Water Quality Improvement Plan for

Milford Creek

Dickinson County, Iowa

Total Maximum Daily Load
for Phosphorus

Iowa Department of Natural Resources
Watershed Improvement Section
2007

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General Report Summary

Milford Creek in Dickinson County (photo taken by IDNR in 2005).

What is the purpose of this report?

This report serves dual purposes. First, it provides local watershed managers and citizens with a resource for understanding and fixing the problems in Milford Creek. Second, it satisfies the Federal Clean Water Act requirement to develop a Total Maximum Daily Load (TMDL) for lower Milford Creek, a.k.a. Mill Creek, which is listed on the state's 2004 Impaired Waters list (303(d) List).

What's wrong with Milford Creek?

Excessive amounts of algae in the stream are causing violations of the state's water quality standards for dissolved oxygen. Too much algal growth results in low nighttime levels of dissolved oxygen in the stream, as well as extreme fluctuations in oxygen levels that stress the aquatic life. This has resulted in a chronic impairment to the stream's fish and invertebrate communities.

What is causing the problem?

The excessive algal growth in Milford Creek is caused by a combination of physical factors and the overabundance of plant nutrients, specifically phosphorus. Phosphorus contributes to oxygen consumption indirectly by causing excessive plant growth in the stream, especially under low flow conditions and warm temperatures. This leads to extreme levels of nighttime respiration by algae and decomposition of dead plants, both of which deplete oxygen levels in the stream.

What can be done to improve Milford Creek?

To improve dissolved oxygen levels and restore aquatic health in Milford Creek, phosphorus loading to the stream needs to be reduced significantly and the stream physical conditions need to be improved. Reducing phosphorus inputs from point and nonpoint sources will help limit algae growth during late summer critical conditions. Reducing stream temperature and light availability will also limit algal growth. Phosphorus removal in wastewater treatment, reductions in urban and agricultural stormwater runoff, and the lowering of lake nutrient concentrations in Lower Gar Lake and the upper Iowa Great Lakes will all help improve water quality in Milford Creek.

Who is responsible for a cleaner Milford Creek?

The water quality in Milford Creek is a shared responsibility and improving it must be considered a cooperative effort. Government and wastewater treatment facilities will be responsible for adjusting effluent limits from point sources, while nonpoint sources can be influenced by everyone living or working in the watershed. Landowners, tenants, businesses, and citizens alike have the ability to improve management practices in the watershed and educate others about why Milford Creek needs their help.

Algae and organic materials (shown in picture) consume oxygen in Milford Creek through respiration and decay (photo taken by IDNR, 2005).

Technical Elements of the TMDL

Name and geographic location of the impaired waterbody for which the TMDL is being established:	Milford Creek, S14, T98N, R37W to S18, T98N, R36W, near the City of Milford in Dickinson County, Iowa
Waterbody ID and location of impaired segment:	IA 06-LSR-0300_0 (from mouth to confluence with unnamed tributary)
Existing stream classification:	IA 06-LSR-0300_0: A1 and B(WW-2) (Primary contact recreation and Type 2 warm water aquatic life)
Impaired beneficial uses:	Aquatic life uses (Class B)
TMDL priority level:	Consent Decree waterbody (High)
Identification of the pollutant and applicable water quality standards:	Phosphorus is indirectly causing violations of the state's numeric dissolved oxygen criteria through excessive algae respiration & decomposition. For Class B(WW-2) streams, the minimum dissolved oxygen concentration is 5 mg/l for at least 16 hours per day and an absolute minimum of 4 mg/l.
Quantification of the pollutant load that may be present in the waterbody and still allow attainment and maintenance of water quality standards:	The maximum amount of total phosphorus that Milford Creek can tolerate under critical environmental conditions is 7.0 lbs per day. Critical environmental conditions refer to periods of low streamflow and high temperatures, when conditions are most stressful for aquatic life. Load capacities for additional flow conditions are provided in the report.
Quantification of the amount the current pollutant load in the waterbody deviates from the pollutant load needed to attain and maintain water quality standards:	Current phosphorus loading to Milford Creek during critical conditions is commonly as high as 91.8 lbs/day. This exceeds the tolerable level by over 92%.
Identification of pollution source categories:	Both point and nonpoint sources of phosphorus contribute to the

	impairment in Milford Creek. Point sources in the watershed include the Iowa Great Lakes Sanitary District WWTP and one permitted open feedlot. Nonpoint sources include urban and agricultural areas, atmospheric deposition, and outflows from Lower Gar Lake and the upper Iowa Great Lakes watershed.
Wasteload allocations for pollutants from point sources:	Under critical environmental conditions, the wasteload allocation for point source wastewater is 6.9 lbs/day total phosphorus. The wasteload allocation for the permitted open feedlot is zero, as animal feeding operations are not allowed to discharge to surface waters. Wasteload allocations for additional flow conditions are provided in the report.
Load allocations for pollutants from nonpoint sources:	Under critical environmental conditions, the load allocation for nonpoint sources is 0.1 lbs/day, which includes background loading from atmospheric deposition. Load allocations for additional flow conditions are provided in the report.
A margin of safety:	A margin of safety is implicit in conservative assumptions used to define the maximum loading capacity.
Consideration of seasonal variation:	The maximum loading capacity was designed to allow the stream to meet water quality standards under critical environmental conditions, during seasonal low flows and high temperatures.
Reasonable assurance that load allocations and wasteload allocations will be met:	The issuance of a NPDES permit for the IGLSD, existence of an approved TMDL for Lower Gar Lake, and the availability of technical and financial assistance grants for local watershed improvements in Milford Creek provide

	reasonable assurance that load reductions can be met.
Allowance for reasonably foreseeable increases in pollutant loads:	No allowance for a future increase in pollutant loading was provided. A new wastewater treatment facility and recent efforts in the Iowa Great Lakes watershed to foster innovative stormwater management through low impact development and citizen education indicate that an increase in pollutant loading is not likely.
Implementation plan:	Although not required by the Clean Water Act, an implementation plan is included in Chapter 4 of this report.

1. Introduction & Summary

The Federal Clean Water Act requires that all states develop lists of impaired waters which are not meeting designated water quality standards. This list is commonly called the 303(d) list. For each impaired waterbody that appears on the list, a total maximum daily load (TMDL) report must be developed.

A TMDL is a calculation of the maximum amount of pollution a waterbody can tolerate without exceeding its water quality standards. The report must allocate portions of the load capacity to both nonpoint and point sources (called the load allocation and wasteload allocation, respectively), allow for a margin of safety, and account for seasonal variations and critical environmental conditions.

This document is the TMDL report for lower Milford Creek, a.k.a. Mill Creek, located in Dickinson County, Iowa. Milford Creek has been identified as not fully supporting its Class B aquatic life uses due to poor biological health and violations of the state's numeric dissolved oxygen criteria. A Stressor Identification (SI) for the stream has determined that excessive algae and macrophyte growth, encouraged by an overabundance of plant nutrients, are the primary causes of the impairment. This TMDL specifically addresses phosphorus as the primary factor controlling algal growth in the stream.

Lower Milford Creek was included in a 2001 lawsuit brought forth against the U.S. Environmental Protection Agency regarding the status of Iowa's TMDL program. The outcome of this lawsuit was a formal Consent Decree which specified that TMDLs be developed for all impaired waters on the 1998 303(d) list by December 15, 2009, which includes lower Milford Creek.

In addition to satisfying legal requirements to develop a TMDL for lower Milford Creek, the purpose of this report is to provide a resource to help guide future improvements in the Milford Creek watershed. Restoring the water quality in Milford Creek will depend upon the cooperation and combined efforts of local citizens, landowners, stream managers, and government agencies alike. This report can help those groups by identifying appropriate load reduction targets, pollutant sources, and management alternatives.

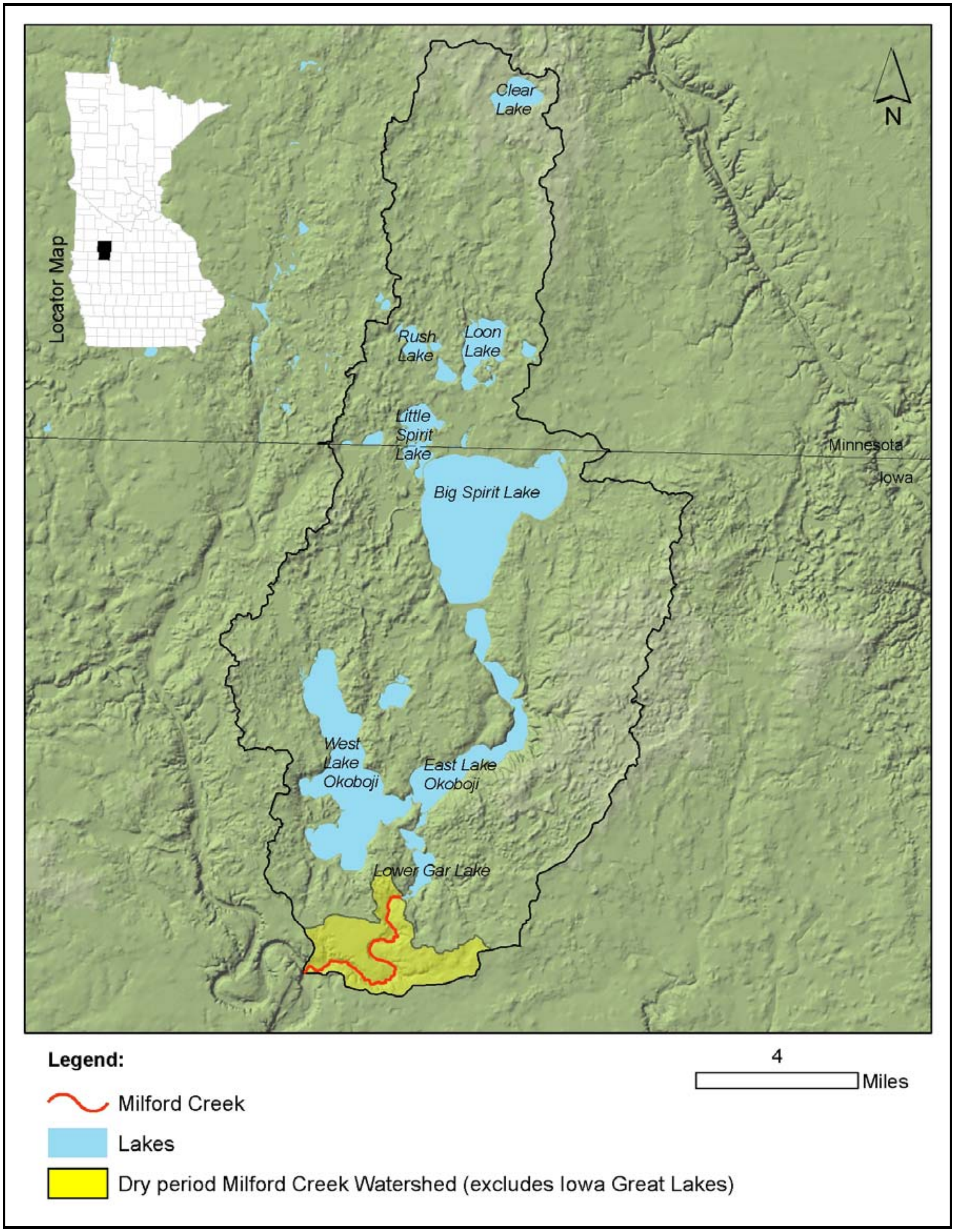

Figure 1. The Milford Creek watershed.

2. Description and History of Milford Creek

Milford Creek is a stream located in central Dickinson County, Iowa. The creek begins at the outlet structure of Lower Gar Lake and flows south and west for 6.2 miles until it reaches the Little Sioux River.

2.1. Milford Creek

Hydrology. Milford Creek is a relatively short, wide, and shallow stream. For 305(b) assessment purposes, the stream is split into two segments: Waterbody ID# IA 06-LSR-0305 (upstream) and Waterbody ID# IA 06-LSR-0300 (downstream) (Figure 2). The upstream segment (2.9 miles long) is rather lake-like, being wide, shallow, and slow-moving. A small drainage ditch which enters the stream just north of the city of Milford is the only defined surface water inflow to this segment.

The downstream segment (3.3 miles long) is more stream-like, with a faster and more steady current. This is the segment to which this water quality improvement plan sets phosphorus targets to meet water quality standards. A small intermittent tributary enters Milford Creek approximately halfway between the headwaters and mouth, marking the divide of the stream's two segments.
Milford Creek is an altered stream system. Under natural conditions, the creek drains Lower Gar Lake and serves as the outlet for the entire chain of the Iowa Great Lakes. Water from Upper Gar, Minnewashta, East and West Okoboji, Big Spirit, and other lakes drains through Milford Creek en route to the Little Sioux River. However, a low-head control structure separates Lower Gar Lake from Milford Creek (Figure 3), and during extended dry weather, outflows from the lake may cease for months to years at a time (Figure 4) (Stenback and Crumpton, 2006).

During dry periods, streamflow in Milford Creek is sustained primarily by discharges from the Iowa Great Lakes Sanitary District (IGLSD) wastewater treatment plant (WWTP), which is located near the head of Milford Creek just below the Lower Gar Lake dam. At times, wastewater effluent can contribute over 90% of the flow to Milford Creek. Between May 26th and August 31st in 2004, wastewater effluent provided an average of 62% of the total flow detected six miles downstream (Figure 5).

Due to the consistency of wastewater discharges, base flow (flow not affected by surface runoff) in Milford Creek is stable at 2 cubic feet per second (cfs) or more throughout the summer; however, when wastewater effluent dominates streamflow, the stream can have a pronounced daily flow cycle (Figure 6). Daytime flows are higher (4-5 cfs) as municipal water users consume water, while overnight flows often drop below 3 cfs as residential water use declines.

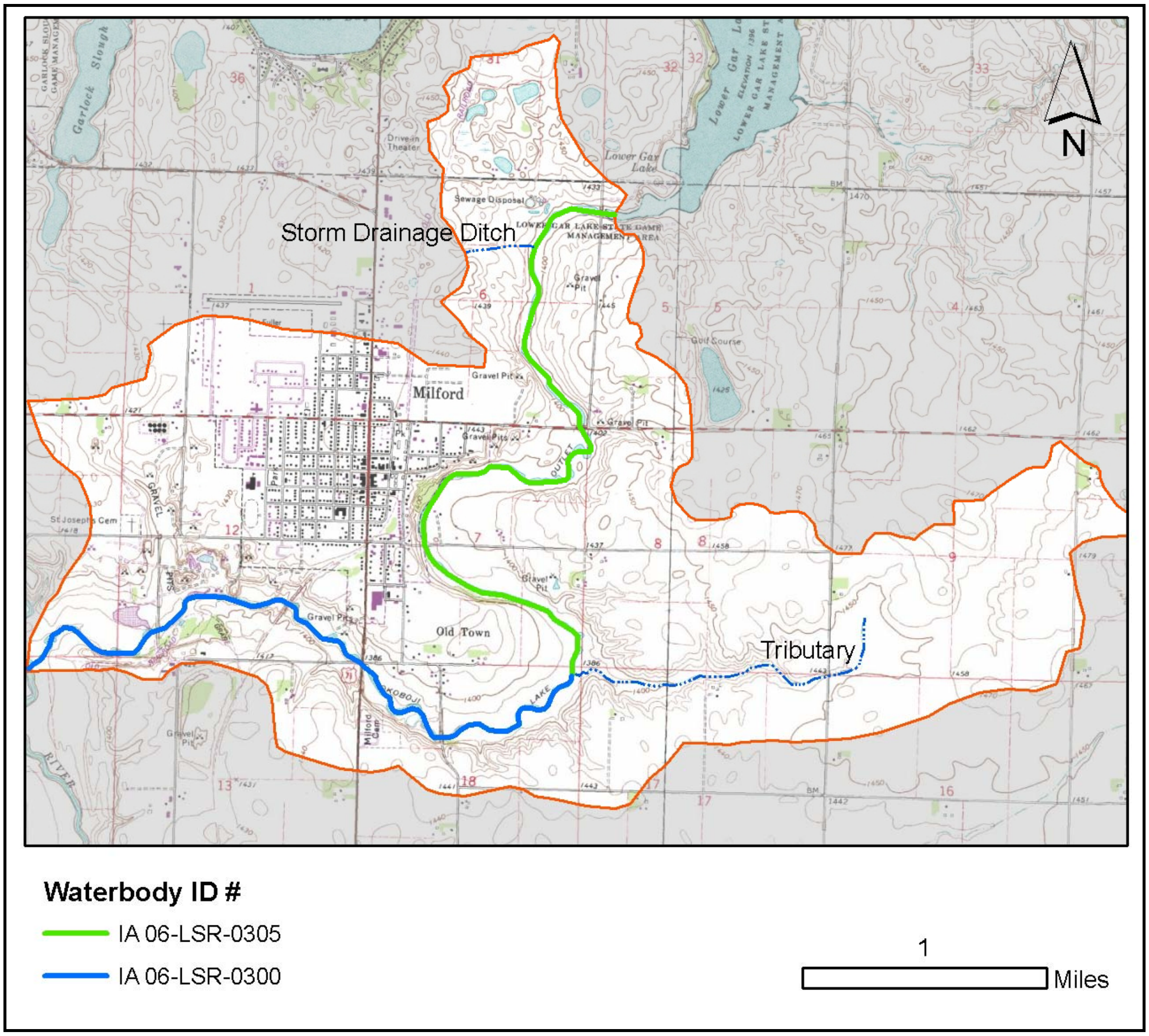

Figure 2. Segmentation of Milford Creek for Clean Water Act reporting purposes.

