Program, which includes TSS monitoring. The Clinton River Watershed Council’s Stream Leaders student water quality monitoring program monitors turbidity and benthic macroinvertebrates.

Monitoring is recommended to include TSS to establish trends that build off of the existing dataset that serves as baseline data. In addition to monitoring for purposes of trend analysis, monitoring plans should also measure management practice effectiveness to determine if management practice implementation is successfully reducing sediment loading from sources in the subwatershed.

Future monitoring needs include developing a better water quality data set at several water quality monitoring locations throughout the subwatershed.

Chapter 9 presents the specific monitoring protocols to be implemented in support of this plan.

Improvement Ideas

In the urban areas, good housekeeping practices such as street sweeping and catch basin cleaning will help to reduce sediment loads. In addition, management practices that promote infiltration while reducing the direct connection of impervious areas to the storm sewer drainage system will decrease sediment loads. These types of management practices include porous pavement, green roofs, bioinfiltration, retention, detention and other low impact development techniques. In addition, the use of swirl separators or sediment traps is another alternative.

Stabilizing exposed soil adjacent to the streambanks and eroding streambanks may typically be accomplished with a vegetative approach (bioengineering). Some streambanks with extremely fast moving water next to it may require the use of hard armoring but in most cases other bioengineering techniques area available to divert or stabilize the forces from the moving water.

Findings from the road-stream crossing survey indicate areas in the subwatershed with potential problems related to hydrology, such as channelization and flashiness. These problems can contribute to sediment loads. Strategies to address hydrology will likely help to reduce associated sediment loads.

Chapter 8 presents the specific actions to be taken towards achieving loading reductions for sediment, as well as other significant stressors.

Phosphorus

Nutrients, both nitrogen and phosphorus, are essential to aquatic ecosystems. However, high levels of nutrients can have a negative impact on water quality. Of the two nutrients, phosphorus is typically in short supply in fresh water and has the greatest potential for adversely impacting water quality. Phosphorus stimulates the growth of plankton and other aquatic plants consumed by fish and other animals. Thus, phosphorus is necessary for a productive and diverse aquatic ecosystem. However, elevated levels of phosphorus can lead to excessive aquatic plant growth and throw off the balance of ecosystem production and consumption. Too many aquatic plants with too few consumers means that plants start to decompose, dissolved oxygen levels needed to support aquatic life begin to drop, and fish and aquatic animal populations begin to decline.

Phosphorus usually exists in nature as part of a phosphate molecule. In a watershed, phosphorus is found as either organic or inorganic phosphate and can either be dissolved in water or suspended in water by attaching to particulate matter (e.g., sediment). Phosphorus cycles through a watershed and is constantly changing form. As it cycles, phosphorus usually moves downstream, dissolved in water and suspended in the water as decomposing plant and animal tissue. Phosphorus attached to particulate matter settles in bottom sediment, where it is used by some benthic macroinvertebrates or covered by additional sediment; when the bottom is stirred, phosphorus re-enters the water column and becomes available again to aquatic plants.

Sources

Phosphorus enters a watershed through both human and natural sources, although contributions from human sources are typically far greater than contributions from phosphate deposits and phosphate rich-rocks. The main sources of phosphorus in a watershed are usually from wastewater treatment plants, fertilizer from residential lawns, fertilizer and animal manure from agricultural lands, failing septic systems, soil erosion from streambanks and construction sites, and stormwater runoff from urban areas. Table 5-8 identifies some general sources and causes of phosphorus based on human activities.

Table 5-8. General sources of phosphorus.

Sources	Cause
Potential Illicit Connections	Function of Design Criteria Unnecessary Inflow Poor Maintenance Increased Development with Poor Stormwater Planning
Animal Waste (Non-Agricultural)	Pet Owners Not Picking Up Waste Lack of Buffer Wildlife
Failing Septic Systems	Poor Maintenance Poor Construction Poor Design Overloaded Used beyond design life
Leaky Sanitary Sewer	Poor Design Poor Construction Poor Maintenance
Sanitary Sewer Overflows (SSOs)	Excessive Infiltration Stormwater Inflow Increased Development Inadequate storm drainage
Fertilizer Use (Non-Agricultural)	Fertilizer Application Lack of Buffer
Atmospheric Deposition	Causes Not Appropriate for this Plan but Education Needed
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
Combined Sewer Overflows (CSOs)	Limited Treatment Capacity Increased Stormwater Runoff from Impervious Surfaces Increased Development

In the subwatershed, the likely predominant source of phosphorus is stormwater runoff from urban areas. The results from the Road-Stream Crossing Survey discussed in Chapter 3 found that proximity of the waterbodies to managed lawns or other urban residential neighborhoods is a common problem in the subwatershed. Managed lawns are potential sources of phosphorus in the subwatershed. In addition, results showed that almost all sites lacked a 100-foot riparian buffer. The results from the Unified Stream Assessment, also discussed in Chapter 3, indicates that the three assessed sites contain potential sources of phosphorus loading. For example, the Plum Brook site contains an impacted buffer that has no adjacent wetlands and is located in a golf course. The neighborhood site assessments revealed that in all but one neighborhood at least 80% of lots had moderately to highly maintained turf grass. Highly managed turf grass is often the source of nutrients from fertilizer, grass clippings, and other yard waste. Based on field observations, 87% of neighborhoods showed indicators for excessive nutrients. The pervious area assessment revealed sites in the subwatershed that contain highly managed turf and no stormwater management practices.

Due to the relationship of phosphorus to sediment, sources of sediment discussed in the previous section are also likely sources of phosphorus. These include streambank erosion, construction activities, and hydrological impacts that affect both erosion and stirring of bottom sediments. The Warren wastewater treatment plant (WWTP), located in the Red Run - East catchment and discharges to the Red Run – South catchment, is also a potential source of phosphorus.

Impact and Impairment

Excessive levels of phosphorus can cause accelerated plant growth and algae blooms that can interfere with aesthetic and recreational uses of water. Decay of algae blooms and aquatic plants can cause odors and the suspended particulate matter can lead to increased turbidity, which reduces light penetration and increases water temperature. Decaying plant and animal tissue requires oxygen, resulting in decreased in-stream dissolved oxygen (DO) concentrations. Low DO levels can negatively impact fish and other important aquatic animals (e.g., benthic macroinvertebrates).

Indicators

Direct measurements of the amount of phosphorus in the watercourse typically focus on measuring orthophosphate using tests that measure total orthophosphate, total phosphorus, dissolved phosphorus, soluble reactive phosphorus, or insoluble phosphorus. Total phosphorus and soluble reactive phosphorus are most commonly used to measure phosphorus in lake and river systems, respectively.

Indirect indicators of phosphorus vary depending on the type of impacts the indicator is intended to measure. For example, if the concern is impact to aquatic life, the indirect indicators for phosphorus could include biological indicators such as fish and benthic macroinvertebrates; periphyton biomass; dissolved oxygen levels; or pH. When concerned about impacts to recreation, appropriate indirect indicators of phosphorus might include periphyton biomass or water quality (EPA 1999).

Water Quality Standards

The water quality standards in Michigan pertaining to phosphorus do not include any numeric values to serve as a benchmark for assessing the amount of phosphorus in a water body. As a result, it is necessary to develop a numeric target for phosphorus. MCHD uses a numeric target of 0.05 mg/L for total phosphorus (TP) (Macomb County Health Department, 2002). Until MDEQ develops and adopts new numeric nutrient criteria, this analysis applied the numeric target value for TP used by Macomb County at this time.

Current and Target Load Estimates to Calculate Load Reduction Percentages

The TP target value presented above serves as the numeric goal for phosphorus levels in the subwatershed. To determine if the current amount of phosphorus entering the subwatershed will meet or exceed the TP target value, it is necessary to estimate the current phosphorus load entering from a variety of sources. In addition to determining the current load, it is also necessary to identify the target load – the amount of phosphorus that sources can contribute without exceeding the TP target value. If the current load is greater than the target load, management activities are necessary to reduce the phosphorus load.

This section presents the estimated current and target phosphorus load at each representative water quality monitoring station and the associated percent reduction in phosphorus loads necessary to meet the TP target value in the subwatershed.

The load duration curve approach estimated current and target sediment loads using monitoring data for TP and a combination of recent and extrapolated flow data. Available total suspended solids sampling data originate from U.S. Geological Survey's (USGS) National Water Information System (NWIS) and the Macomb County Health Department. Table 5-9 presents the TP data used for this analysis. Although other TSS data are available, the analysis focused on the most recent data with the most samples in the period of record.

Table 5-9. TP data used to estimate current and target loads.

Station ID	Period of Record	Count	Avg. (mg/L)	Min. (mg/L)	Max. (mg/L)
CR06	9/20/2004 - 11/2/2005	27	0.59	0.04	1.40

Table 5-10 presents the existing and target annual TP load (tons per year) for the in-stream sampling locations in the subwatershed. In addition, Table 5-10 states the percent annual load reduction necessary to achieve the TP target value of 0.05 mg/L.

Table 5-10. Estimated existing annual TP loads and associated reductions.

Station ID	Existing Load (t/yr)	Target Load (t/yr)	Load Reduction (%)
CR06	21	3	-88%

Data from water quality monitoring station CR06 show that the existing TP loads from all catchments, except East and West Plum Brook, require a 88 percent reduction to achieve the target load that will meet the TSS target value. Due to a lack of information for East and West Plum Brook, the 88 percent reduction will be applied to the existing loads in these two catchments.

Load Reduction Goals by Catchment

To calculate the phosphorus load reduction goals by catchment, it is necessary to have an estimate of the phosphorus loading from the sources in each catchment. Using readily available information, such as land use and precipitation data, STEPL is able to provide an estimated phosphorus load for each catchment. As mentioned during the discussion of sediment loading, STEPL does not estimate loads from streambank erosion or account for upstream load contributions. Given the relationship between soil and phosphorus, it is likely that the estimated loads for both sediment and phosphorus will be less than actual loads from each catchment – particularly those experiencing streambank erosion.

The total estimated phosphorus load for each catchment and the applicable percent load reduction provide the total estimated load reduction for each catchment. Given that the STEPL model does not account for streambank erosion, and there is a strong connection between sediment and phosphorus, an additional load that estimates the amount of phosphorus associated with streambank erosion is added on to the estimated load. The additional phosphorus load associated with streambank erosion is estimated by using the 10% additional sediment load estimated to account for streambank erosion and multiplying that number by a factor of 0.0005. MDEQ uses this factor when estimating the amount of sediment associated with a ton of sediment erosion. The additional 10 percent is an estimated number and may be higher or lower than the amount contributed by actual streambank erosion. This percentage will be updated if and when better data on phosphorus load contributions from streambank erosion become available. Table 5-11 presents the estimated total phosphorus load from each catchment, including the additional estimated load to account for streambank erosion. Table 5-12 presents the estimated load reduction by catchment.

Table 5-11. Estimated phosphorus load by catchment.

Catchment	Estimated Phosphorus Load (ton/year)	Additional Load to Account for Streambank Erosion (0.0005 * 10% additional load for sediment)	Total Estimated Sediment Load (ton/year)
Red Run - South	22.29	0.05 (0.0005* 108)	22.34
Big Beaver Creek	4.52	0.04 (0.0005* 88)	4.56
Plum Brook - West	2.48	0.01 (0.0005*27)	2.49
Plum Brook - East	2.16	0.02 (0.0005*37)	2.18
Red Run - East	6.51	0.05 (0.0005*99)	6.56
George W. Kuhn	1.42	0	1.42

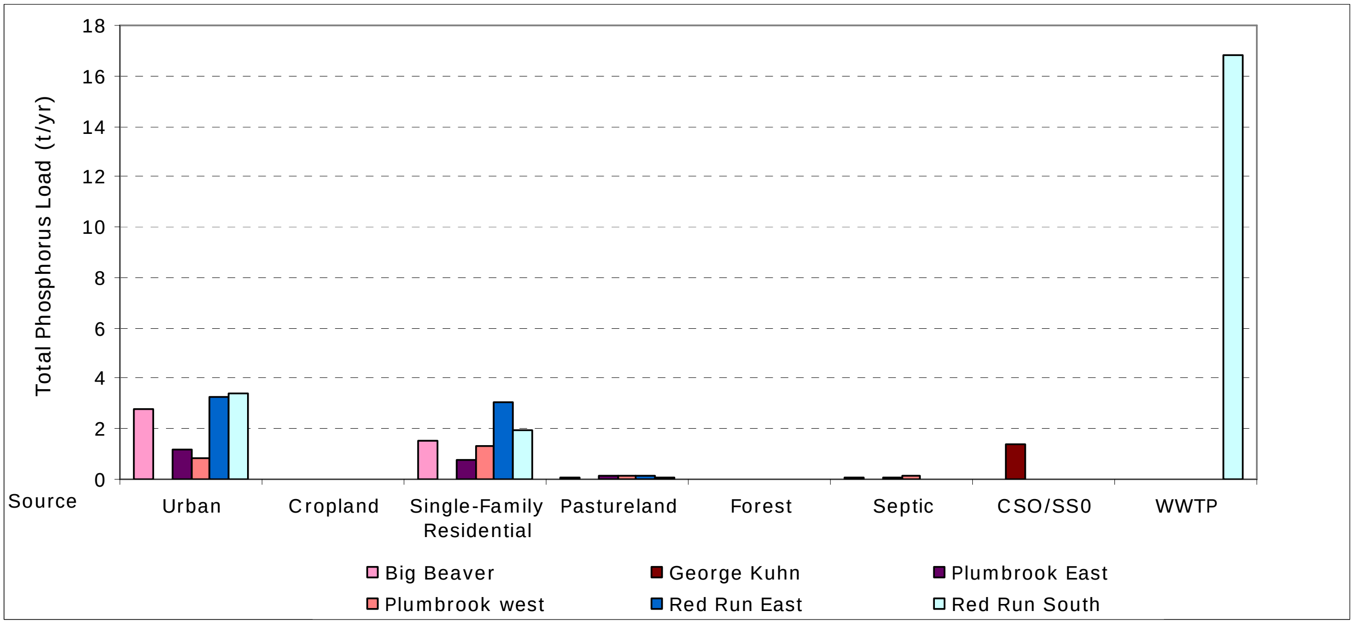
Table 5-12. Estimated TP load reduction needed by catchment.

Catchment	Estimated Phosphorus Load Reduction Needed (tons/year)	
Red Run - South	20	88% reduction from current load of 22.34 t/yr
Big Beaver Creek	4	88% reduction from current load of 4.56 t/yr
Plum Brook - West	2	88% reduction from current load of 2.49 t/yr
Plum Brook - East	2	88% reduction from current load of 2.18 t/yr
Red Run - East	6	88% reduction from current load of 6.56 t/yr
George W. Kuhn	1	88% reduction from current load of 1.42t/yr

Critical Areas

Critical areas are the geographic portions of a watershed that contribute the greatest amount of a pollutant and have the most significant impact on the watershed. Identifying critical areas is an important step when determining how to achieve the TP load reductions necessary to meet the TP target value. The most significant sources of phosphorus loading in the subwatershed are runoff from croplands, septic systems, and stormwater runoff from urbanized areas, according to the analysis conducted using the STEPL model. Figure 5-4 presents a comparison of the relative contributions of phosphorus loading from different sources by catchment.