Figure 3. Low head dam separating Lower Gar Lake from Milford Creek (image from IDNR Use Attainability Analysis 2006).

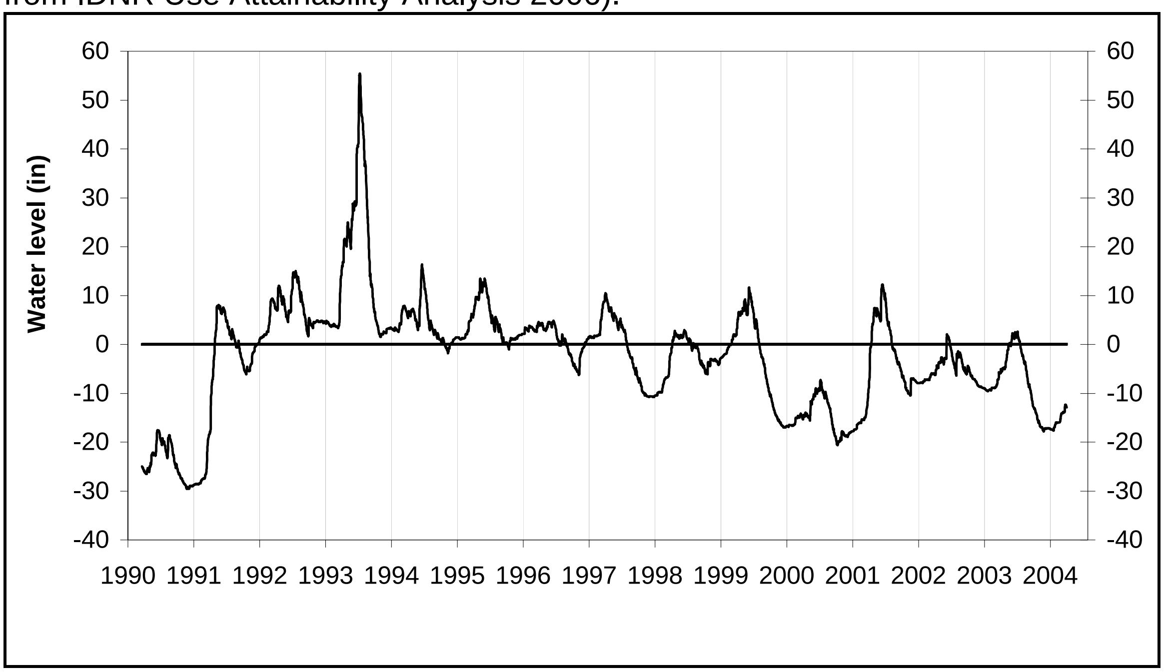

Figure 4. Water levels in West Lake Okoboji collected by IDNR. When gage height exceeds zero, water flows from Lower Gar Lake into Milford Creek.

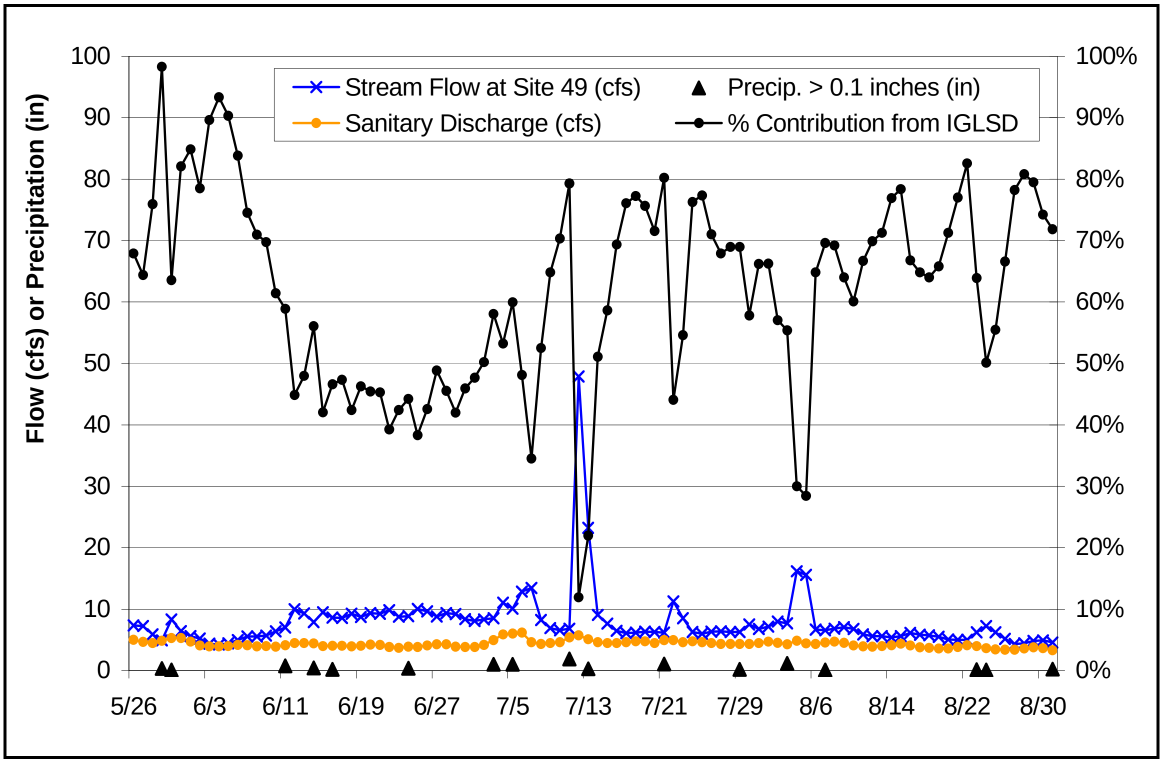

Figure 5. Flow contribution of the IGLSD to Milford Creek in summer 2004.

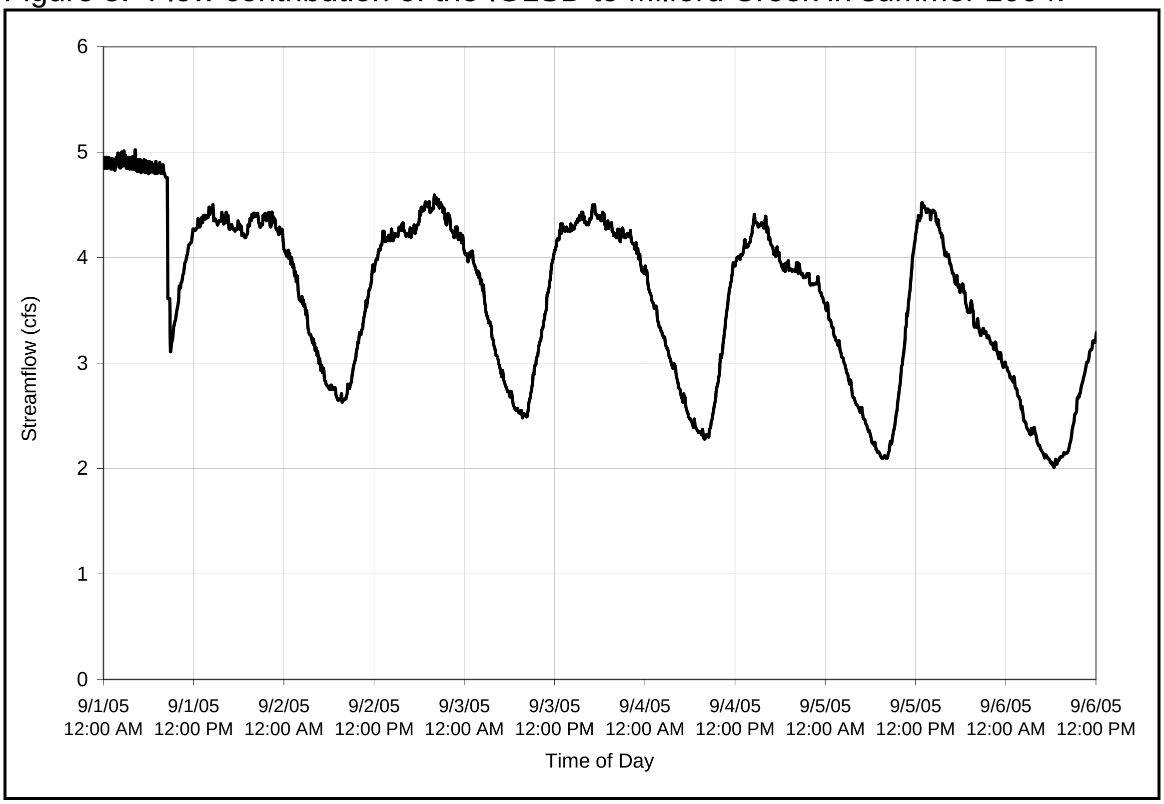

Figure 6. Continuous streamflow record from Milford Creek from 9/1/2005-9/6/2005 (Site #4). The cyclical pattern results from wastewater influence in the stream.

2.2. The Milford Creek Watershed

Milford Creek has a total watershed area of approximately 93,766 acres, shown previously in Figure 1. During dry periods, when no water is received from Lower Gar Lake, the catchment area draining directly to the stream is reduced to approximately 4,065 acres, depicted (Figures 1 and 2).

Land Use. Land use in the watershed is predominantly agricultural, with the most common crops being corn, soybeans, and hay (Table 1). Pasture and livestock production, primarily corn and hogs, are also prevalent. There is one permitted animal feeding operation (AFO) in the immediate drainage area, located near the mouth of Milford Creek.

Urban development and expansion are also prevalent in this region, due to the economic and recreational attraction provided by the Iowa Great Lakes. Human populations in the watershed vary greatly by season, due to demographic patterns and tourism.

Table 1. 2002 Land use in Milford Creek watershed (IDNR, 2004).

Land use	Entire IGL watershed		Area draining directly to Milford Creek (excluding IGL)	
	Acres	Pct.	Acres	Pct.
Row crop	45,945	49%	1,478	36%
Pasture	4,688	5%	803	20%
Grass	12,190	13%	732	18%
Urban/Developed	3,751	4%	568	14%
CRP	5,626	6%	294	7%
Timber	3,751	4%	87	2%
Hay	938	1%	81	2%
Water/Wetland	16,878	18%	22	1%
Total	**93,766**	**100%**	**4,065**	**100%**

Soils, climate, and topography. The watershed ranges from nearly level to strongly sloping (0-14%), with prairie-derived soils developed from Wisconsin till, loamy and sandy glacial outwash, and alluvium. The most common soil types in the watershed are Clarion and Nicollet on the uplands, and Wadena, Estherville, and Coland on the outwash plains and stream valleys. Average annual precipitation is 28.3 inches.

2.3. Biological Impairment

Problem statement. Lower Milford Creek is biologically impaired, which means it is not fully supporting the aquatic life that should be present in the stream. Since 1994, the Class B (aquatic life) designated uses in lower Milford Creek have been assessed by the Iowa Department of Natural Resources (IDNR) as either “partially supported” or “not supported” for 305(b) purposes. The original assessment was based on a 1990 survey showing low habitat diversity and fish populations in the stream. A stream use assessment done later in October of 1995 found that the fish community lacked several of the expected species/genera for Class B(LR) streams in the same ecoregion.

In 2001, biological and chemical monitoring was done in support of TMDL development at two sites on Milford Creek (shown in Figure 7). Results of this monitoring documented the stream's chronically impacted biological community as well as water chemistry problems ("extremely high levels of total phosphorus…and potential problems with organic enrichment"). Since then, lower Milford Creek has remained on Iowa's impaired waters list for each successive 305(b) cycle.

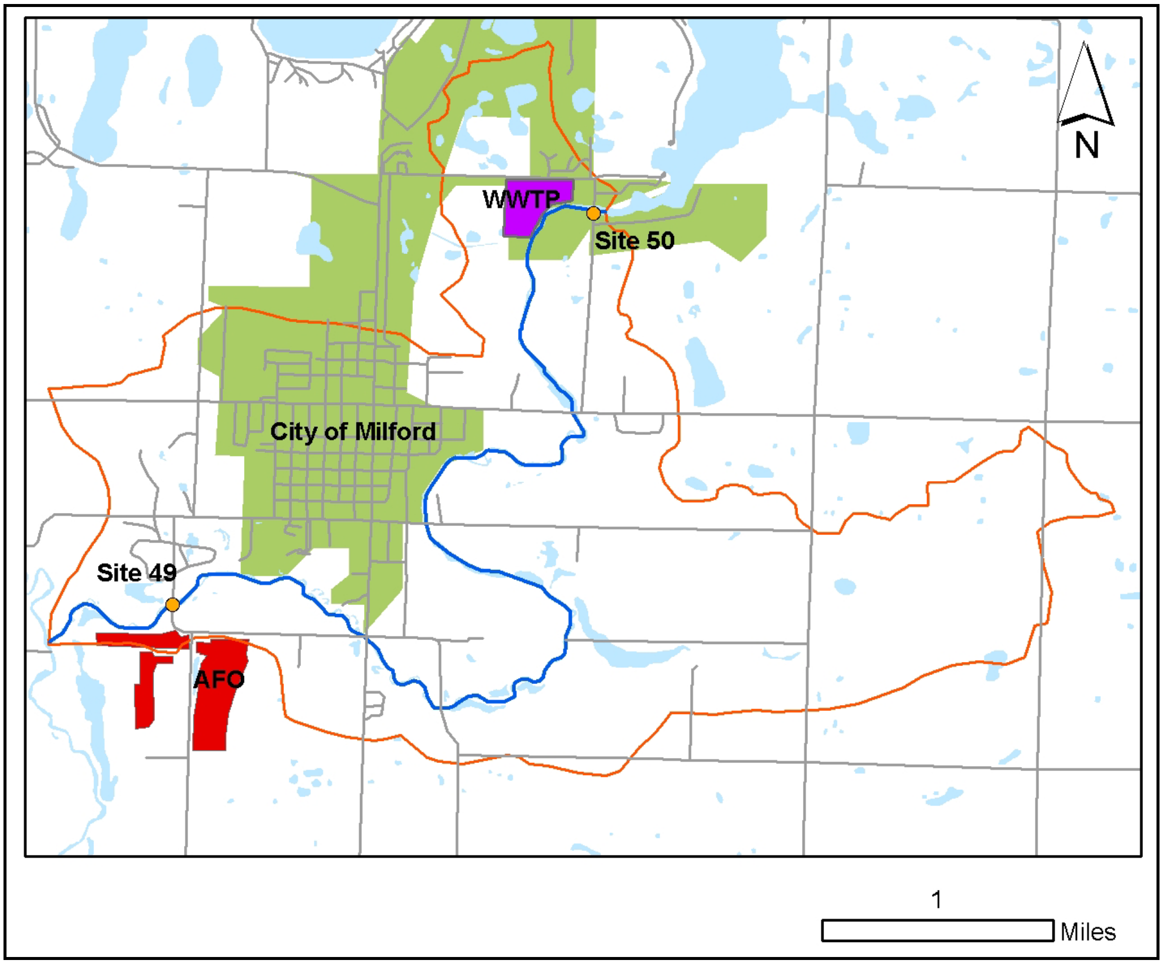

Figure 7. 2001 monitoring sites in Milford Creek.

Bioassessments and the Index of Biotic Integrity (IBI). Stream biological assessments incorporate benthic macroinvertebrate sampling, fish sampling, and habitat descriptions to identify and quantify aquatic life impairments in warmwater streams. Biological data are summarized numerically into a Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) and a Fish Index of Biotic Integrity (FIBI). The FIBI and BMIBI combine several quantitative metrics to provide a broad assessment of the stream on a scale from 0 to 100. A report on the Iowa bioassessment monitoring program is available online at www.iowadnr.gov (Wilton, 2004).

Table 2 shows the FIBI and BMIBI scores measured in Milford Creek in 2001 and the Biological Impairment Criteria (BIC) used to determine aquatic life use impairments in

Class B streams in Iowa. The BIC are determined using a reference stream approach, in which the 25th percentile of data collected at stream ecoregion reference sites from 1994-2004 serves as the impairment criterion. In Milford Creek, the BMIBI score of 44 is well below the BIC of 62, while the FIBI score ranks slightly better (50), it still falls short of the riffle stream BIC.

IBI scores from lower Milford Creek effectively characterize the stream's biological impairment. This segment compares well to the type of waterbodies used to develop reference stream BIC, and the low BMIBI and FIBI scores adequately reflect the stream's biological condition. Thus, the lower segment was given a "not supporting" assessment of Class B uses in the most recent 305(b) assessment to indicate a higher degree of confidence.

Table 2. 2001 FIBI and BMIBI scores in Milford Creek compared to Des Moines Lobe (Ecoregion 47(b)) reference conditions.

Index	Site 49 (downstream)	Ecoregion 47(b) Biological Impairment Criteria
BMIBI	44	62
FIBI (riffle)	50	53
FIBI (non-riffle)	Not applicable	32

Stressor Identification. In order to determine the cause of the biological impairment in lower Milford Creek, the DNR followed the protocol outlined in the EPA Stressor Identification Guidance document (USEPA, 2000). The Stressor Identification (SI) is a process used to relate biological impairments to one or more specific causal agents and to separate water quality impacts from habitat impacts. The full SI document is included in the appendix of this report (IDNR, 2004b).

On page 13 of the Milford Creek SI, it is stated:

> *"Milford Creek is primarily impaired by degraded water quality and secondarily by habitat alterations. The main water quality problem is nutrient enrichment which is allowing excessive growth of plants and algae which are depleting dissolved oxygen supplies at night. Flow alteration and silt/sediment deposition also contribute to the biological impairment.*
>
> *For the purposes of TMDL development, the cause of impairment is low dissolved oxygen and excess aquatic plant and algal growth caused by excess nutrients and high BOD."*

Physical observations of Milford Creek lend support to the notion that excessive macrophyte and algal growth exist in the stream, as documented by many photos (shown previously and in Appendix E). This abundant algae and plant growth leads to the extreme fluctuations of dissolved oxygen in the stream from daytime to nighttime, which is recorded using continuously operating data loggers. Data from one of these samplers is shown in Figure 8. Such drastic changes in stream oxygen levels stress aquatic life, and the nighttime lows are sufficient to violate state water quality standards and cause fish kills such as the two shown in Appendix D.

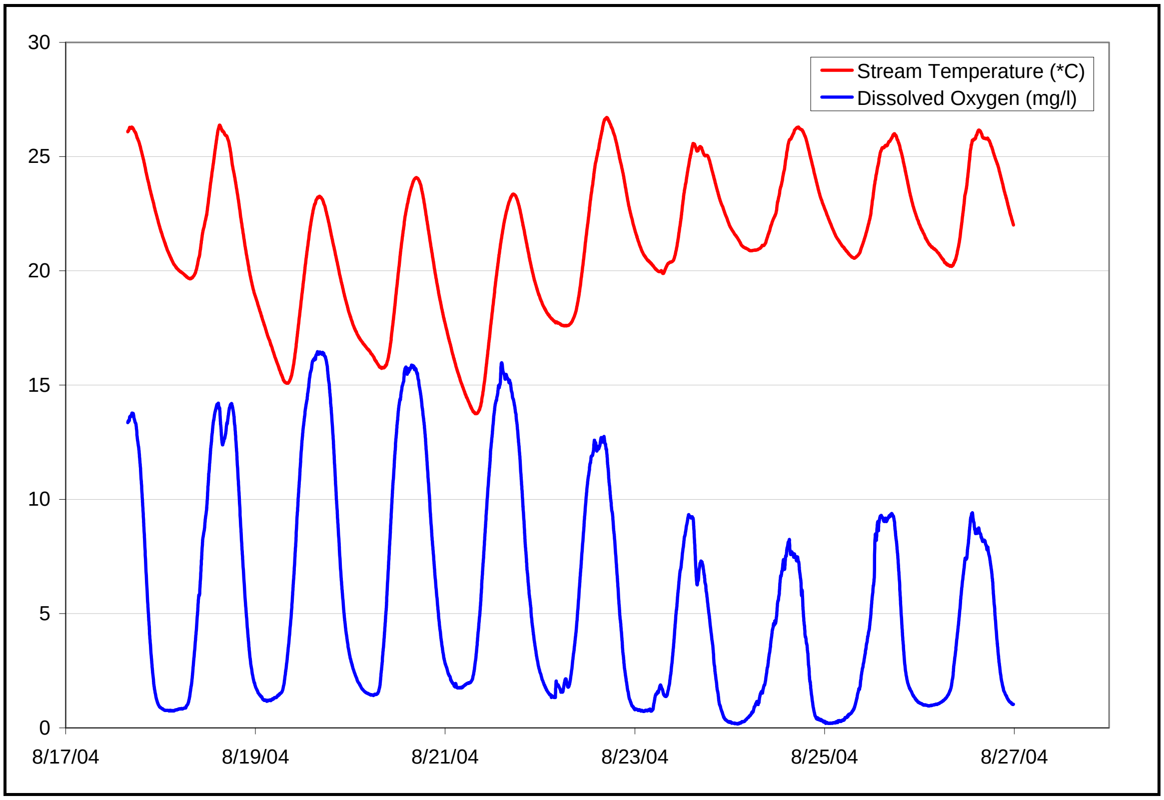

Figure 8. Continuous autosampler data collected at Site #49 during low streamflow period (no flow over Lower Gar dam).

The excessive plant and algal growth in Milford Creek can be attributed to a combination of nutrient enrichment and physical water conditions. During wet/cool periods, or when flow is being received from Lower Gar Lake, dissolved oxygen levels in Milford Creek may be generally sufficient to the support aquatic life uses (Figure 9). However, hot and dry periods provide ideal conditions for abundant plant & algae growth and the extreme dissolved oxygen fluctuations seen in Figure 8.

To define the critical nutrient targets for lower Milford Creek, the Qual2K stream model was used to establish a mechanistic linkage between nutrients in the stream, algal growth, and dissolved oxygen levels. Based on this modeling, phosphorus was determined to be the primary limiting nutrient which controls algae growth in Milford Creek---reductions in nitrate+nitrite and ammonia did not significantly affect stream dissolved oxygen levels under critical environmental conditions. Therefore, this TMDL focuses on lowering phosphorus levels in the stream to control the excessive algae, improve dissolved oxygen levels (to comply with water quality standards), and increase biotic integrity index scores.

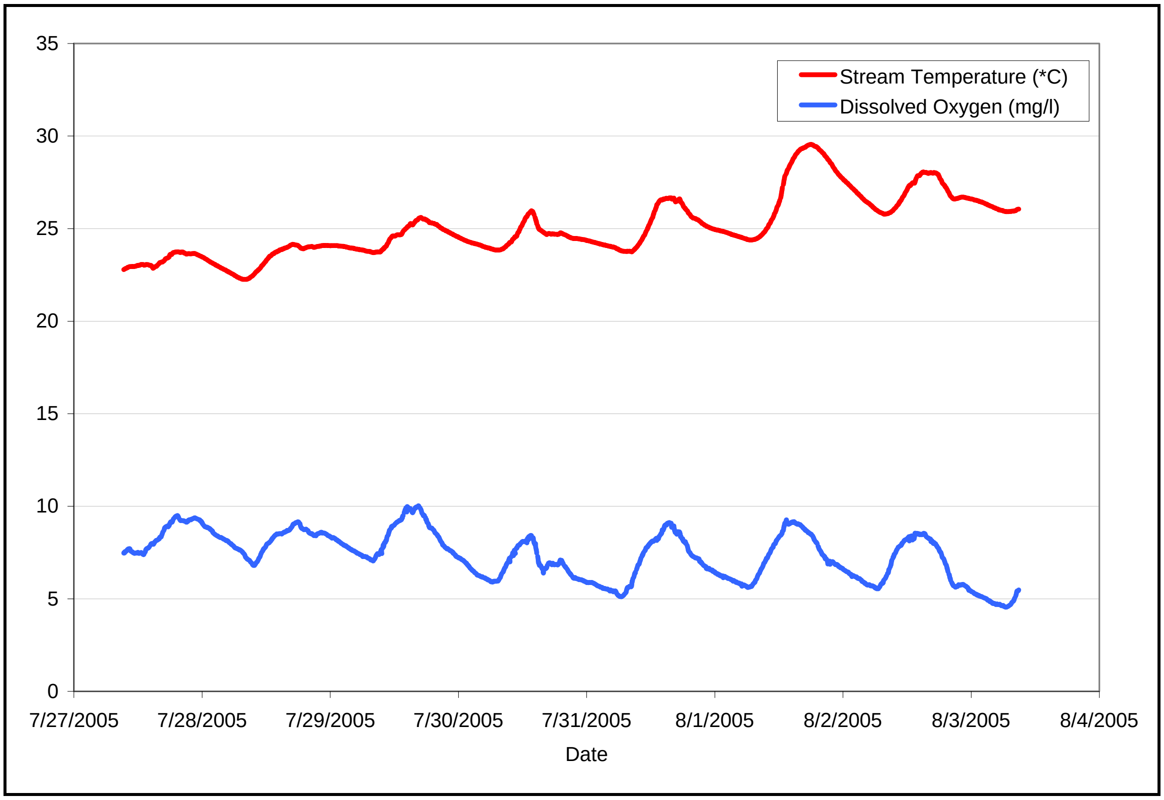

Figure 9. Continuous autosampler data collected at Site #50 during high streamflow period (flow over Lower Gar dam).

3. Total Maximum Daily Load (TMDL) for Phosphorus

A Total Maximum Daily Load (TMDL) is required for Milford Creek by the Federal Clean Water Act. This chapter will quantify the maximum amount of phosphorous that lower Milford Creek can tolerate in order to meet the state's water quality standards for dissolved oxygen.

3.1. Problem Identification

Applicable water quality standards. The State of Iowa does not have numeric criteria for phosphorus in streams or lakes. Rather, state water quality standards protect aquatic life in all Class B streams by giving numeric dissolved oxygen criteria. Milford Creek is currently designated as a Class B(WW-2) in the downstream segment (IAC, 2006).

For Class B(WW-2) streams, Iowa water quality standards state that dissolved oxygen must be no less than 5.0 mg/l dissolved oxygen for at least 16 hours out of every 24-hour period, and never less than 4.0 mg/l dissolved oxygen.

Data sources. Biological assessment data was collected at two sites (#49 and #50) in 2001. Water chemistry data was collected monthly at the same two sites from March through November of 2001. Additional samples were collected in May and June of 2002 at Site 50 and June through August at Site 49 in 2004. In 2005, at the request of local stakeholders, an additional round of monitoring was conducted in the stream to better understand and characterize the pollutant sources. This included adding five new water chemistry monitoring sites (Figure 10), automatic samplers to measure continuous dissolved oxygen, temperature, and flow, and a time-of-travel study using tracer dyes.

Point source effluent data was provided by the Iowa Great Lakes Sanitary District wastewater treatment facility. This data included average and maximum daily flows (1998-present), hourly flows from 8/29/05-9/15/05, monthly discharge monitoring reports for CBOD5, ammonia nitrogen, pH, temperature, toxicity, total suspended solids (1991-present), and weekly effluent total and dissolved phosphorus concentrations from 2/23/05 to 6/20/06.

To quantify pollutant loading from Lower Gar Lake and the rest of the Iowa Great Lakes to Milford Creek, information from a 2006 Iowa State University study was utilized (Stenback and Crumpton, 2006). This study established a mass-balance budget for water and total phosphorus in the Iowa Great Lakes system, which included estimating exports to Milford Creek during the years 1999-2005. A supplemental study was also performed to estimate long term loadings from the IGLSD WWTP (summary in Appendix E).

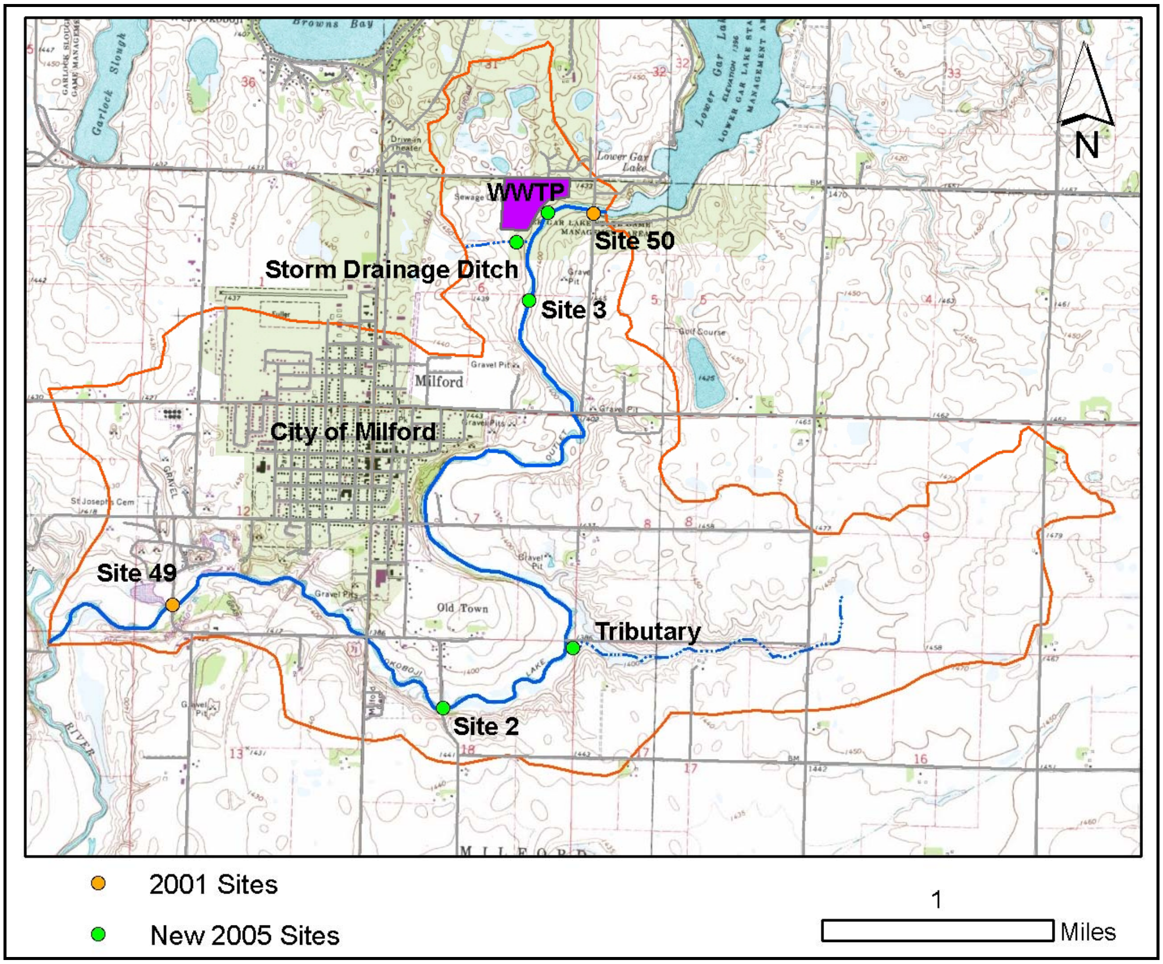

Figure 10. Location of 2005 monitoring sites in Milford Creek.

Interpreting Milford Creek data. Total phosphorus concentrations in Milford Creek are unusually high. The maximum concentration measured in the stream occurred on August 30, 2005 (Site 3) and was 3.6 mg/l or 3600 µg/l. The median total phosphorus concentration during 2001-2005 sampling was 1.1 mg/l or 1100 µg/l. For comparison, the United States EPA recommends a maximum concentration of 0.118 mg/l or 118 µg/l total phosphorus in the Western Corn Belt Plains Ecoregion and 0.076 mg/l or 76 µg/l in the Corn Belt and Northern Great Plains Ecoregion to control nuisance algae growth in streams and rivers (USEPA, 2000).