Figure 5-4. Estimated phosphorus load by source and catchment.



The STEPL model does not take into account streambank erosion. Therefore, the STEPL results do not reflect phosphorus loads associated with streambank erosion. As a result, the TP loading from the STEPL analysis is less than the estimated annual load of TP presented in Table 5-11.

Although the STEPL model results provide only an estimate, the information is helpful in understanding the relative contributions of phosphorus loading from sources within the subwatershed and how to prioritize these sources when selecting management practices to achieve load reductions.

Results from the STEPL model indicate that estimated phosphorus loads from the Warren WWTP are the most significant in the subwatershed. Other significant loads originate from urban runoff, including single-family residential areas. Urban sources of phosphorus can include fertilizer use, yard waste, pet waste, and automotive products deposited on roads and parking lots. Given the relationship of phosphorus to sediment (i.e., particulate phosphorus binds to sediment), surface runoff containing sediment is of concern. Within the urbanized areas, sediment picked up by the surface runoff is readily conveyed to a gutter (an impervious channelized flow path) which runs along most streets and washes into a traditional storm sewer drainage system, which quickly discharges to the sediment to the nearby water courses. The traditional catch basin sumps offer some limited opportunity to remove sediment (and thus phosphorus).

Defining critical areas for phosphorus in the subwatershed requires consideration of the results from both the load duration curve analysis approach and the STEPL model. These results represent both measured and estimated data. Based on TP load reductions and estimated source contributions of the phosphorus load, the critical areas to address in the subwatershed include those described below.

Although the Warren wastewater treatment plant discharging to Red Run South appears to have the most significant phosphorus load in the subwatershed, this facility is regulated under an NPDES permit. The critical area analysis focuses on reducing phosphorus loads from diffuse sources within the subwatershed. Based on TP load reductions and estimated source contributions of the phosphorus load, the critical areas to address include those discussed below.

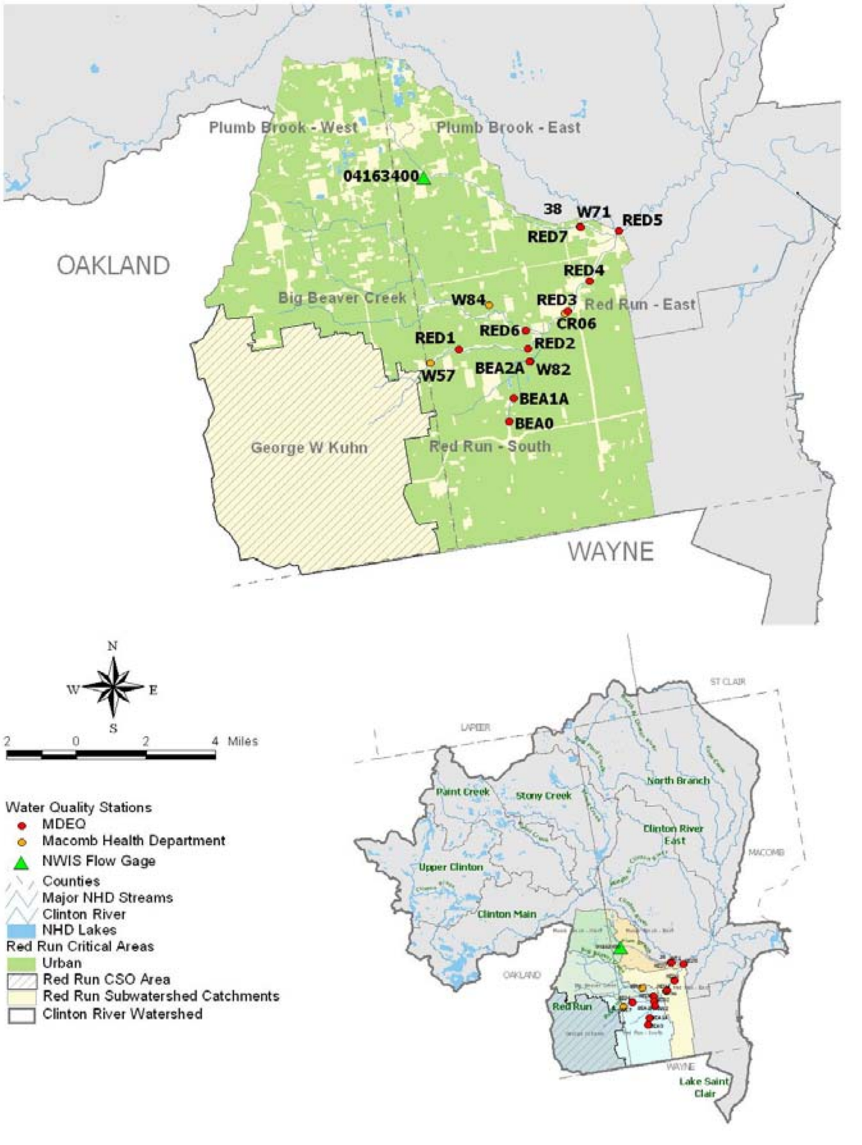
1 Urban Sources in All Catchments except George W. Kuhn

Urban sources, including single family residential, in all catchments except the George W. Kuhn, contribute an estimated 20.2 tons per year of phosphorus to the subwatershed, which is approximately 95 percent of the overall estimated phosphorus load from all sources (excluding the WWTP). Results from STEPL clearly indicate that urban runoff is estimated to be the most significant source of phosphorus load in the subwatershed. Although STEPL estimates that some catchments contribute more of the load from urban sources than others, it is essential that all catchments in the subwatershed, except the George W. Kuhn, consider their urban sources as a critical area. By identifying all urban sources in these catchments as a critical area, most communities in the subwatershed will share the responsibility to achieve the phosphorus load reduction targets. Urban sources in three of the catchments are also critical areas for sediment; many of the measures taken to reduce sediment loads are likely to help reduce phosphorus loads simultaneously. Figure 5-5 shows the location of urban land uses in all catchments. Detailed information from the USSR surveys that identify areas with high potential for nutrient pollutant load contributions will help to further prioritize efforts in these catchments. Similar assessments in other areas of these catchments are likely needed to determine the potential for phosphorus pollution from managed turf, curb and gutter, and other related urban land uses.

2 Known Areas of Exposed Soil

Field data collected through the visual assessments show that sources of sediment other than those accounted for in STEPL exist in the subwatershed. The unified stream assessment conducted at three locations in the subwatershed revealed severe bank erosion in Big Beaver Creek, with five locations recommended for bank stabilization. MCPWO and volunteers documented poor streambank conditions at one location on the Big Beaver Creek, three locations on the Plum Brook, and one location on the Nelson Drain. They also documented fair conditions at three downstream locations on the Red Run Drain. This type of information should help to further pinpoint critical areas related to streambank erosion and allow for prioritization of streambank restoration activities to reduce sediment loading that will also contribute to additional phosphorus loading.

Figure 5-5. Location of urban land uses in all catchments except George W. Kuhn.



3 Soil Erosion from Construction Related Activities

These areas are problems particularly when immediately adjacent to a water course or in an urbanized area with direct access to a storm sewer system. Although these areas were not considered in the STEPL model, it is well documented that soil erosion from construction related activities is a severe problem in rapidly developing areas and contributes significant sediment loads to the waterways. Although most of the subwatershed is built out, there are opportunities for limited new development and redevelopment. As mentioned in Chapter 2, portions of the subwatershed are projected to have increase in residential land use ranging from 2 to 13 percent. Open space is projected to decline from 9 to 5 percent. It is important to note that construction-related soil erosion control is addressed through a permitting program discussed in more detail in Chapter 7, and does not fall under the scope of this plan.