In general, phosphorus levels are lower at the upstream site and higher at the downstream site. Figure 11 shows the boxplots for all total phosphorus data measured at four locations along the stream from 2001-2005, moving from upstream (Site 50) to downstream (Site 49). Between Sites 50 and 3, two sources of flow enter the stream: the IGLSD wastewater treatment plant and a small rural drainage ditch. Wastewater inputs, high in phosphorus content, cause a significant increase in downstream water column concentrations. This is also evident in Figure 12 which shows concentrations measured at four different sites on the same day for different sampling periods.

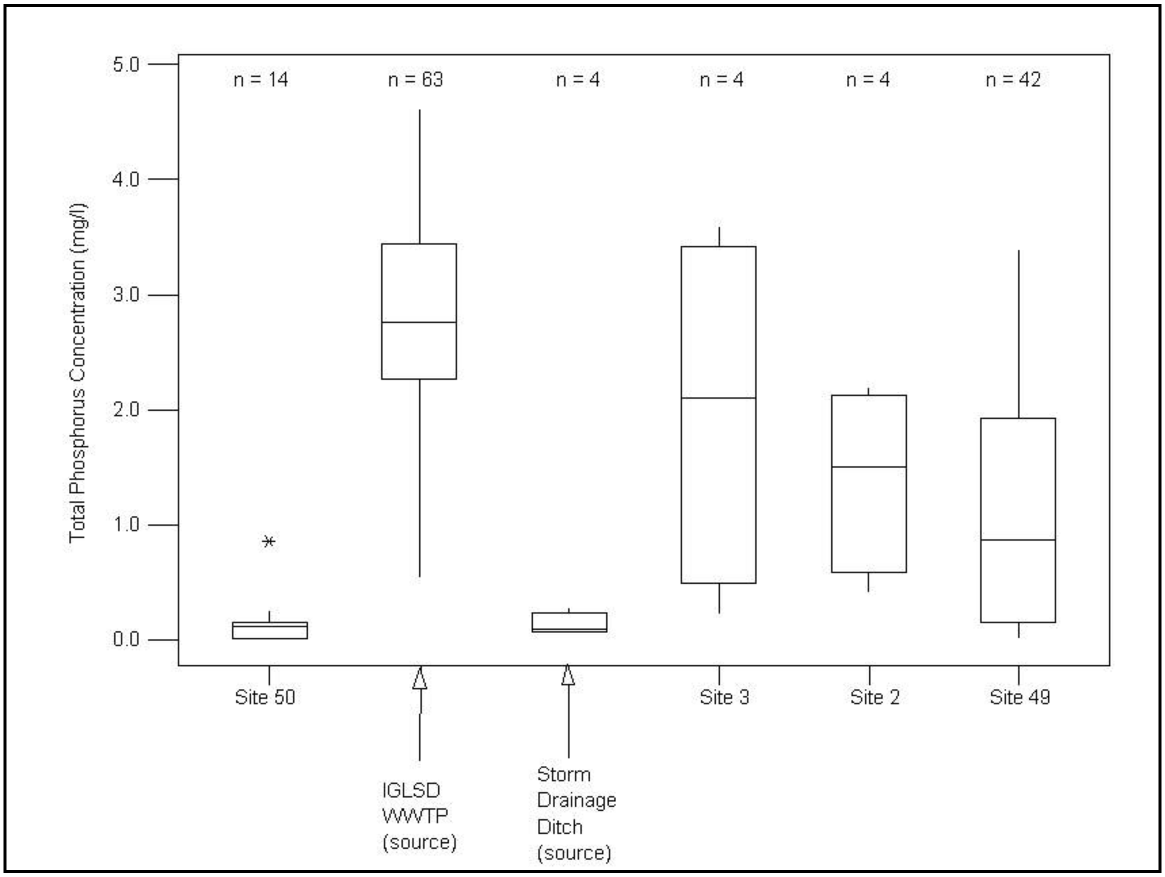

Figure 11. Total phosphorus boxplots from upstream (left) to downstream (right), including data collected at two surface water inflows.

Temporally, total phosphorus concentrations are highest in the stream in late summer and early fall, when the stream is dominated by wastewater. This contrasts with many streams and rivers in Iowa where nutrient loading is driven primarily by nonpoint source runoff. Figure 13 shows the monthly total phosphorus boxplots in Milford Creek.

Measured levels of chlorophyll indicate high plant and algal growth in Milford Creek. In August 2004 at site 49, chlorophyll a concentrations were 72 µg/l in the water column, 130 µg/cm^2 in the periphyton, and 38 µg/cm^2 in the sediment. Observations and photos taken of the stream also document high levels of aquatic plant growth and are included in Appendix D.

Dissolved oxygen measurements taken over several two-week periods using automatic samplers show that oxygen levels fluctuate widely over each 24-hour period, with nighttime concentrations often dipping below 2 mg/l for four to twelve hours at a time. During low flow/late summer periods, these violations occur throughout the length of the stream and is documented at all monitoring sites.

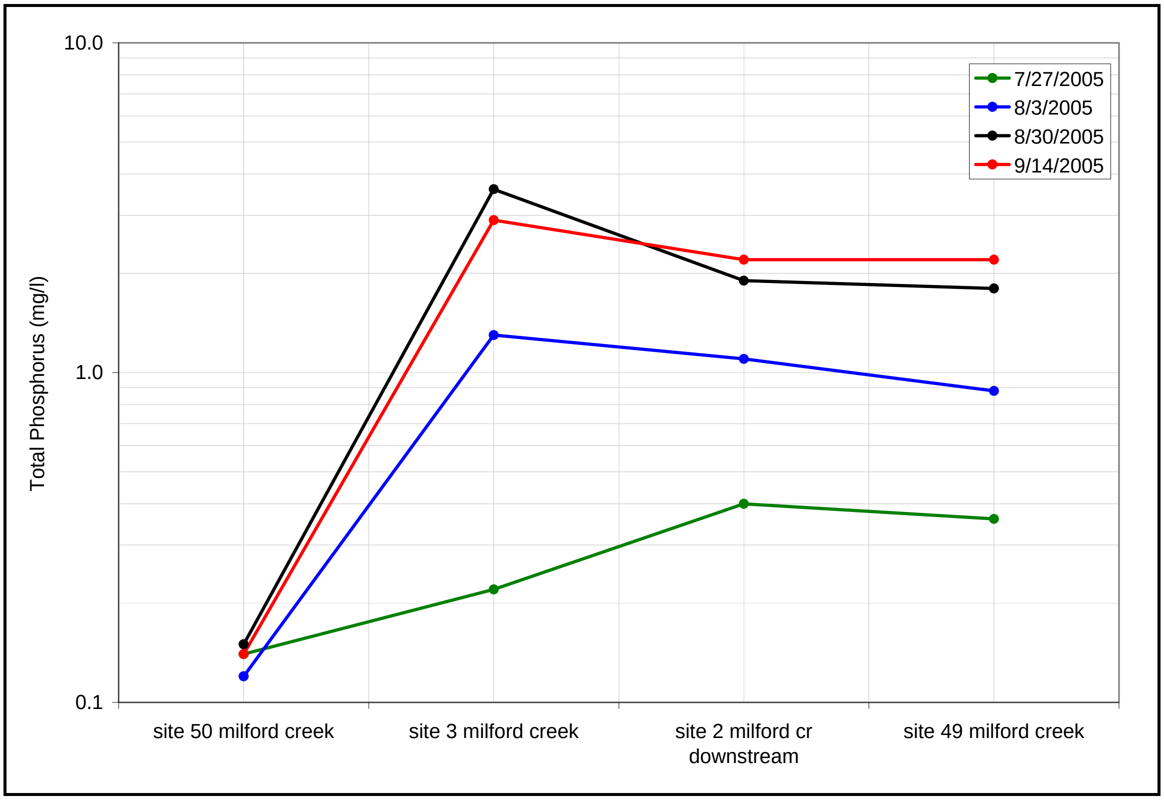

Figure 12. Total phosphorus measurements taken at multiple sites along the stream for four different dates in 2005.

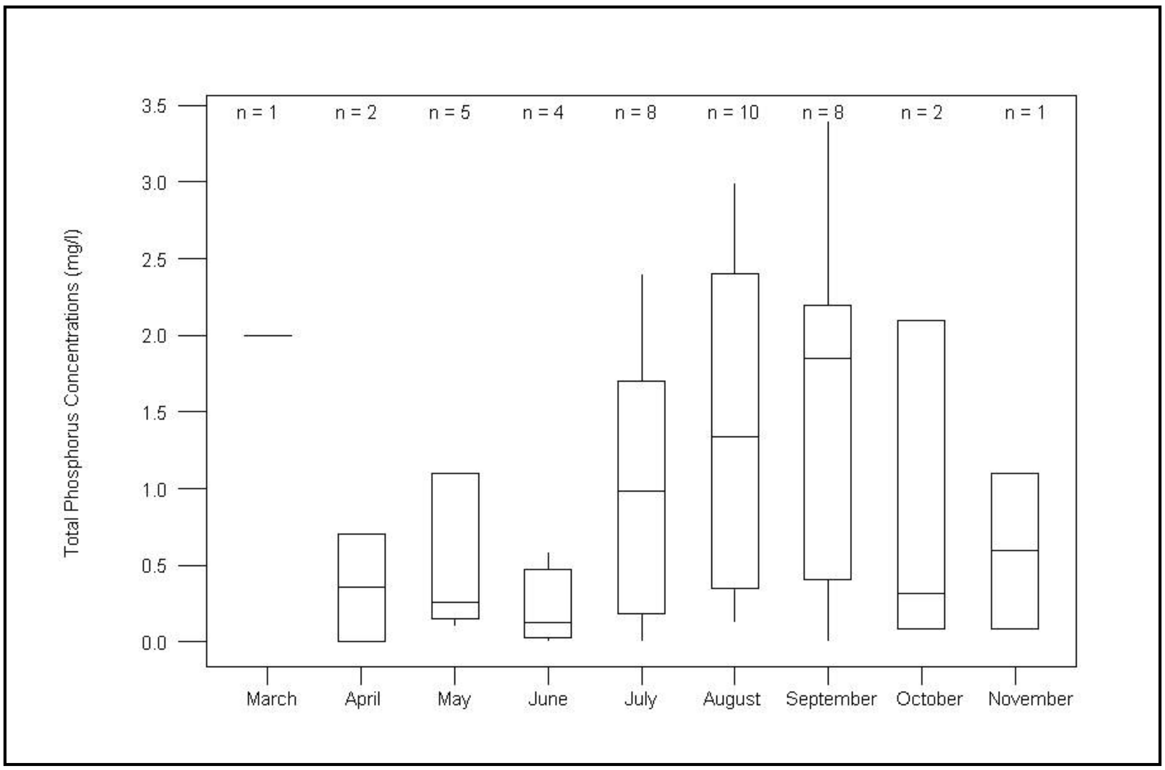

Figure 13. Total phosphorus boxplots by month (all sites combined).

3.2. TMDL Target

General description of the pollutant. Phosphorus is widely recognized as a primary limiting nutrient for plant growth in freshwater aquatic systems (Kalff, 2002). Under normal conditions, phosphorus is scarce in the environment (USEPA, 1999). Naturally-occurring phosphorus exists in rocks and natural phosphorus deposits in the earth's crust and is released by the processes of weathering, leaching, erosion, and mining. Anthropogenic inputs of phosphorus to aquatic ecosystems include synthetic plant fertilizers and waste materials from industrial, sanitary, and livestock production systems. Phosphorus reaches waterbodies via atmospheric deposition, direct discharge, surface runoff, and erosion (particulate matter/sediment-attached). In freshwater systems, phosphorus exists in either organic or inorganic forms (USEPA, 1999).

Selection of environmental conditions. A TMDL must be designed so that state water quality standards are being met at all times, and especially during critical environmental conditions. The critical environmental conditions in lower Milford Creek occur during sustained warm and dry periods, when no flow is contributed from Lower Gar Lake and conditions are ideal for plant & algal growth. High temperatures reduce the saturation point for dissolved oxygen and create a stressful environment for aquatic life, while reduced streamflow and water velocity allow algae blooms to occur and drive dissolved oxygen levels to extreme levels during the day and below state water quality standards at night. Such conditions occur during the summer months, especially in the months of July, August, and September. To ensure an adequate margin of safety, critical conditions for Milford Creek are deemed to occur between the months of June and October.

Waterbody pollutant loading capacity (TMDL). This TMDL was designed as a steady-state or critical condition loading capacity. It defines the maximum amount of total phosphorus that the targeted segment can assimilate under critical environmental conditions and still meet state water quality standards for dissolved oxygen. Under low streamflow conditions, the maximum loading capacity is 7.0 lbs/day total phosphorus. However, under higher streamflow conditions the stream is able to assimilate higher phosphorus loads; thus, the load capacity varies with flow. At peak streamflow, the total maximum daily load is 1,607.4 lbs/day. Appendix C provides information on how these load capacities were determined.

Chronic/long term nutrient enrichment also contributes to the plant growth and algae problems in Milford Creek, since phosphorus is constantly recycled between the water column and various storage sinks such as benthic sediment, vegetation, and organic matter. Therefore, a long term waterbody loading capacity is also provided. The long term total phosphorus loading capacity for Milford Creek is estimated to be 9,221 lbs/year on an average basis.

Decision criteria for water quality standards attainment. The criterion to be used for determining attainment of water quality standards is the numeric criteria for dissolved oxygen as defined in Chapter 61[567], Table 2 of the Iowa Administrative Code (IAC, 2006). This standard is described in Section 3.1 of this report. Index of Biotic Integrity

IBI scores for fish and benthic macroinvertebrates in the downstream segment of Milford Creek are also to be used for assessing compliance for 305(b) reporting purposes.

3.3. Pollution Source Assessment

Potential pollutant sources. Nonpoint sources of phosphorus in the Milford Creek watershed include overland surface runoff from urban and agricultural areas (carrying dissolved and sediment-attached phosphorus), discharges from Lower Gar Lake during wet periods, and atmospheric deposition directly onto the water surface.

Point sources of phosphorus in the Milford Creek watershed include two facilities registered under the National Pollutant Discharge Elimination System: the Iowa Great Lakes Sanitary District wastewater treatment plant and Derner's of Milford animal feeding operation (AFO). The locations of these point sources can be seen in Figure 7 (shown previously), with permit details in Table 3.

Table 3. NPDES permits in the Milford Creek watershed.

Name	Permit Type	NPDES #	EPA #	Description
Iowa Great Lakes Sanitary District WWTP	Municipal	30500901	IA0059765	Rotating biological contactor undergoing upgrade to activated sludge
Derner's of Milford AFO	Agricultural	3000010	IA0077593	4000-head beef cattle 80-acre open feedlot

Existing loading. Milford Creek carries high phosphorus loads on a regular basis. Measurements taken in the stream during 2001, 2002, 2004, and 2005 sampling show calculated total phosphorus loads ranging from less than 2 lbs/day at the upstream monitoring site up to nearly 200 lbs/day at the downstream monitoring site (n = 34). The median total phosphorus load during sampling periods was 15.1 lbs/day at the upstream site and 90.6 lbs/day at the downstream site.

Based on monitoring data and modeled estimates, the majority of phosphorus in Milford Creek is contributed by point source wastewater inputs. This is especially true in dry years when no lake water is received from Lower Gar Lake. Figures 14 and 15 show the estimated phosphorus contributions to Milford Creek during two alternative years, 2003 and 2004. 2003 was a rather dry year, with just 20.4 inches of total rainfall (18^{th} percentile for 55 years of data) (IEM, 2007). During that year, phosphorus from wastewater inputs made up 93% of the total annual load in Milford Creek, with the remaining 7% coming from nonpoint source runoff in the immediate drainage area.

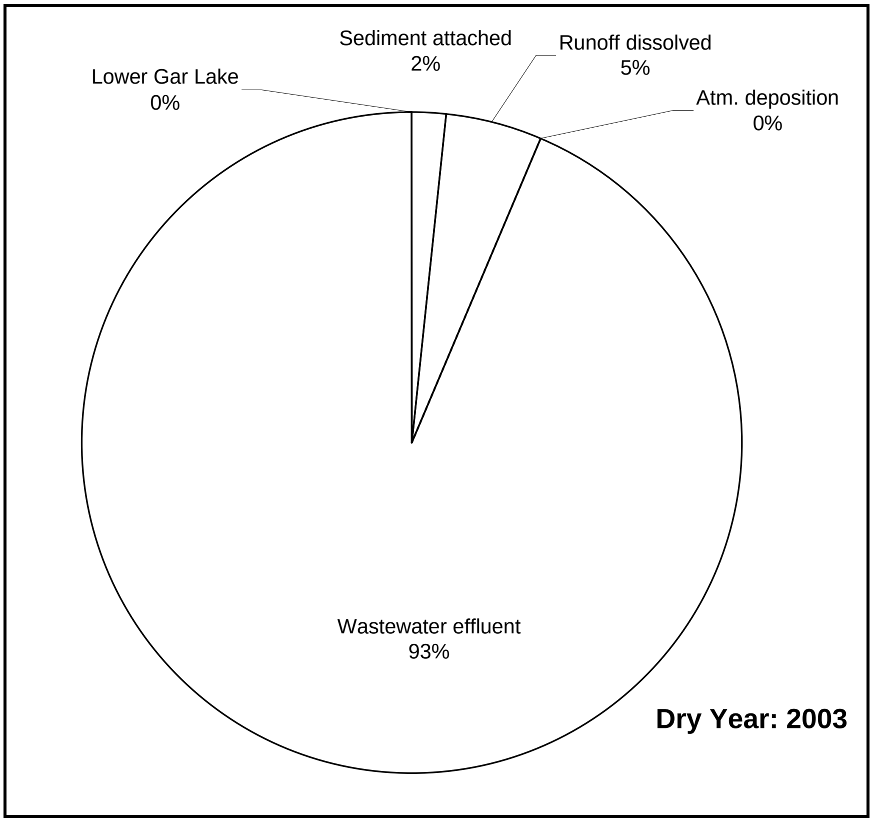

Figure 14. Estimated phosphorus loading by source in 2003.

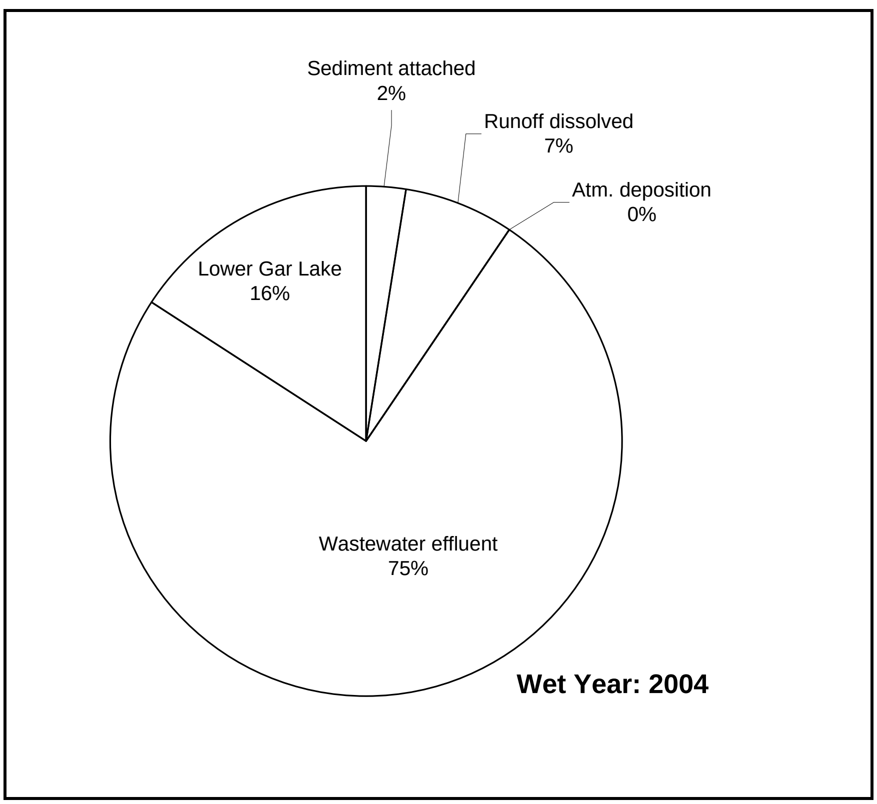

Figure 15. Estimated phosphorus loading by source in 2004.

In 2004, however, 37.7 inches of rain fell in Milford, Iowa (95th percentile of 55 years of data) (IEM, 2007). During this year, exports of phosphorus to Milford Creek from Lower Gar Lake contributed 16% of the total annual phosphorus budget, but point source wastewater still made up 75% of the total inputs. Appendices C and E contain information on the methods and assumptions used in estimating existing phosphorus loads for this TMDL.

Based on the study results from Stenback and Crumpton (2006), phosphorus loading from the wastewater treatment plant is relatively constant from year to year, but varies seasonally according to tourism and climate in the Iowa Great Lakes region. Phosphorus loading is affected by the fluctuating human population, being highest in the summer months and lowest in the winter months, while concentrations are influenced by rainwater infiltration and inflow (I&I) into the sewer system. The combination of dry weather (low I&I) and a greater population equivalent explains why both phosphorus concentration and loading from the WWTP are greatest in the summer months, particularly in late summer when critical environmental conditions also occur in the stream (Figures 16 and 17). Overall, the total phosphorus output from the IGLSD WWTP averages 66.2 lbs/day, with highs in summer time reaching 91.8 lbs/day.

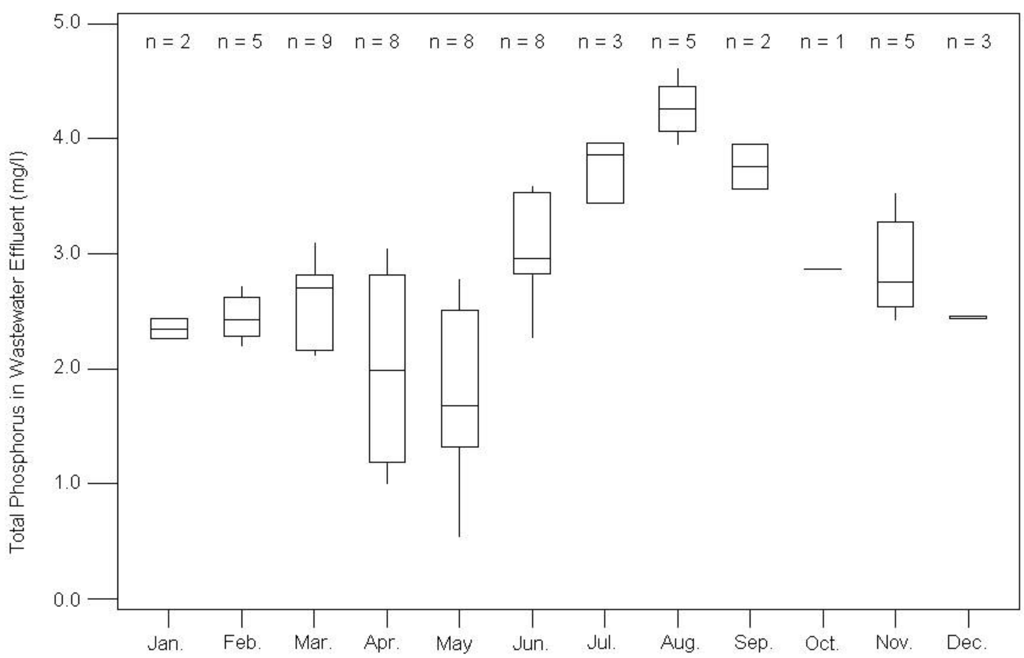

Figure 16. Monthly boxplots of total phosphorus measured in IGLSD WWTP effluent.

Departure from load capacity. During critical environmental conditions, phosphorus loads in Milford Creek are as high as 91.8 lbs/day. The Total Maximum Daily Load for lower Milford Creek to attain water quality standards under these same conditions is 7 lbs/day total phosphorus. This would necessitate a 92.5% reduction in total phosphorus loading during dry period flows.

Allowance for increases in pollutant loads. The IGLSD wastewater treatment plant is currently constructing a new, upgraded facility. There are also significant efforts underway in the upper Iowa Great Lakes watershed to use stormwater best management practices and low-impact development in existing and expanding urban areas. Therefore, a future allowance for potential increases in phosphorus loading was deemed not necessary for this TMDL.

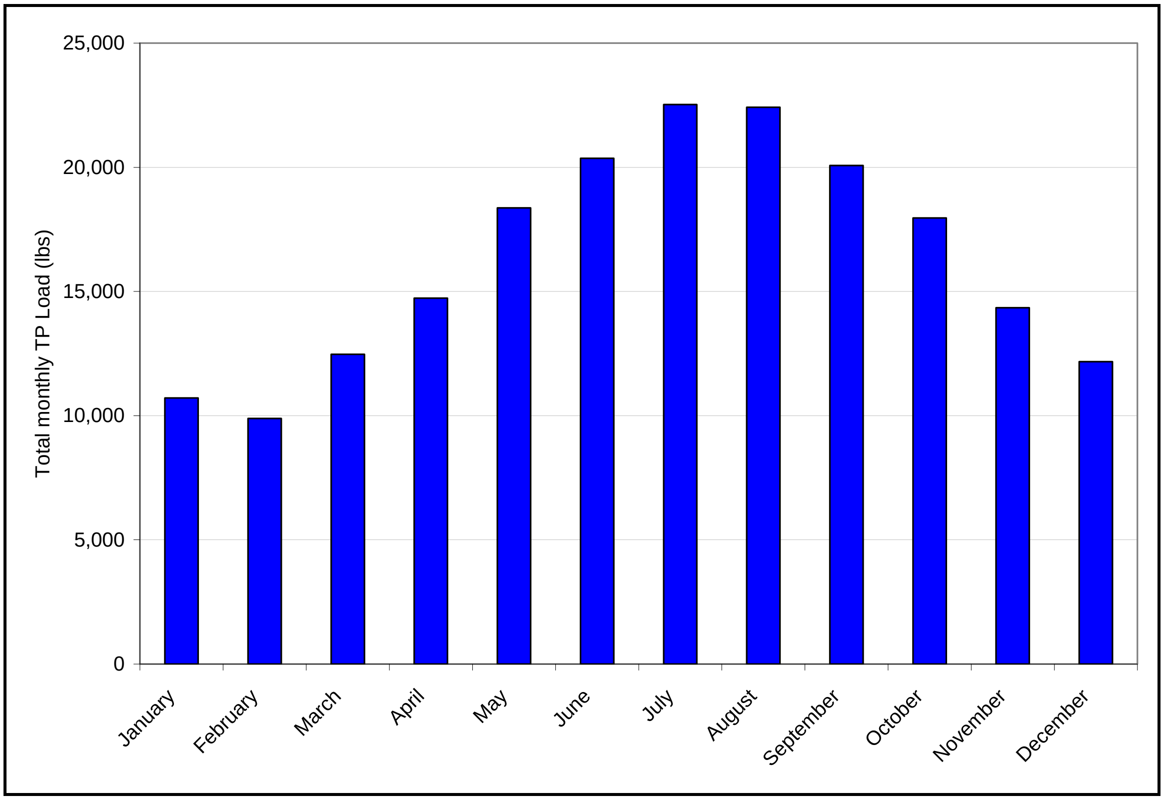

Figure 17. Modeled total phosphorus loading from IGLSD WWTP by month.

3.4. Pollutant Allocation

Wasteload allocation. The wasteload allocation (WLA) represents the fraction of the total allowable pollutant load that can be attributed to permitted point sources. In this TMDL, it was determined using the Qual2K stream model under critical environmental conditions. During low streamflow periods, the wasteload allocation for total phosphorus is 6.9 lbs/day.

This WLA is based on meeting a target concentration in wastewater (0.5 mg/l TP), thus loads will vary depending on flow conditions. Under high flow conditions, the total phosphorus wasteload would be 42.8 lbs/day (Table 4). Stream modeling to determine this WLA was done using existing permit limits for CBOD5, ammonia, and other parameters under the assumption that those pollutants will remain constant in future permit issuances, with no reductions being necessary.

Table 4. Total phosphorus wasteload allocation for the Iowa Great Lakes Sanitary District WWTP.

Name	Max. Total Phosphorus Concentration	Min. Critical Conditions Flow (MGD) and TP WLA (lbs/day)	ADW Flow† (MGD) and TP WLA (lbs/day)	AWW Flow† (MGD) and TP WLA (lbs/day)	MWW Flow† (MGD) and TP WLA (lbs/day)
IGLSD WWTP	0.5 mg/l or 500 µg/l	1.645 MGD 6.9 lbs/day	2.22 MGD 9.3 lbs/day	5.17 MGD 21.6 lbs/day	10.26 MGD 42.8 lbs/day

†Design flows for new activated sludge plant construction permit. ADW = Average dry weather; AWW = Average wet weather; MWW = Max wet weather.

Permitted animal feeding operations are not allowed to discharge to surface waterbodies; rather, NPDES regulations require that they employ practices such as runoff holding ponds to retain event-driven pollutants on site. Derner's of Milford employs both a runoff holding pond and solids settling diversion to capture and infiltrate stormwater runoff. Therefore, it receives a wasteload allocation of zero.

Load allocation. The load allocation (LA) represents the fraction of the total allowable pollutant load attributed to nonpoint sources. Under low streamflow conditions, the total phosphorus load allocation is 0.1 lbs/day, including background loading from atmospheric deposition. This value was derived using monitored data from the drainage ditch and tributary which feed Milford Creek, both of which barely flow and contain little phosphorus during dry weather periods.

Under high flows, nonpoint source phosphorus loads may dominate over point source loads. Peak flows received from Lower Gar Lake and runoff from the immediate watershed may exceed 600 cfs (Stenback and Crumpton, 2006 and Appendix C). Under these conditions, the maximum load allocation for nonpoint sources is 1,564.6 lbs/day.

The long term nonpoint source load allocation is set at 2,813 lbs/year (on average). This value was set based on reducing nonpoint source loading to a level that is equivalent to the reductions called for in the 2003 Lower Gar Lake TMDL report, i.e. a 50% reduction in phosphorus loading.

Margin of safety. The margin of safety (MOS) for this TMDL is implicit based on conservative assumptions applied in modeling to define the allowable pollutant loading. By establishing the TMDL and WLA using a concentration-based target at critical environmental conditions, it is ensured that water quality standards will be met at all other times of the year when receiving flows are higher and conditions are less suitable for algal response to dissolved phosphorus loads.

3.5. Reasonable Assurance

When a TMDL is developed for waters impaired by both point and nonpoint sources, and the WLA is based on an assumption that nonpoint source load reductions will occur, EPA's 1991 TMDL Guidance states that the TMDL should provide reasonable assurances that nonpoint source control measures will achieve expected load reductions. Based on modeling for this TMDL, reductions in total phosphorus loading from the IGLSD wastewater treatment plant can allow the lower segment of Milford Creek to meet and maintain numeric criteria for dissolved oxygen.

The 2003 TMDL for Lower Gar Lake outlines a plan to reduce phosphorus loading and achieve water quality standards in that lake, which would in turn help water quality in Milford Creek (IDNR, 2003). In 2006, encouraged by additional state funding for lake restoration, 127 of Iowa’s principal public lakes were ranked for lake restoration suitability based upon a number of socio-economic, water quality, watershed factors. The ranking process resulted in a priority list of thirty-five lakes; Lower Gar Lake is included in this list. Reduction of the phosphorus load from Lower Gar Lake is critical, as it is the dominant nonpoint source to Milford Creek. Additionally, in recent years there have been substantial efforts in the Iowa Great Lakes region to improve and protect water quality, educate landowners and citizens about water quality issues, and reduce nutrient delivery to the lakes. Innovative stormwater management and low impact development, extensive water monitoring, and numerous activist groups provide evidence of the region’s devotion to enhancing and protecting their water resources. Technical and financial assistance available from the IDNR Watershed Improvement Section and IDALS Division of Soil Conservation provide the economic potential for local groups to achieve the load reductions called for in this report.