Monitoring Progress

Monitoring the reductions in the phosphorus load requires continued monitoring of total phosphorus, as well as other indicators of phosphorus (e.g., water clarity, dissolved oxygen). The Macomb County Health Department conducts ongoing monitoring through its Surface Water Sampling Program, which includes TP monitoring. The Clinton River Watershed Council's Stream Leaders student water quality monitoring program monitors for phosphates.

Monitoring is recommended to include total phosphorus to establish trends that build off of the existing dataset that serves as baseline data. In addition to monitoring for purposes of trend analysis, monitoring plans should also measure management practice effectiveness to determine if management practice implementation is successfully reducing phosphorus loading from sources in the subwatershed.

Future monitoring needs include developing a better water quality data set at several water quality monitoring locations throughout the subwatershed.

The specific monitoring protocols to be implemented in support of this plan are presented in Chapter 9.

Improvement Ideas

In the urban areas, efforts to reduce the amount of phosphorus entering the storm sewer system will help to reduce the phosphorus load from urban runoff. This includes first taking action to reduce the source of phosphorus, such as amount of fertilizer leaving residential, commercial, industrial areas, as well as roadsides. In addition, management practices that promote infiltration while reducing the direct connection of impervious areas to the storm sewer system will also help to decrease phosphorus loads – less stormwater carrying phosphorus will travel through the system. These types of management practices include porous pavement, green roofs, bioinfiltration, retention, detention and other low impact development techniques. In addition to reducing fertilizer use or promoting the use of phosphorus-free fertilizer, good housekeeping practices such as street sweeping and catch basin cleaning will help to reduce sediment loads that likely contain elevated levels of phosphorus.

Other actions to address erosion and sediment control have the potential to also reduce phosphorus loading. This includes stabilizing exposed soil adjacent to the streambanks and eroding streambanks using a vegetative approach (bioengineering). Some streambanks with extremely fast moving water next to it may require the use of hard armoring, but in most cases other bioengineering techniques area available to divert or stabilize the forces from the moving water. Addressing areas experiencing hydrologic modification could also reduce sedimentation and associated increased phosphorus loads.

The specific actions to be taken towards achieving loading reductions for sediment are presented in Chapter 8.

Pathogens

Pathogens are disease-causing microorganisms. They can be transported in stormwater runoff to streams and rivers. Three general categories of pathogens include bacteria, protozoans, and viruses. When found in water at elevated levels, pathogens can pose a serious health concern, potentially affecting water-based recreation and drinking water supplies. Illnesses associated with pathogens range from vomiting to death in sensitive populations. Risks to human health may vary depending on factors that influence the survival and reproduction of water-borne pathogens. Factors include temperature, sunlight, moisture, soil conditions, and settling in sediment (EPA, 2001).

In June 2006, MDEQ prepared and released a draft Total Maximum Daily Load (TMDL) for pathogens (i.e., *Escherichia coli* (*E. coli*),) for Red Run Drain and Bear Creek. The draft TMDL provides detailed information on data, sources, and activities to achieve water quality standards.

Sources

Given the size and variability of pathogens, it is difficult to identify their sources and track their movement. Pathogens can enter watersheds from both point and nonpoint sources. Wastewater treatment plants and combined sewer overflows are typically the most significant point sources of pathogens. Nonpoint sources of pathogens in urban areas include failing sewer lines, pet waste, wildlife, and urban litter (EPA, 2001). In agricultural and rural areas, pathogens can originate from failing septic systems, uncontrolled manure storage areas, and land application of manure. Pathogens settle in bottom sediment and are prone to resuspension during storm events or from recreational activity. Table 5-13 identifies some general sources and causes of pathogens based on anthropogenic influences.

The known sources of pathogens in the subwatershed include stormwater runoff from urban areas, illicit discharges and connections into the storm sewer system, sanitary sewer and combined sewer overflows, other wastewater treatment issues (e.g., septic systems). Suspected sources of pathogens include wildlife, pet waste, and possible sediment resuspension related to altered hydrology.

Chapter 2 documents past instances of sanitary sewer overflows (SSOs) in the subwatershed. There were 22 recorded SSO events releasing approximately 9.23 million gallons of raw or diluted sewage in the subwatershed between 2000 and 2006. In addition to SSO events, CSO discharge events can also contribute pathogens to the subwatershed, even though CSOs are partially treated. According to the *E. coli* Total Maximum Daily Load (TMDL) developed for Red Run Drain and Bear Creek, five CSOs occurred in 2004 that resulted in approximately 370 million gallons of partially treated sewage released to the Red Run River from the George W. Kuhn Retention Basin (MDEQ, 2006). In addition to overflows, regular functions of wastewater treatment plants can also contribute pathogens. For example, the Warren wastewater treatment plant is a permitted blending facility. Although this facility treats wastewater from separate sanitary sewer systems, rain events can cause influent rates to exceed the capacity of the facility and result in the need to overflow partially treated wastewater.

Table 5-13. General sources of pathogens.

Sources	Cause
Illicit Connections	Poor Construction and Maintenance Practices Function of Design Criteria Unnecessary Inflow (e.g. connected downspouts and footing drains) Increased Development with Poor Stormwater Planning
Sanitary Sewer Overflows (SSOs)	Excessive Infiltration Stormwater Inflow Increased Development with Poor Stormwater Planning Inadequate storm drainage
Combined Sewer Overflows (CSOs)	Excessive Stormwater Quantity Increased Development with Poor Stormwater Planning Lack of Stormwater Pollution Prevention
Animal Waste (Non-Agricultural)	Pet Owners Not Picking Up Waste Wildlife Lack of Buffer
Failed Septic Systems	Poor Design Poor Construction Poor Maintenance Overloaded Used beyond design life
Leaky Sanitary Sewer	Poor Design Poor Construction Poor Maintenance
Dumping	Lack of Adequate Disposal Facilities Poor Enforcement

MDEQ's draft TMDL documents several illicit connections in the subwatershed that lead to pathogen loads during dry weather. For example, Macomb County Health Department's illicit discharge elimination program identified school sanitary systems improperly connected to the separate storm sewer system. Over 126 storm sewer system outfalls of the more than 1,000 outfalls screened during dry weather showed evidence of an illicit connection (MDEQ, 2006).

Impact and Impairment

The presence of pathogens in water has the potential to negatively affect public health and can impair recreational and drinking water uses. Primary and secondary contact with recreational water contaminated by pathogens presents an elevated risk for gastrointestinal, respiratory, eye, ear, nose, throat, and skin diseases. As mentioned in Chapter 3, pollution-related, beach-closing information obtained from the Oakland County Website (OC, 2005) indicates that the beaches on Sandshores Lake, Troy Lake, and Walker Lake in Troy were closed at times in 2004, the beach on Emerald Lake in Troy was closed at times in 2004 and 2002, the beach on Avon Lake in Rochester Hills was closed at times in 2004 and 2001, and the beach on Spencer Lake in Rochester Hills was closed at times in 2001.

Indicators

Directly measuring pathogens in water presents a variety of challenges. As a result, bacteria associated with pathogens are measured as an indicator of the presence of pathogens. Fecal indicators, such as total coliform, fecal coliform, and *E. coli*, are commonly used indicator organisms. Although there is scientific support for the use of *E. coli* and other fecal indicators in determining the presence of pathogens, concerns exist about the correlation between the indicator, the presence of pathogens, and the incidence of disease (EPA, 2001). However, despite these concerns, *E. coli* is one of the most frequently used and publicly recognized indicators for pathogens, particularly for purposes of beach health reporting.

Water Quality Standards

Water quality standards in Michigan contain numeric criteria for E. coli to protect total body contact recreation and partial body contact recreation designated uses. To protect total body contact recreation, in-stream water quality is not to exceed 300 *E. coli* per 100 milliliters. For partial body contact recreation, in-stream water quality is not to exceed a maximum of 1000 *E. coli* per 100 milliliters.

The component of the standard that applies to total body contact recreation (maximum of 300 counts/100 mL) was used to determine the extent of water quality exceedances in the subwatershed and identify critical areas.

Comparison of Current Concentration Data to the Water Quality Standard

The water quality standard for total body contact recreation presented above serves as the numeric goal for *E. coli*, a pathogen indicator organism. Rather than looking at *E. coli* loads from sources in the subwatershed, this section presents an analysis of the existing *E. coli* concentration data and directly compares these data to the water quality standard to indicate where a critical area might exist. Previous load reduction analysis conducted for the planning process indicates that significant load reductions throughout the subwatershed are necessary to achieve the water quality standard. Using a concentration-based approach is consistent both with the Macomb County Health Department's beach health reporting approach and the MDEQ draft *E. coli* TMDL for the subwatershed. The nature of pathogens and *E. coli* as an indicator organism make it significantly challenging to estimate relative source contributions without the use of sophisticated and resource-intensive techniques (e.g., *E. coli* source tracking using DNA fingerprinting). It is appropriate to assume that all known and suspected sources of pathogens require significant attention to reduce pathogen loads to the subwatershed. Table 5-14 presents the available *E. coli* data used to determine recent concentrations. These data are generated through Macomb County Health Department surface water quality monitoring programs. The geometric mean provides information on the average number of *E. coli* counts per 100 milliliters; counts above 300 indicate exceedances of the pathogen water quality standard. The percent reduction indicates how far the average concentration must drop to meet water quality standards – this is not a percent reduction in pathogen loads from sources. The number of samples exceeding the water quality standard out of the total number of samples (i.e., count) provides a percentage of samples that exceed the water quality standard.

Table 5-14. *E. coli* data used to estimate current and target loads.

Station ID	Period of Record	Count	Geometric Mean (#/100mL)	Reduction %	# of Samples Exceeding 300 counts/mL	% of Samples Exceeding 300 counts/mL
CR06	9/20/2004 - 10/21/2005	56	2,223	-87%	48	86%
RED1	5/18/2004 - 9/29/2004	70	194		33	47%
RED2	5/18/2004 - 10/21/2005	67	143		24	36%
RED3	5/18/2004 - 9/29/2004	68	87		19	28%
RED4	5/18/2004 - 9/29/2004	66	152		26	39%
RED5	5/18/2004 - 9/29/2004	68	122		27	40%
RED6	5/18/2004 - 9/29/2004	66	146		28	42%
RED7	5/18/2004 - 9/29/2004	66	84		19	29%
W57	5/23/2000 - 9/16/2003	10	1,253	-76%	10	100%
W71	5/23/2000 - 9/16/2003	11	745	-60%	9	82%
W82	5/23/2000 - 9/16/2003	11	5,696	-95%	11	100%
W84	5/23/2000 - 9/16/2003	11	1,135	-74%	10	91%

Table 5-15 presents the existing and target annual *E. coli* load (billion cells per year) for the in-stream sampling locations in the subwatershed. In addition, Table 5-15 states the percent annual load reduction necessary to achieve the water quality standard for total body contact recreation of 300 *E. coli*/100 mL.

Table 5-15. Existing annual loads and associated reductions.

Station ID	Existing Load (10^9 cells/yr)	Target Load (10^9 cells/yr)	Load Reduction (%)
Red Run River - South (41)	100,594	16,738	-83%
Red Run River - South (W82)	1,492,882	43,749	-97%
Big Beaver Creek (W84)	149,324	796	-99%
Plum Brook - West (38)	61,078	61,287	0%
Plum Brook - East (38)			
Red Run River - East (42b)	2,229,110	145,325	-93%
Red Run (RED5)	940,154	224,907	-76%
George W Kuhn (W57)	38,379	3,655	-90%

Critical Areas

For other stressors, critical areas are defined as the geographic portions of a watershed that contribute the greatest amount of a pollutant and have the most significant impact on the watershed. For *E. coli*, the analysis focuses on concentration data rather than loading data. Therefore, it is difficult to estimate the geographic portions of the watershed that contribute the greatest amount of pathogens. Concentration data can provide an understanding of what portions of the subwatershed have relatively higher or lower levels of pathogens; this provides an indication of which catchments might contribute a relatively greater pathogen load.

MDEQ has cited *E. coli* to be both a wet weather and dry weather issue in the subwatershed, with wet weather events resulting in the most significant loads. Therefore, the critical area analysis for the subwatershed will focus on the priority sources that contribute to wet weather pathogen loads – urban areas in all catchments.

Monitoring Progress

Monitoring the progress of reducing pathogens will rely on existing *E. coli* monitoring efforts by the Macomb County Health Department. The Macomb County Health Department monitors for *E. coli* on a regular basis through the Macomb County Bathing Beach and Surface Water Quality Program. In addition, the Department conducts initial investigations of stormwater outfalls through the Illicit Discharge Elimination Program, which includes sampling for *E. coli*.

Another indicator of pathogens, fecal coliform bacteria, is monitored through the Clinton River Watershed Council's Stream Leaders student water quality monitoring program.

Continued *E. coli* monitoring will establish trends that build off of the existing dataset that serves as baseline data. In addition to monitoring for purposes of trend analysis, monitoring should also measure management practice effectiveness to determine if management practice implementation is successfully reducing *E. coli* loads from sources in the subwatershed. The issue of pathogen source identification is an important and challenging topic; as progress is made in this arena, it would be beneficial to incorporate source identification monitoring to help distinguish the sources of *E. coli* in the subwatershed.

Given the challenges associated with using *E. coli* as an indicator organism for pathogens, future monitoring needs include identifying an alternative indicator for pathogens. Future monitoring needs for E. coli also include the identification and use of acceptable source tracking techniques to aid in distinguishing anthropogenic sources of pathogens from wildlife and other natural sources.

The specific monitoring protocols to be implemented in support of this plan are presented in Chapter 9.

Improvement Ideas

MDEQ's draft TMDL states that *E. coli* loads occur during both wet weather events and during dry weather, with the most significant loads after wet weather events (MDEQ, 2006). As a result, improvement strategies should address both wet weather and dry weather sources of pathogens.

Reducing pathogen loads associated with wet weather events depends on both effective stormwater management and pollution prevention activities. In urban areas, management practices that promote infiltration while reducing the direct connection of impervious areas to the storm sewer drainage system will decrease *E. coli* loads. These types of management practices include porous pavement, green roofs, bioinfiltration, retention, detention and other low impact development techniques. Reducing the amount of stormwater runoff from urban areas will also help to alleviate the stress placed on separate and combined sanitary sewers that might have illicit connections to the storm sewer system or inflow/infiltration problems due to age or lack of adequate maintenance. Limiting the amount of pathogens picked up by stormwater runoff through pollution prevention activities will also help to reduce loads. Pollution prevention activities can include efforts to properly manage domestic pet waste and limit the populations of anthropogenic wildlife, such as geese, pigeons, raccoons, and rats, are likely to help reduce *E. coli* loads associated with urban runoff.

To address *E. coli* loads from failing septic systems, development and implementation of an effective performance-based on-site system management approach is key. As stated in Chapter 2, there is a documented lack of authority at the state and local levels to identify and remediate failing septic systems. Performance-based on-site programs include rigorous and ongoing system management, such as periodic inspections and required maintenance. The assumed failure rate is likely to decrease using this type of management approach, resulting in a reduced phosphorus loading. Macomb County does enforce a point-of-sale regulation that requires evaluation of on-site sewage disposal systems prior to property transfer. According to the draft TMDL, Macomb County issued 726 septic repair permits in 2004 and 2005 (MDEQ, 2006). Although most sanitary discharges are connected to the sanitary sewer system, repair of failing septic systems will likely help reduce *E. coli* loads and ensure the receiving waters meet the *E. coli* water quality standard.