3.6. TMDL Summary

The following equation represents the Total Maximum Daily Load (TMDL) and its components for total phosphorus in Milford Creek:

TMDL = Point source WLA + Nonpoint source LA + Margin of Safety

Under critical environmental conditions,

7.0 lbs/day = 6.9 lbs/day + 0.1 lbs/day + Implicit MOS

Under high flows,

1,607.4 lbs/day = 42.8 lbs/day + 1,564.6 lbs/day + Implicit MOS

On a long term average basis,

9,221 lbs/year = 6,408 lbs/year + 2,813 lbs/year + Implicit MOS

4. Implementation Plan

This implementation plan is not a requirement of the Federal Clean Water Act. However, the Iowa Department of Natural Resources recognizes that technical guidance and support are critical to achieving the goals outlined in this TMDL. The plan may be useful to local professionals, watershed managers, and citizens for decision-making support and planning purposes.

4.1. General Approach

Removing the impairment from Milford Creek will take extensive effort and cooperation by multiple stakeholders. Reductions in phosphorus loading to the stream will generate immediate benefits in the downstream segment, but may take time in the upper portion as bed and bank storage sinks are gradually depleted through nonpoint source reductions. A combination of strategic management actions can, with time, help restore Milford Creek to a healthy ecosystem able to support diverse aquatic life.

Improving water quality conditions in the upstream segment of Milford Creek is problematic due to its altered hydrology and shallow lake-like conditions. These environmental conditions prohibit the upstream segment from meeting water quality standards through wasteload reductions alone. Because the Federal Clean Water Act does not give authority to regulate nonpoint sources of pollution, an adaptive management approach is recommended to evaluate tradeoffs and effectiveness of alternative management actions in the upper portion of Milford Creek.

4.2. Strategies

Reduce phosphorus inputs from wastewater. On a long term basis, it is estimated that point source wastewater contributes over 80% of the total phosphorus load to Milford Creek. Because of the channel’s shallow depth, wide channel, and low gradient, significant reductions in phosphorus are necessary to limit algal growth to levels consistent with meeting water quality standards. As modeling for the TMDL demonstrates, critical concentrations of total phosphorus in wastewater effluent would need to be reduced to 0.5 mg/l or less to meet minimum dissolved oxygen standards in the stream.

The Clean Water Act requires that effluent limits in NPDES permits be consistent with “the assumptions and requirements of any available WLA” in an approved TMDL. Therefore, reductions in phosphorus loading from the IGLSD wastewater treatment plant should be made in accordance with the wasteload allocations proposed in this TMDL via future NPDES permit limits. Information on phosphorus removal using biological, chemical, and filtration technologies is available from the U.S. EPA (USEPA, 2007).

Reduce phosphorus loading from watershed nonpoint sources and Lower Gar Lake. Nonpoint sources of phosphorus to Milford Creek also need to be reduced significantly in order to meet water quality standards in the upper segment. Depending on a number of factors, surface runoff received from the watershed or flows over the dam from Lower Gar Lake may dominate phosphorus loading to Milford Creek from nonpoint sources. Therefore, a combination of management strategies is necessary to effectively deal with nonpoint source loading.

In the immediate watershed drainage area to Milford Creek (excluding the Iowa Great Lakes), it is estimated that the dominant source of phosphorus is urban land. Urban areas generally have a higher rate of phosphorus export (per unit area) than rural areas due to the higher concentration of humans, pets, and their associated activities (USEPA, 1999). A variety of urban stormwater best management practices (BMPs) are being used in the Iowa Great Lakes region and should be further expanded to reduce urban pollutant loading to Milford Creek.

Portions of the total nonpoint source phosphorus load also come from agricultural areas in the watershed. Fertilizer and manure application should be carefully timed and incorporated into the soil when/where possible, and management practices which reduce surface runoff and promote infiltration during heavy rains should be utilized. Sediment erosion practices can also be effective, since phosphorus adsorbs to sediment particles and can be released to the stream water column under anaerobic conditions. Figures 18 and 19 depict the estimated nonpoint source loading areas for total phosphorus and sediment delivery in the Milford Creek watershed.

Phosphorus loading from Lower Gar Lake and the upper Iowa Great Lakes will be most effectively reduced through a combination of lake management activities and watershed loading reductions in the upper Iowa Great Lakes. The TMDL report for Lower Gar Lake provides a plan for reducing phosphorus loading to this lake and its watershed (IDNR, 2003).

Investigate and implement alternative management actions. A single-tracked approach to improving water quality in Milford Creek may be unsuccessful. Reductions in phosphorus loading are needed to limit algal growth and improve dissolved oxygen levels, but restoring the overall health of the ecosystem may require or be better achieved through physical and biological improvements to the stream channel. This is especially true along the upstream segment of Milford Creek.

Alternative management actions may include planting trees in the riparian zone for shade and temperature reduction, harvesting and removal of aquatic plant biomass, and channel deepening. Such practices, done in concert with nutrient reductions, will have a positive impact on dissolved oxygen levels by limiting environmental factors for algal growth. Trees provide shade and cooler water temperatures which limit plant growth, and harvesting aquatic plant biomass permanently removes stored nutrients which would otherwise be recycled back into the ecosystem. Channel deepening/dredging could possibly improve bed gradient and stream velocity, increase channel storage, remove benthic phosphorus, and limit light penetration to benthic algae. Finally, removing the old rock/debris dam below the Lower Gar Lake dam to prevent fish entrapment could help eliminate unsightly fish kills during drought periods. Obviously, a cost-benefit analysis to determine the effectiveness of various alternatives would be needed.

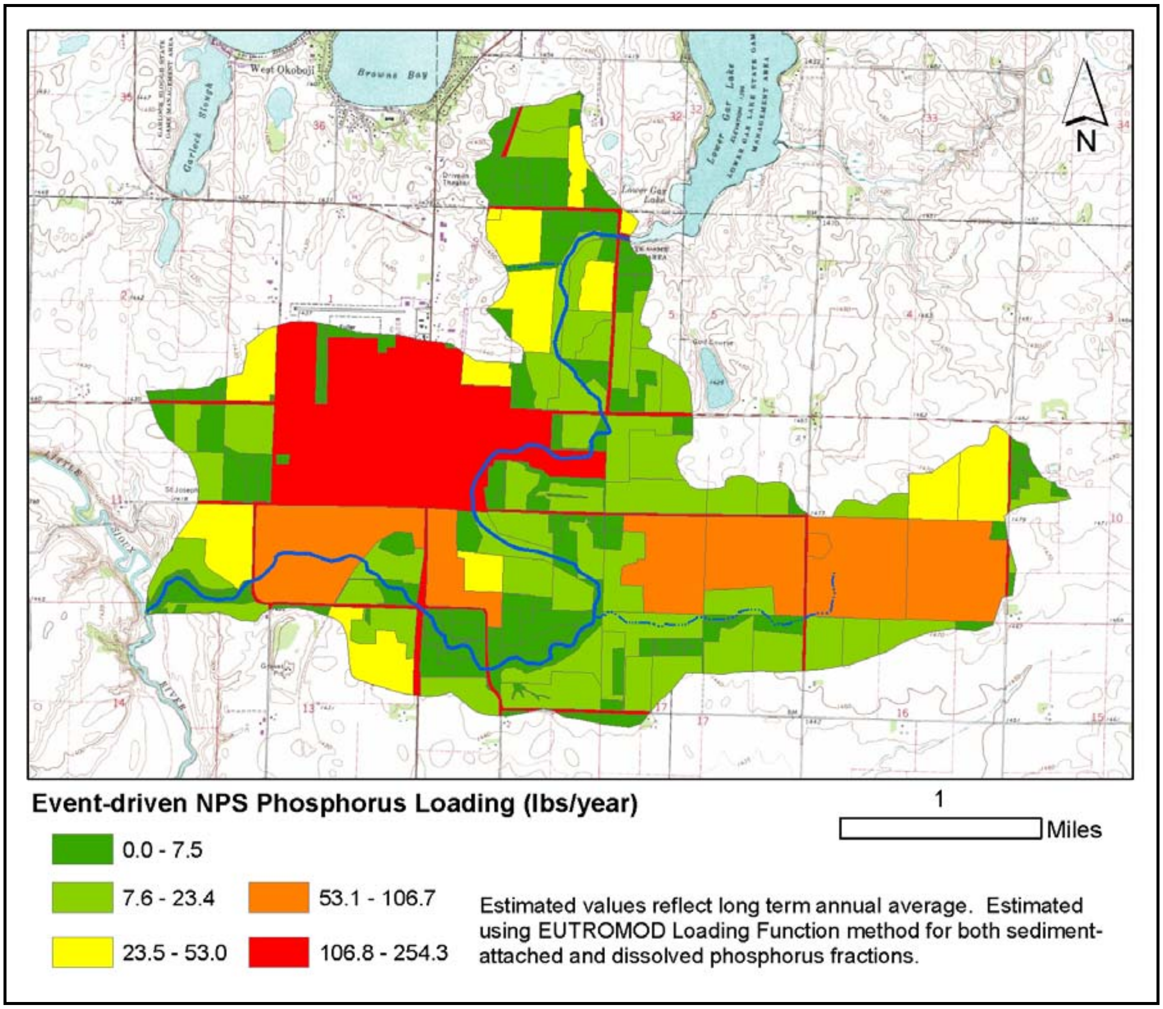

Figure 18. Estimated annual phosphorus loads delivered from nonpoint sources.

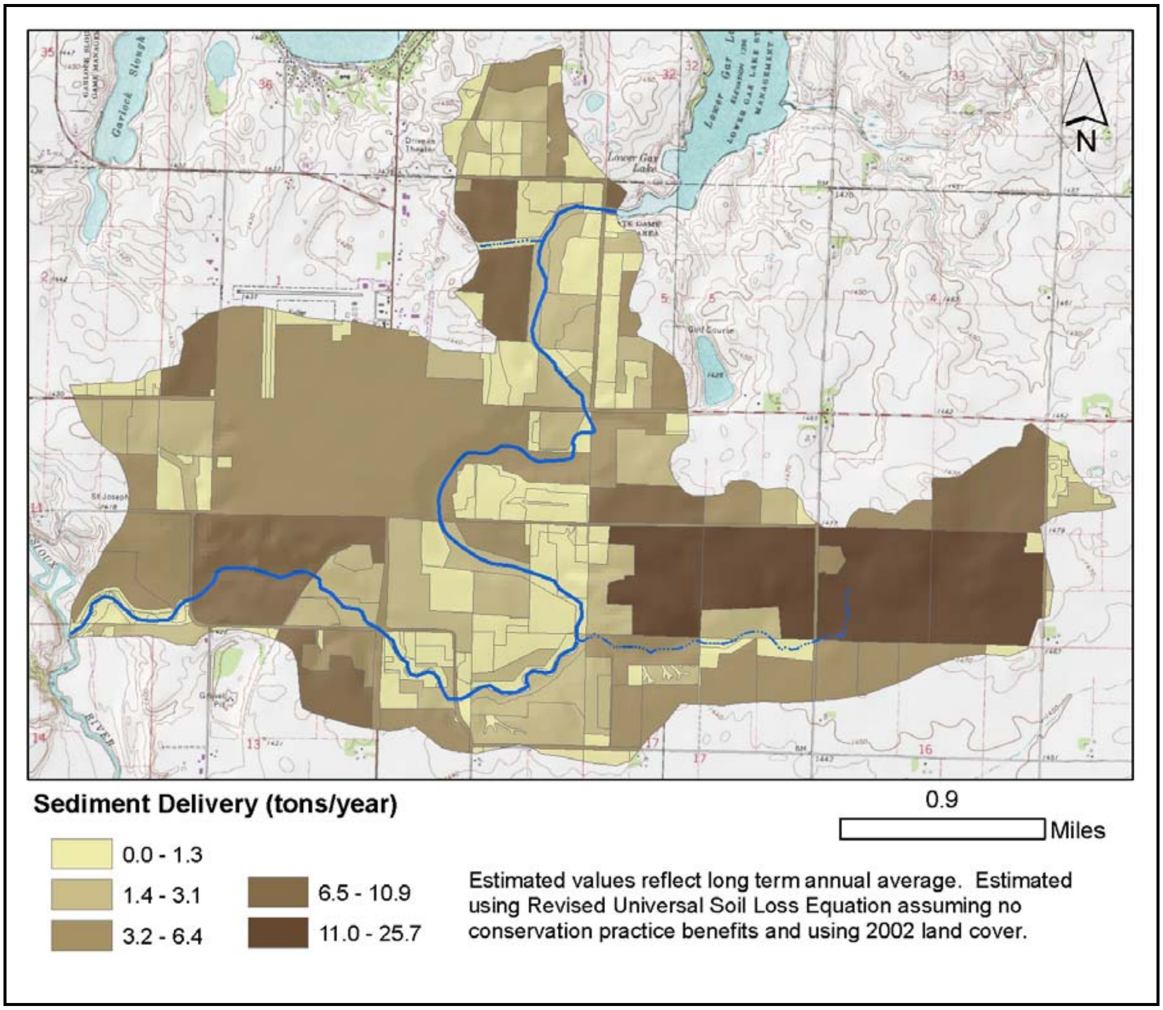

Figure 19. Estimated sediment delivery to Milford Creek. Phosphorus attached to sediment can be released to the water column under anoxic conditions.

5. Future Monitoring

Further monitoring is needed in Milford Creek to follow-up on the implementation of the TMDL. Water quality monitoring is a critical element in understanding the current conditions and natural variations of water resources. Furthermore, monitoring is necessary to track changes in water quality and the effectiveness of improvements made in the watershed.

5.1. Monitoring Plan to Track TMDL Effectiveness

Monitoring at the IGLSD facility will continue as required by NPDES permit. Currently, monitoring includes reporting CBOD5 and ammonia three times per week and average flow on a daily basis, plus various other parameters. Although not required to report the data, the IGLSD performs additional monitoring for effluent dissolved oxygen and other parameters. Future monitoring requirements will include dissolved oxygen, total phosphorus, and total nitrogen.

5.2. Supplemental Water Monitoring Plan for Local Stakeholders

The purpose of this section is to outline what an appropriate monitoring plan would look like for Milford Creek should any watershed monitoring groups become active and aspire to collect water quality data in the future. Financial and logistical constraints may prohibit full deployment of this plan, but if resources allow it would provide a rather comprehensive dataset for assessment purposes. Local knowledge should drive the more specific details of all future monitoring efforts.

To adequately monitor the stream’s health as it relates to the 303(d) biological impairment, there are five major components that are needed. These five components are listed in Table 5, along with more specific details on the parameters, locations, and sampling frequencies. Local groups or citizens interested in implementing this water monitoring plan should contact the Iowa DNR Watershed Monitoring and Assessment Section for technical assistance and training.

Table 5. Proposed monitoring plan for Milford Creek.

Component	Sample Frequency	Locations	Parameters/Details
1. Point source phosphorus monitoring	Once per week	Final effluent of IGLSD WWTP	Grab sample for total phosphorus and dissolved phosphorus, to be implemented into NPDES permit monitoring requirements
2. Water chemistry sampling	Bi-weekly from March to November	STORET sites #11300001, #11300012, #11300015, #11300002	All common parameters listed in Appendix A of the Iowa Water Monitoring Plan 2000 (http://wqm.igsb.uiowa.edu/publications/plan2000.htm)
3. Biological and physical habitat assessments	Annually, at low-flow conditions	STORET sites #11300001, #11300002	Monitoring should be done in accordance with the *Biological Assessment of Iowa's Streams* and *Habitat Evaluation Procedures for Wadeable Streams and Rivers in Iowa* available from the IDNR Watershed Monitoring and Assessment Section.
4. Continuous dissolved oxygen and flow measurements	Continuously (6-minute intervals) from June to October	STORET sites #11300001, #11300012, #11300015, #11300002	Continuous streamflow and dissolved oxygen autosampler deployment according to UHL protocols
5. "Snapshot" monitoring	Twice per summer; once during early season high flows and once in late season low flows	2005 sampling locations shown in Figure 10	To serve needs of Qual2K modeling, collect all common water chemistry parameters (see #2) at each site when a full 24-hour period of continuous dissolved oxygen data is available for all continuous monitoring sites (see #4). Also, physical parameters to be collected at each stream site include streamflow, avg. width, avg. depth, and avg. velocity.

6. Public Participation

The original draft TMDL for Milford Creek was presented at a public meeting at the Iowa Great Lakes Maritime Museum on January 19, 2005. A revised Draft TMDL was made available for public comment from August 2, 2007 through September 4, 2007. A public meeting was held on August 13, 2007 at the Iowa Great Lakes Maritime Museum. The meeting was attended by representatives of the Dickinson County Supervisors, Dickinson County Soil and Water Conservation District, Iowa Great Lakes Sanitary District, Dickinson County Conservation Board, and the general public. Comments received at the meeting and during the public comment period are included in Appendix F.