Efforts to address dry weather sources of pathogens are focused on implementation of illicit connection elimination programs. Both Macomb and Oakland Counties are conducting these types of programs. The Rouge River watershed is currently undertaking a study to determine the effectiveness of illicit connection elimination programs; results from this study will help Macomb and Oakland Counties assess the effectiveness of their efforts in reducing pathogens to the Red Run subwatershed.

The specific actions to be taken towards achieving loading reductions for sediment are presented in Chapter 8.

Hydrologic Flow

Stream flows vary in characteristic ways over time frames ranging from hours and days to seasons and years. The flow regime includes such factors as the magnitude and frequency of floods and low flow periods, the seasonal occurrence of various flow rates, and the rates of change of flow. The flow regime of a stream reflects the operation of the hydrologic cycle within its watershed. Climate, topography, geology, soils, vegetation, watershed size and shape, stream pattern, land use, water use, and dams all impact the timing and pathways of water movement to and through stream and hence the stream’s flow regime.

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 may cause streambank erosion, sedimentation, and poor conditions for plants, fish and macroinvertebrates. In addition the surface runoff from precipitation collects and transports various pollutants to the receiving waters thus not only affecting the flow characteristics in the receiving water but also the pollutant concentrations.

Sources

Hydrologic flow changes in receiving water courses are due to a loss of infiltration into the soil, a loss of evaporation, loss of storage or increased flow channelization. These occurrences are typical of development regardless of the new land use. For example in urban areas loss of infiltration, storage and evaporation result as impervious surfaces are created and the soil is compacted due to construction operations. Refer to the discussion on the relevance of impervious cover in Chapter 2 for additional information.

Another key cause of changes in hydrologic flow is the loss of storage such as wetlands and floodplains. As discussed in Chapter 2, wetland coverage in the subwatershed is currently 1.6 percent of land area. The Plum Brook – West catchment is 6.4 percent wetlands and accounts for 48 percent of the subwatershed total. The Plum Brook – East catchment is 3.8 percent wetlands and accounts for 22 percent of the subwatershed total. The other catchments have less than 1.7 percent of their land as wetland and account for no more than 18 percent of the wetland total. The lack of wetlands in the southern-most portions of the subwatershed can be attributed in part to the intense urban development of these areas.

Table 5-16 summarizes various sources of changes to the hydrologic flows.

Table 5-16. Hydrologic flow change sources.

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

Impact and Impairment

The typical changes in hydrologic flow due to development in the surrounding watershed include an increase in the flashiness of the watercourse, an increased peak flow, a reduction in the base flow due to loss of interflow and groundwater flow through the soil, and an increase in the total volume of water transported. A decrease of water is also possible if significant water withdrawals are occurring, however this is not the case in this watershed.

Increases in peak flow rates may literally wash benthic macroinvertebrates, fish, amphibians and vegetation downstream if the peak velocities and shear forces are great enough. With the increased flow rates and occurrence comes an increase in the erosion potential within the watershed. The impacts and impairment of this are discussed under sediment as a stressor.

The increased runoff from developed areas also has the potential to carry with it pollutants that would not otherwise enter the watercourse. For example in a residential development fertilizers may be carried by rainwater through the engineered stormwater conveyance system and be discharged to a river. Hence if the increased runoff were controlled not only would the stream experience less impact due to changes in hydrologic flow but would also not receive the fertilizer applied to the yard, in the above example.

A good discussion of the impacts of hydrologic flow may be found in "Hydrologic Impacts Due to Development: The Need for Adequate Runoff Detention and Stream Protection" by the MDEQ May 2002.

The loss of wetlands and connected floodplains in the watershed results in the same hydrologic changes as discussed above. In addition the loss storage areas help prevent the movement of sediment, filter pollutants, provide habitat and support a wide diversity of plants and animals.

Indicators

Many different indicators may be used for hydrologic flow. The most obvious indicator is that of the flow profile itself monitored throughout the day as it is at a USGS gauging station. The challenge with gauging station data is in interpretation based on all of the other variables affecting flow, for example precipitation, temperature, wind, length of records, etc. Flashiness indices are one method of analyzing flow records. The term flashiness reflects the frequency and rapidity of short term changes in stream flow, especially during runoff events. A variety of indices have been developed to describe natural flow regimes, their degree of alteration, and progress in their remediation.

Other indicators of changes in hydrologic flow look at the impact left behind such as streambank erosion, embeddedness, and population and biodiversity of organisms.

Erosion of streambanks is a natural process; severely eroding streambanks may be an indicator of changes in the hydrologic flow regime. Various methods are available to monitor the rate of eroding streambanks; these typical center around some type of reference marks or pins. Photographic monitoring also provides some reference framework for this. Fallen trees into the river may be an indicator of active erosion although this may be difficult to tell. The presence of exposed roots on the riverbanks with the fine roots in tack (looks like the roots are hairy) may indicate actively eroding streambanks.

The loss of storage may be calculated based on mapping, survey data, and perhaps modeling and used as an indirect measurement of the hydrologic change.

Water Quality Standards

Water quality standards specific to hydrologic flow are not available. The water quality rules discussed under the MDEQ's administrative rules focus on chemical composition, taste or odor producing substances, radioactive substances, plant nutrients, microorganisms, dissolved oxygen, and temperature. The rules surrounding floodplain also do not address hydrologic flow specifically but rather look to net increases to the floodplain, typically the one percent probability floodplain (100-year). Since hydrologic flow variations are in and of themselves not regulated, attention must be focused on the impacts associated with the changes of hydrologic flow.

Available Data

Unfortunately, no data exists with which to analyze changing flow patterns. However, trends in the Clinton River indicate that the river (and its tributaries) is becoming more responsive to rainfall by exhibiting higher peak flow rates and increased 'flashiness'. This generally implies that the few waterbodies in the subwatershed are exhibiting similar flow patterns. The discussion provided below is taken from the Clinton River East Subwatershed (CREW) Management Plan.

Discussed in Chapter 3 of the CREW plan , stream flow data are available at USGS gauging stations. In the CREW, there are two locations where sufficient stream flow data exist to conduct a meaningful analysis. These sites (#04164000 on the Clinton River near Fraser at Garfield Road; and # 0416550 on the Clinton River in Mt. Clemens at Moravian Drive) are detailed in the Chapter 3.

Land use data and aerial mapping is available to estimate percent imperviousness, discussed in Chapter 3. Soil mapping information is available from the NRCS which is used in hydrologic flow computations. Flow conveyance information is available from the respective County Drain Commissioner's offices as well as from some municipalities.

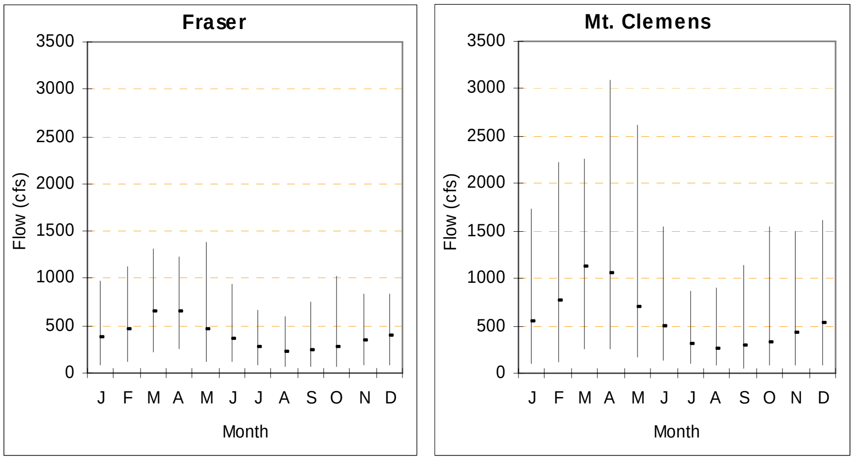
Information on indicators is available in the form of organism biodiversity and population data (discuss in Chapter 3), and physical characteristics as observed from the various inventory and screening efforts previously discussed.