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8. Appendices

Appendix A --- Glossary of Terms and Acronyms

303(d) list: Refers to section 303(d) of the Federal Clean Water Act, which requires a listing of all public surface water bodies (creeks, rivers, wetlands, and lakes) that do not support their general and/or designated uses. Also called the state's "Impaired Waters List."

305(b) assessment: Refers to section 305(b) of the Federal Clean Water Act, it is a comprehensive assessment of the state's public water bodies ability to support their general and designated uses. Those bodies of water which are found to be not supporting or just partially supporting their uses are placed on the 303(d) list.

319: Refers to Section 319 of the Federal Clean Water Act, the Nonpoint Source Management Program. Under this amendment, States receive grant money from EPA to provide technical & financial assistance, education, & monitoring to implement local nonpoint source water quality projects.

AFO: Animal Feeding Operation. A livestock operation, either open or confined, where animals are kept in small areas (unlike pastures) allowing manure and feed become concentrated.

Base flow: The fraction of discharge (flow) in a river which comes from ground water.

BMIBI: Benthic Macroinvertebrate Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of bottom-dwelling invertebrates.

BMP: Best Management Practice. A general term for any structural or upland soil or water conservation practice. For example terraces, grass waterways, sediment retention ponds, reduced tillage systems, etc.

CAFO: Confinement Animal Feeding Operation. An animal feeding operation in which livestock are confined and totally covered by a roof, and not allowed to discharge manure to a water of the state.

Credible data law: Refers to 455B.193 of the Iowa Administrative Code, which ensures that water quality data used for all purposes of the Federal Clean Water Act are sufficiently up-to-date and accurate.

Cyanobacteria (blue-green algae):	Members of the phytoplankton community that are not true algae but can photosynthesize. Some species can be toxic to humans and pets.
Designated use(s):	Refer to the type of economic, social, or ecologic activities that a specific water body is intended to support. See Appendix B for a description of all general and designated uses.
DNR (or IDNR):	Iowa Department of Natural Resources.
Ecoregion:	A system used to classify geographic areas based on similar physical characteristics such as soils and geologic material, terrain, and drainage features.
EPA (or USEPA):	United States Environmental Protection Agency.
FIBI:	Fish Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of fish species.
FSA:	Farm Service Agency (United States Department of Agriculture). Federal agency responsible for implementing farm policy, commodity, and conservation programs.
General use(s):	Refer to narrative water quality criteria that all public water bodies must meet to satisfy public needs and expectations. See Appendix B for a description of all general and designated uses.
GIS:	Geographic Information System(s). A collection of map-based data and tools for creating, managing, and analyzing spatial information.
Gully erosion:	Soil movement (loss) that occurs in defined upland channels and ravines that are typically too wide and deep to fill in with traditional tillage methods.
HEL:	Highly Erodible Land. Defined by the USDA Natural Resources Conservation Service (NRCS), it is land which has the potential for long term annual soil losses to exceed the tolerable amount by eight times for a given agricultural field.

IGLSD: Iowa Great Lakes Sanitary District. Municipal sewage treatment plant located in Milford, Iowa that discharges to Milford Creek.

Integrated report: Refers to a comprehensive document which combines the 305(b) assessment with the 303(d) list, as well as narratives and discussion of overall water quality trends in the state's public water bodies. The Iowa Department of Natural Resources submits an integrated report to the EPA biennially in even numbered years.

LA: Load Allocation. The fraction of the total pollutant load of a water body which is assigned to all combined *nonpoint sources* in a watershed. (The total pollutant load is the sum of the waste load and load allocations.)

Load: The total amount (mass) of a particular pollutant in a waterbody.

MOS: Margin of Safety. In a total maximum daily load (TMDL) report, it is a set-aside amount of a pollutant load to allow for any uncertainties in the data or modeling.

MS4 Permit: Municipal Separate Storm Sewer System Permit. An NPDES license required for some cities and universities which obligates them to ensure adequate water quality and monitoring of runoff from urban storm water and construction sites, as well as public participation and outreach.

Nonpoint source pollution: A collective term for contaminants which originate from a diffuse source.

NPDES: National Pollution Discharge Elimination System, which allows a facility (e.g. an industry, or a wastewater treatment plant) to discharge to a water of the United States under regulated conditions.

NRCS: Natural Resources Conservation Service (United States Department of Agriculture). Federal agency which provides technical assistance for the conservation and enhancement of natural resources.

Periphyton: Algae that are attached to substrates (rocks, sediment, wood, and other living organisms).

Phytoplankton: Collective term for all self-feeding (photosynthetic) organisms which provide the basis for the aquatic food chain. Includes many types of algae and cyanobacteria.

Point source pollution: A collective term for contaminants which originate from a specific point, such as an outfall pipe. Point sources are generally regulated by an NPDES permit.

PPB: Parts per Billion. A measure of concentration which is the same as micrograms per liter (µg/l).

PPM: Parts per Million. A measure of concentration which is the same as milligrams per liter (mg/l).

Riparian: Refers to site conditions that occur near water, including specific physical, chemical, and biological characteristics that differ from upland (dry) sites.

RUSLE: Revised Universal Soil Loss Equation. An empirical model for estimating long term, average annual soil losses due to sheet and rill erosion.

Secchi disk: A device used to measure transparency in water bodies. The greater the secchi depth (measured in meters), the more transparent the water.

Sediment delivery ratio: A value, expressed as a percent, which is used to describe the fraction of gross soil erosion which actually reaches a water body of concern.

Seston: All particulate matter (organic and inorganic) in the water column.

Sheet & rill erosion Soil loss which occurs diffusely over large, generally flat areas of land.

SI: Stressor Identification. A process by which the specific cause(s) of a biological impairment to a water body can be determined from cause-and-effect relationships.

Storm flow (or stormwater): The fraction of discharge (flow) in a river which arrived as surface runoff directly caused by a precipitation event. *Storm water* generally refers to runoff which is routed through some artificial channel or structure, often in urban areas.

STP: Sewage Treatment Plant. General term for a facility that processes municipal sewage into effluent suitable for release to public waters.

SWCD: Soil and Water Conservation District. Agency which provides local assistance for soil conservation and water quality project implementation, with support from the Iowa Department of Agriculture and Land Stewardship.

TMDL: Total Maximum Daily Load. As required by the Federal Clean Water Act, a comprehensive analysis and quantification of the maximum amount of a particular pollutant that a water body can tolerate while still meeting its general and designated uses.

TSI (or Carlson's TSI): Trophic State Index. A standardized scoring system (scale of 0-100) used to characterize the amount of algal biomass in a lake or wetland.

TSS: Total Suspended Solids. The quantitative measure of seston, all materials, organic and inorganic, which are held in the water column.

Turbidity: The degree of cloudiness or murkiness of water caused by suspended particles.

UAA: Use Attainability Analysis. A protocol used to determine which (if any) designated uses apply to a particular water body. (See Appendix B for a description of all general and designated uses.)

UHL: University Hygienic Laboratory (University of Iowa). Provides physical, biological, and chemical sampling for water quality purposes in support of beach monitoring and impaired water assessments.

USGS: United States Geologic Survey (United States Department of the Interior). Federal agency responsible for implementation and maintenance of discharge (flow) gauging stations on the nation's water bodies.

Watershed: The land (measured in units of surface area) which drains water to a particular body of water or outlet.

WLA: Waste Load Allocation. The fraction of waterbody loading capacity assigned to point sources in a watershed. Alternatively, the allowable pollutant load that an NPDES permitted facility may discharge without exceeding water quality standards.

WQS: Water Quality Standards. Defined in Chapter 61 of Environmental Protection Commission [567] of the Iowa Administrative Code, they are the specific criteria by which water quality is gauged in Iowa.

WWTP: Waste Water Treatment Plant. General term for a facility which processes municipal, industrial, or agricultural waste into effluent suitable for release to public waters or land application.

Zooplankton: Collective term for all animal plankton which serve as secondary producers in the aquatic food chain and the primary food source for larger aquatic organisms.

Appendix B --- General and Designated Uses of Iowa's Waters

Introduction

Iowa's water quality standards (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code) provide the narrative and numerical criteria by which water bodies are judged when determining the health and quality of our aquatic ecosystems. These standards vary depending on the type of water body (lakes vs. rivers) and the assigned uses (general use vs. designated uses) of the water body that is being dealt with. This appendix is intended to provide information about how Iowa's water bodies are classified and what the use designations mean, hopefully providing a better general understanding for the reader.

All public surface waters in the state are protected for certain beneficial uses, such as livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and other incidental uses (e.g. withdrawal for industry and agriculture). However, certain rivers and lakes warrant a greater degree of protection because they provide enhanced recreational, economical, or ecological opportunities. Thus, all public bodies of surface water in Iowa are divided into two main categories: *general* use segments and *designated* use segments. This is an important classification because it means that not all of the criteria in the state's water quality standards apply to all water ways; rather, the criteria which apply depend on the use designation & classification of the water body.

General Use Segments

A general use segment water body is one which does not maintain perennial (year-round) flow of water or pools of water in most years (i.e. ephemeral or intermittent waterways). In other words, stream channels or basins which consistently dry up year after year would be classified as general use segments. Exceptions are made for years of extreme drought or floods. For the full definition of a general use water body, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

General use waters are protected for the beneficial uses listed above, which are: livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and industrial, agricultural, domestic and other incidental water withdrawal uses. The criteria used to ensure protection of these uses are described in section 61.3(2) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

Designated Use Segments

Designated use segments are water bodies which maintain flow throughout the year, or at least hold pools of water which are sufficient to support a viable aquatic community (i.e. perennial waterways). In addition to being protected for the same beneficial uses as the general use segments, these perennial waters are protected for more specific activities such as primary contact recreation, drinking water sources, or cold-water fisheries. There are a total of thirteen different designated use classes (Table B1) which may apply, and a water body may have more than one designated use. For definitions of the use classes and more detailed descriptions, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

Table B1. Designated use classes for Iowa water bodies.

Class prefix	Class	Designated use	Brief comments
A	A1	Primary contact recreation	Supports swimming, water skiing, etc.
	A2	Secondary contact recreation	Limited/incidental contact occurs, such as boating
	A3	Children's contact recreation	Urban/residential waters that are attractive to children
B	B(CW1)	Cold water aquatic life – Type 2	Able to support coldwater fish (e.g. trout) populations
	B(CW2)	Cold water aquatic life – Type 2	Typically unable to support consistent trout populations
	B(WW-1)	Warm water aquatic life – Type 1	Suitable for game and nongame fish populations
	B(WW-2)	Warm water aquatic life – Type 2	Smaller streams where game fish populations are limited by physical conditions & flow
	B(WW-3)	Warm water aquatic life – Type 3	Streams that only hold small perennial pools which extremely limit aquatic life
	B(LW)	Warm water aquatic life – Lakes and Wetlands	Artificial and natural impoundments with "lake-like" conditions
C	C	Drinking water supply	Used for raw potable water
Other	HQ	High quality water	Waters with exceptional water quality
	HQR	High quality resource	Waters with unique or outstanding features
	HH	Human health	Fish are routinely harvested for human consumption

Appendix C --- Modeling and Methods

TMDL Modeling Approach

Introduction. The water quality model used in the development of this TMDL was Qual2K. This model assumes steady state hydraulics, constant wasteloads, complete mixing in the stream, and one-dimensional advection and dispersion along the longitudinal axis of the stream. The stream was divided into ten reaches with a varying number of computational elements in each reach. Throughout its length, each reach is assumed to have the same slope, cross-section, channel roughness, re-aeration rate, and biological rate constants. Each computational element is assumed to be a well-mixed reactor and these are strung together sequentially to represent the stream reaches. For a full description and user's manual on Qual2K, visit the EPA's website: http://www.epa.gov/athens/wwqtsc/html/qual2k.html.

Calibration. The model was calibrated to the physical conditions in Milford Creek for a representative date (8/31/2005) when the stream was at critical conditions: low streamflow, when wastewater effluent made up the majority of streamflow, stable weather conditions, and available monitoring data. Parameters in the model were adjusted until the predicted results compared favorably with data collected in the stream that day. The calibrated model would then be used to analyze the outcome of implementing alternative WLA scenarios for total phosphorus by assessing the effect on algal growth and dissolved oxygen concentrations downstream. The results of this analysis would be used to identify the target wastewater total phosphorus concentration needed to meet and maintain dissolved oxygen water quality standards in Milford Creek during critical conditions.

Figure D1 shows how Milford Creek was divided into reaches or segments for the model. Monitoring data from Site 50 was used to define headwater boundary conditions while data collected at the IGLSD wastewater treatment plant, storm drainage ditch, and tributary sites were used to define surface water inflows to the stream. Because it was modeled during critical conditions, there was very little inflow to the stream other than IGLSD wastewater. Weather data was obtained from the Iowa Environmental Mesonet (IEM, 2007). Monitoring data for sites 49, 2, and 3 were used to compare model results to measured data and to adjust the model parameters during the calibration procedure. Tables D1 and D2 list the parameters that were adjusted during the calibration.

Figure D2 depicts the model's performance for two important physical parameters: velocity and depth. Figures D3 and D4 depict the longitudinal (lengthwise from upstream to downstream) model performance of stream temperature and dissolved oxygen, while Figures D5 and D6 depict the diurnal (24-hour) model performance for these same two parameters at Site 3.

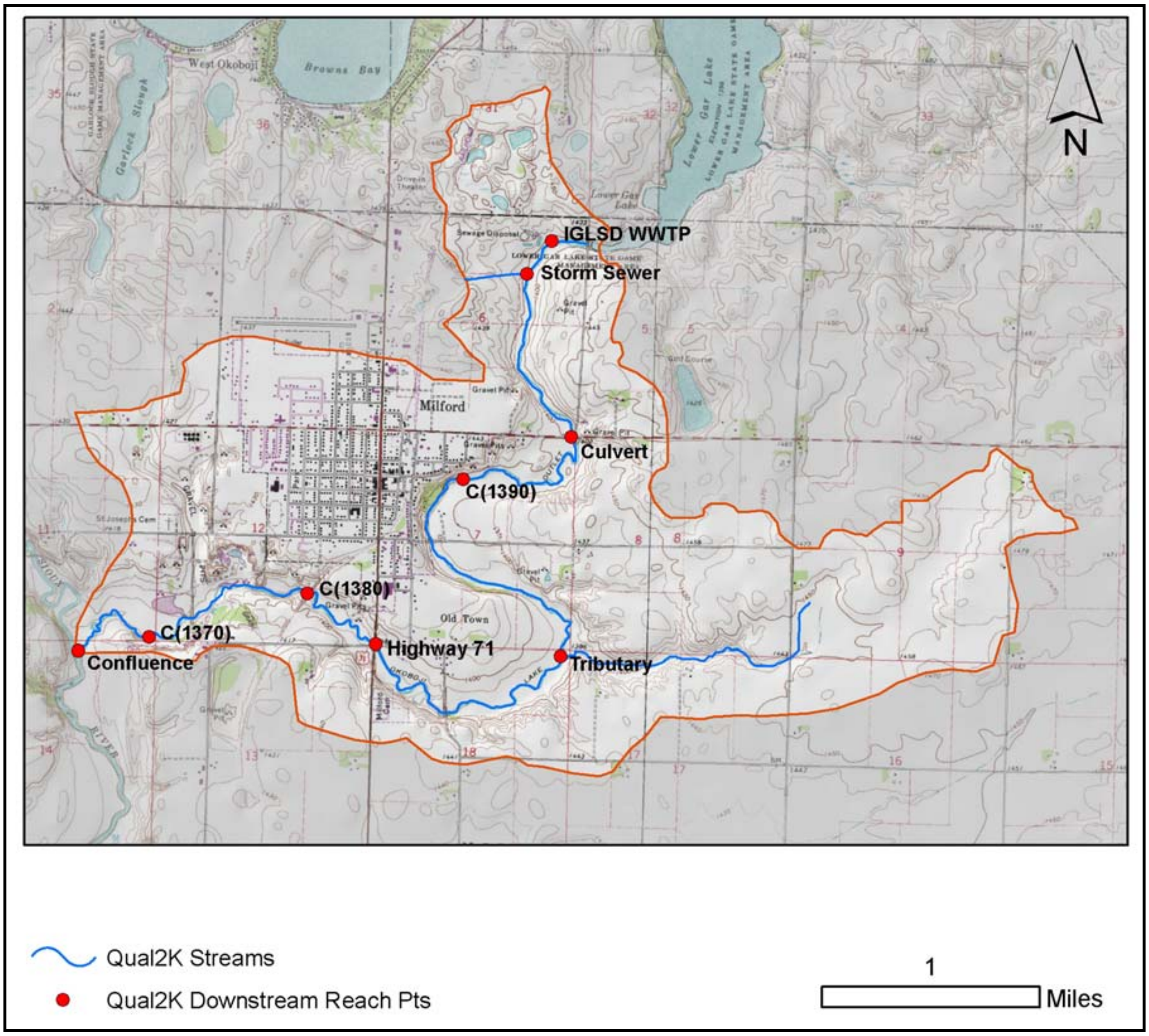


Figure D1. Segmentation of Milford Creek for Qual2K model.