Load Estimates

Load estimates for hydrologic flow are not specifically available rather surrogate estimates are used, namely the stream flow variations, flashiness indices and the amount of imperviousness within the watershed.

Figure 5-6 shows the monthly mean stream flows (in cfs) for the entire data span at the two USGS stations.

Figure 5-6. Monthly mean stream flows.



The vertical bar above each month illustrates the range of flow recorded and the horizontal tick mark on each vertical bar is the monthly mean stream flow. This is meant to illustrate the flow variability within each month and also between the months.

The flow data show the yearly variance in flow from January, increasing until its peak in March/April, decreasing to its lowest in August, then increasing again.

As one would expect, the downstream gage exhibits greater mean flows and greater variances in flows. For example, the stream flow at the Fraser gauge had a maximum annual mean of 563 cfs in 1985 with a monthly variation from 72 cfs in October 1953 to 1,352 cfs in May of 1956. The Mt. Clemens gauge had a maximum annual mean of 1,959 in 1975 with a monthly variation from a 51 cfs in July 1934 to a high of 3,090 cfs in April 1947.

The preceding analysis only addresses flow variability. One common metric used to characterize the change in basin response is a stream flashiness index. Flashiness is a characterization that quantifies the time response of a river to a rainfall event. In this analysis, the flashiness index used was based on a method described in a paper by researchers from Heidelberg University (Baker, et al, 2004) in the Journal of American Water Resources Association (see 'Flashiness Index' sidebar for additional information).

Figure 5-7 and Figure 5-8 present the results for such an analysis at the two gages of interest in the subwatershed (USACE, 2005).

Figure 5-7. Flashiness indices and trend at the Fraser gage.

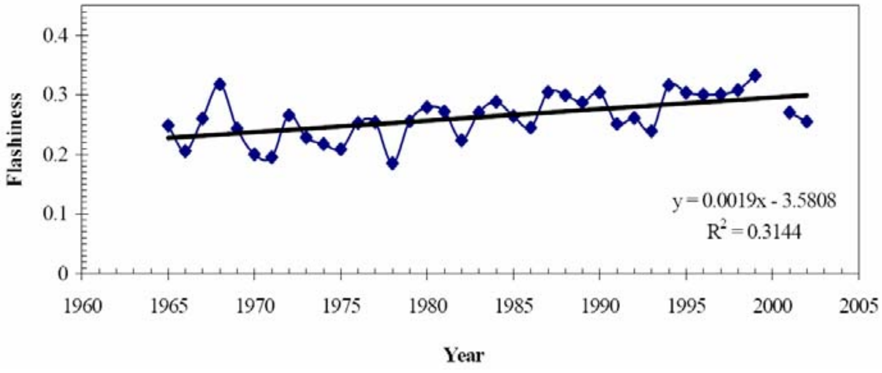
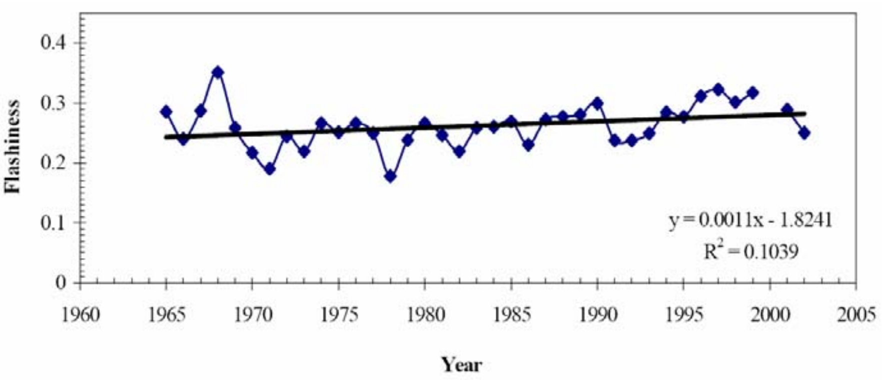


Figure 5-8. Flashiness indices and trend at the Mt. Clemens gage.



Flashiness Index

The Richards-Baker, or "RB" index is a ratio of the absolute value of the sum of the daily flow changes to the sum of the total daily flows. Although this index may vary spatially for a particular year, the temporal trend of this index is a relative indication of basin response to rainfall and is a good indicator of hydrologic changes in the watershed.

Source: Baker, et al., 2004.

As can be seen in the figures, the flashiness index shows an increasing trend over the last 35 years. As any rainfall deviation over this period was statistically insignificant, this indicates that the Clinton River is generally becoming more responsive (exhibiting higher peak flow rates) most likely due to increasing impervious surfaces in the river's headwater areas.

A visual representation of the impervious cover from the land use data can be found in Chapter 2. The remaining discussion is based on this data as the impervious percentage coefficients were derived based on regional information.

The impervious cover for the subwatershed as a whole is 32 percent. The Red Run – South, Big Beaver Creek, and Red Run - East catchments have the greatest percentages of impervious surface, with over 33 percent each. The Plum Brook - West catchment has the lowest impervious percentage at 20.3 percent. The other catchments have impervious percentages of 29.7% for the Plum Brook – East and 29.6 percent for the George W. Kuhn catchment.

Analysis of stream systems across the country seems to indicate that there are thresholds at which watershed imperviousness results in measurable degradation of waters. The Impervious Cover Model (ICM) (Schueler, 1994) describes this relationship, some threshold values of imperviousness, the characteristics of streams impacted by imperviousness, and recommended actions to address issues in these streams.

The ICM, although a powerful tool to predict the quality of streams based on impervious cover change, has limitations and is not an absolute indicator. It is not generally applicable at scales greater than 10 miles and is based primarily on data from the northwest portion of the U.S. It is important to understand that the ICM is applicable at a single point along a waterbody; the analysis of imperviousness must consider the entire area of land tributary to that point. From the information presented above, it can be said that the Plum Brook at the outlet of the Plum Brook – West catchment has a tributary area that is 20.3 percent impervious and therefore falls within the impacted category. While the Plum Brook – East catchment has an impervious area of 29.7 percent, the ICM classification of the Plum Brook at the outlet of the Plum Brook – East catchment must include the total tributary area, which includes the Plum Brook – West catchment. This total area is then approximately 25 percent impervious and the river is classified as impacted at that location.

While outside the scope of this plan, it is recommended, in the future, to properly analyze the streams in the subwatershed in the context of the ICM. This involves defining drainage areas for numerous points along each stream to be analyzed and conducting the impervious analysis as described in the beginning of this section. At this point, it can be said, based on the catchment-aggregated data, that the impervious coverage for a given catchment can be compared to the ICM values to determine the likely classification of the small streams in that catchment. The remaining discussion in this section approaches the topic in such a manner.

As a whole, the subwatershed is affected by the high percentage of imperviousness. While some areas are expected to exhibit serious problems, others have impervious levels that imply the possibility to maintain high levels of water quality and general waterbody health.

While short-term actions for areas most affected by impervious surfaces are related to minimizing existing problems, the long-term outlook for these areas can be geared towards restoration if the right steps are taken. However, one of the purposes of the ICM is to identify streams that are outside of the severe impacts of imperviousness, so that limited resources can be funneled towards the protection of these resources. This approach is much more cost-effective than trying to restore streams severely degraded by high levels of imperviousness.

It should also be noted that the suggested relationship between impervious cover and the expected stream quality was developed for urban subwatersheds (typically with a drainage area less than 10 square miles) and may not accurately reflect conditions for agricultural areas.

Critical Areas

The critical areas for hydrologic flow are the highest developed areas as estimated by the impervious cover analysis. The more imperviousness associated with a given site, the higher the flashiness, the greater the peak flows will be increased, and the greater the total runoff volume due to the reduction in evaporation, transpiration, infiltration and storage.

All impervious areas which are directly connected to a stormwater conveyance system (often referred to as DCIA or directly connected impervious areas) should be considered for restoration potential. The areas with a higher percent impervious may be given higher priority based on their potential to more adversely affect the receiving water body. Likewise impervious areas which have a high potential for containing other pollutants should also be given a higher priority over impervious surfaces with no other pollutants.

When considered on the subwatersheds level those subwatersheds which have a percent imperviousness greater than or equal to 10 percent are considered the critical areas. Three categories are provided:

1 Urban Drainage Catchments

These areas are comprised of those with impervious cover greater than 60 percent. No catchments fall into this classification.

2 Non-Supporting Catchments

These areas are comprised of those with impervious cover between 26 and 60 percent. All catchments, except Plum Brook - West, fall into the category of 'Non-supporting' implying that many waterbodies in these catchments may be affected by impervious cover such that they show impacted water quality, low biodiversity, and have unstable channel banks. Watershed protection activities in these catchments should focus on reducing bacterial contamination and implementing pollutant load reducing BMPs.

3 Impacted Catchments

The Plum Brook – West catchment falls within the 'Impacted' category. Waterbodies in this catchment are expected to show some signs of degradation. Watershed protection activities in these catchments should focus on protecting the critical elements of water quality and implementing protection strategies that focus on reducing pollutant loads from existing impervious areas. It is important to recognize that the aforementioned catchment is a 'headwater area' for the Plum Brook and the fact that it is not classified in the 'Non-supporting' category is a positive in terms of future water quality potential.

Keep in mind that regardless of the overall subwatershed area weighted percent impervious, all directly connected impervious areas are good candidates for restoration potential.

For protection consideration, critical areas are considered those that have an impervious cover less than 10 percent in the category of "Sensitive." These are generally the undeveloped parcels or parcels with open green space included. No catchments in the subwatershed fall into this category.

Load Reduction Targets

No specific load reduction is targeted for hydrologic flow. Rather the target is to see a downward trend for the R-B Index. Trending of the Index should be looked at on no less than a five year basis and not annually.

No specific target is set for the impervious cover analysis. The desire is to see no "effective" increase in hydraulically significant percent impervious. Hydraulically significant impervious areas are those impervious areas directly connected to the receiving water. The intent is not to limit development and consequently the impervious area, but rather when development occurs to do so in an environmentally friendly manner such as the premise of low impact development techniques.

The target for the wetlands and floodplains is to see no net loss of additional storage within the watershed.

Monitoring Progress

Use of the R-B Index will be used at the two USGS gauging stations in the CREW to monitoring progress over time. Trending of the Index should be looked at on no less than a 5 year basis and not annually. Flow monitoring in the Red Run subwatershed is necessary to develop a baseline for future trend analysis of the R-B Index in this subwatershed.

Progress will also be monitored through the other indicator parameters as identified in the *Indicator* section.

Improvement Ideas

In order to reduce the flashiness of a stream the high impervious cover areas may be retrofitted to slow down the runoff discharge and promote the use of infiltration and evapotranspiration. This may be accomplished through the use of bioretention and infiltration practices such as rain gardens, green roofs, porous pavement and vegetated swales. The use of detention facilities is appropriate to reduce the peak discharge however these types of facilities do not generally reduce the total volume of runoff discharged and therefore are not as effective as some other means.

For new development and significant redevelopment areas development standards should be put into place promoting the use of low impact development techniques. Public education and input should be included in formulating development standards.

Directly related to the flow regime stemming from high impervious areas is the ability and tendency of the runoff to pick up other pollutants and discharge them to the receiving waters. In order to minimize the impact of this any retrofit projects undertaken to reduce the discharge should also include best management practices to reduce the pollutants carried by the storm water. In addition, good housekeeping practices and education should be included to reduce the opportunity for the pollutants to come in contact with the storm water.

The degradation and loss of storage should also be thwarted by first completing inventories and assessments of the existing wetlands and floodplains and then providing protection measures. In addition, those areas capable of being restored should be prioritized and worked on as possible.

Critical Area Summary

Based on the critical area analyses presented in the previous sections, BMPs applied in the urban areas of the subwatershed have the potential to help mitigate multiple stressors.

Other Stressors

Aside from the stressors discussed above in detail, other known stressors are present in the watershed. For each of these stressors, the sources and causes are identified.

Contaminated Sediments

Chemicals such as PCBs, metals (e.g., mercury, lead, zinc), and pesticides tend to bind to particles and collect in bottom sediments. Elevated concentrations of these chemicals have been documented over several decades in a number of locations along the Clinton River from Pontiac to the mouths of both the river and the spillway (EPA, 2003). Based on the MCHD sampling, persistent problems have been documented in Bear Creek at Van Dyke Road and in the Red Run Drain at Utica Road. The problems common to both sites include elevated heavy metals, PCBs, organic chemicals, and E. coli in the sediment (although the 2004 sediment samples at the Red Run site showed improvement). Additional problems at the Red Run site include the sediment COD and the presence of oil and grease / petroleum hydrocarbons. A 2005 MDEQ report documenting water chemistry conditions discussed conditions on the Plum Brook and Schoenherr Road, the Spencer Drain at Chicago Road, the Big Beaver Creek at Ryan Road, and the Red Run Drain at M-53, 14 Mile Road, and 15 Mile Road. Sediment chemistry was also sampled at the 14 Mile Road location. The sediments at the 14 Mile Road site had excessive mercury concentrations and elevated lead and zinc.

Table 5-17 presents the potential sources and causes of contaminated sediments in the subwatershed. The sources of these contaminants include historical point source discharges, as well as existing nonpoint sources. Contaminated sites, such as landfills and leaking underground storage tanks, might also contribute pollutants contaminating sediments. More work is necessary to understand the sources and causes of contaminated sediments, including the mixing and transport of sediments. When present at elevated levels in sediments, chemicals can kill or harm bottom-dwelling organisms and can also accumulate in aquatic organisms and move up the food chain to fish, shellfish and eventually humans. Contaminated sediments have also resulted in a restriction to dredging activities because of the concern for re-suspending chemicals currently buried.

Table 5-17. Contaminated Sediments - Sources and Causes

Sources	Cause
Resuspension of buried contaminated sediments	Disturbance from storm events Disturbance from recreational and navigational activities
Contaminated sites (landfills and underground storage tanks)	Age of materials Lack of maintenance and monitoring
Stormwater runoff	Automotive fluids and by-products on impervious surfaces Improper disposal of hazardous materials Improper materials storage and good housekeeping practices

Polychlorinated Biphenyls

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. Table 5-18 lists potential sources and causes of elevated PCB levels in the subwatershed. The Clinton River Spillway is noted for having elevated levels of PCBs. 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, 2006).

Table 5-18. 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

Habitat Alteration

Habitat alteration is affecting the fisheries, other aquatic life, and wildlife. Habitat loss has resulted from the urbanization of the watershed and the conversion of the natural land cover to parking lots, buildings, homes, and lawns. In addition to the direct loss of stream habitat, the increased imperviousness has also resulted in a significant modification to the natural flow regime. High quality stream habitats with intact riparian zones and natural channel morphology are essential to a healthy aquatic community because they provide shelter, spawning areas, and can help filter excess pollutants such as nutrients and sediment.

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