Table D1. Calibration parameters for Qual2K "Rates" sheet.

Parameter	Default Value	Calibrated Value
Inorganic suspended solids:		
Settling velocity	0.3	2
Oxygen:		
Reaeration model	User specified	USGS(channel-control)
Slow CBOD:		
Hydrolysis rate	0.1	2
Fast CBOD:		
Oxidation rate	0.23	6
Ammonium:		
Nitrification	1	2
Nitrate:		
Denitrification	0	1
Organic P:		
Hydrolysis	0.2	0.25
Phytoplankton:		
Respiration rate	0.2	0.1
Death rate	0.2	0.1
Nitrogen half sat constant	25	1
Phosphorus half sat constant	5	0.14
Light constant	100	35
Ammonia preference	25	80
Settling velocity	0.5	0.15
Bottom Algae:		
Max Growth rate	50	200
Respiration rate	0.1	0.5
Excretion rate	0.05	0.1
Temp correction	1.07	0.15
Death rate	0.1	0.05
Light constant	100	50
Subsistence quota for nitrogen	0.72	1.5
Subsistence quota for phosphorus	0.1	0.3
Maximum uptake rate for nitrogen	72	720
Maximum uptake rate for phosphorus	5	100
Internal nitrogen half sat constant	0.9	9
Internal phosphorus half sat constant	0.13	1.3
Detritus (POM):		
Dissolution rate	0.5	1.7
Settling velocity	0.1	1
Inorganic suspended solids:		
Settling velocity	0.3	2

Table D2. Calibration parameters for Qual2K "Light and Heat" sheet.

Parameter	Default Value	Calibrated Value
Downwelling atmospheric longwave IR radiation		
atmospheric longwave emissivity model	Brunt	Brutsaert
Sediment heat parameters		
Sediment thermal thickness	15	10
Sediment heat capacity	0.4	1

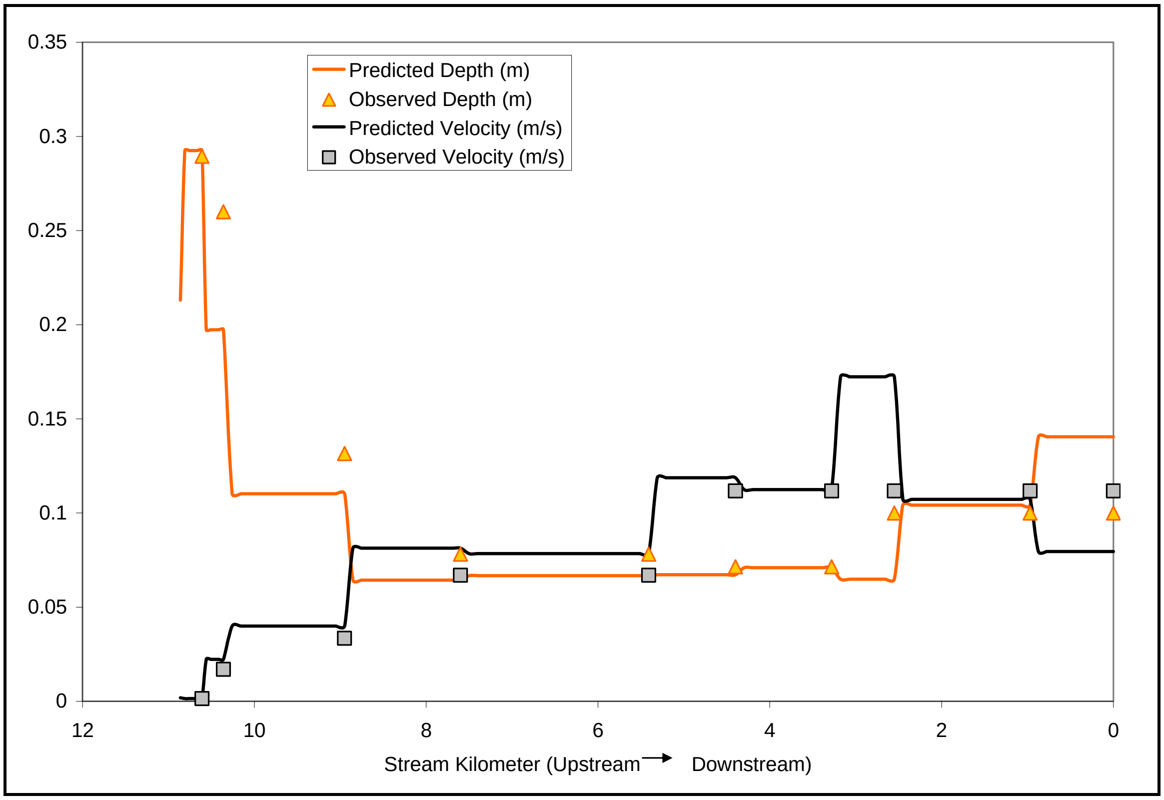


Figure D2. Model performance for hydraulic depth and avg. velocity.

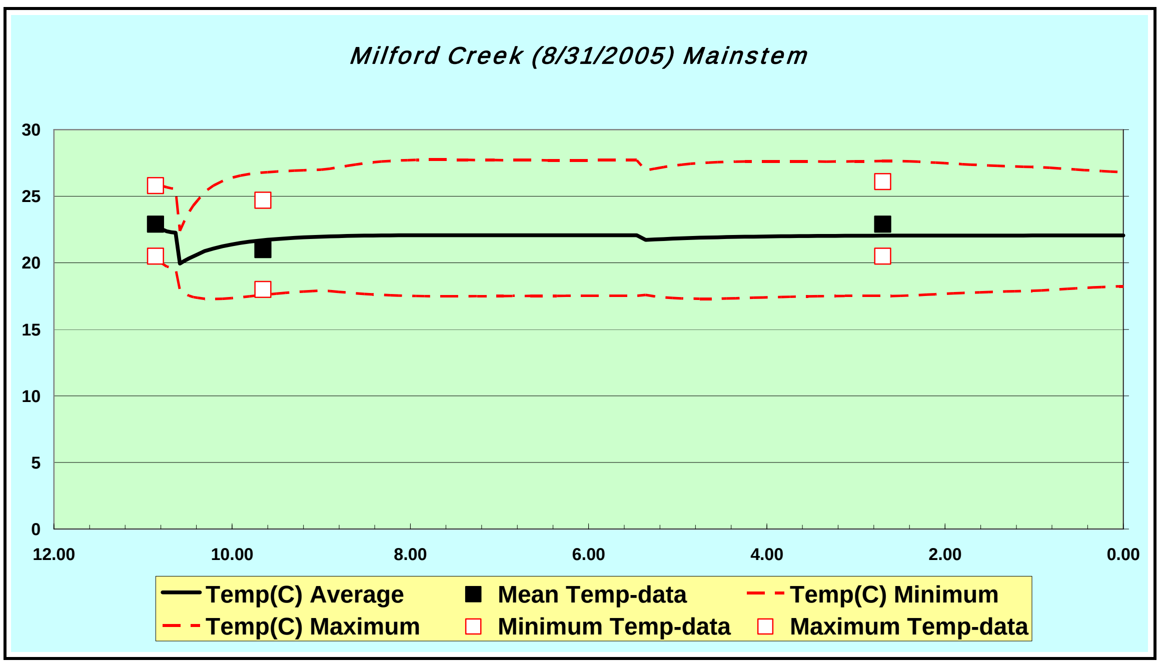


Figure D3. Model performance for longitudinal stream temperature.

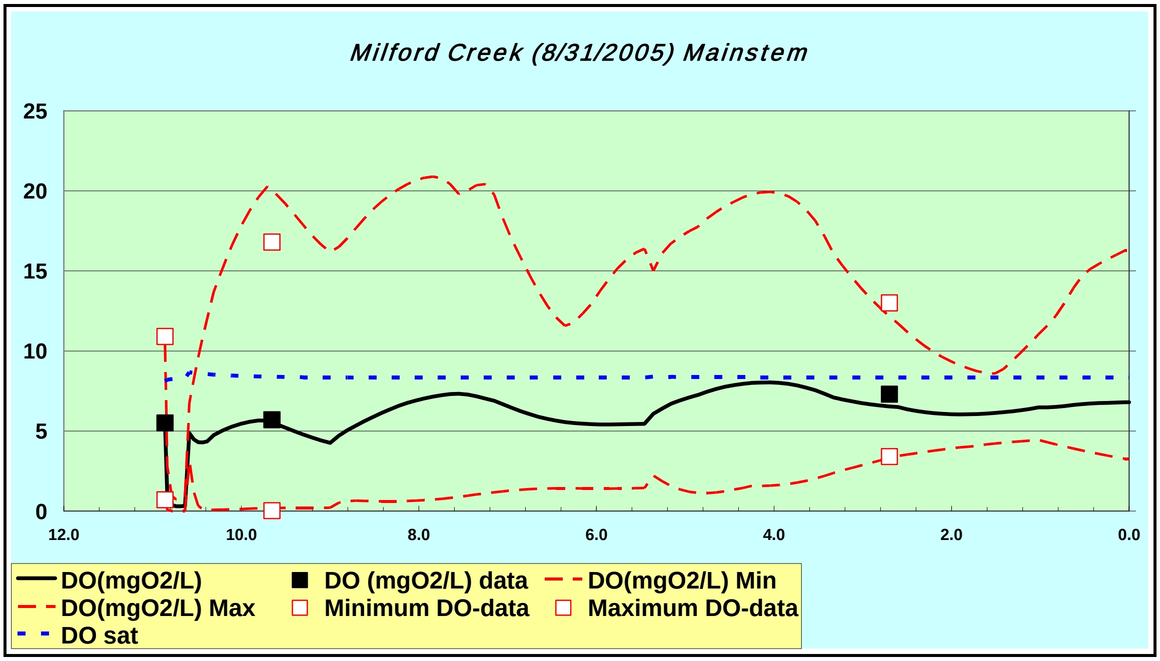


Figure D4. Model performance for longitudinal dissolved oxygen.

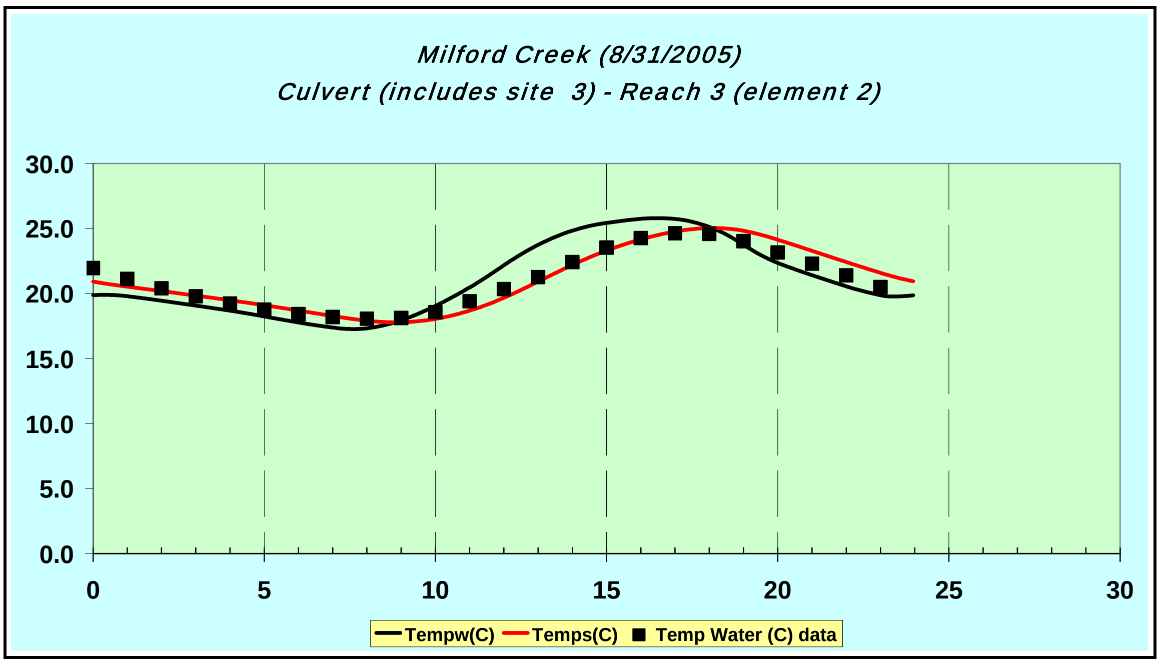


Figure D5. Model performance for diel stream temperature.

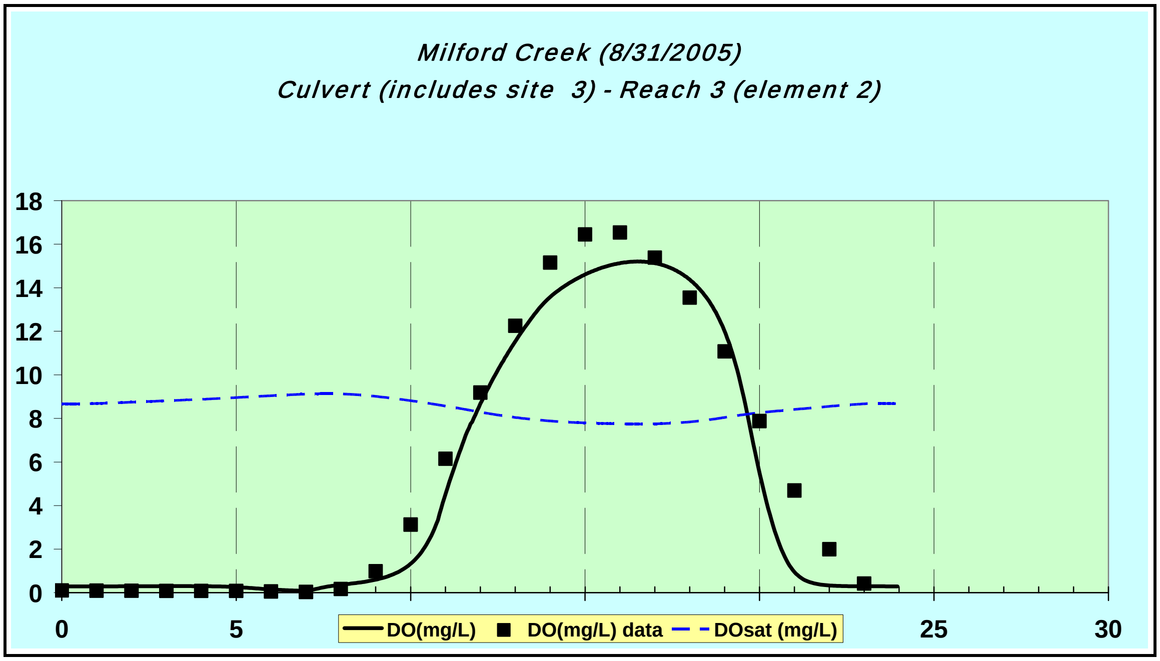


Figure D6. Model performance for diurnal (24-hour) dissolved oxygen.

Results. Following the calibration, a series of model runs were analyzed to determine the effects of alternative phosphorus wasteload scenarios on algal growth and dissolved oxygen. Prior to that, however, a determination of the baseline stream conditions was made by "removing" the wastewater treatment plant as a source of inflow to the stream. Figures D7 and D8 show the longitudinal and diurnal results for this analysis.

Under the current conditions (wastewater total phosphorus = 3.94 mg/l), model results show that dissolved oxygen criteria are not met in the downstream segment until stream kilometer 1.81 (distance from mouth). However, in a hypothetical scenario in which the wastewater treatment plant is eliminated, stream dissolved oxygen levels are able to meet water quality standards throughout the entire downstream segment of Milford Creek. This result reflects the impact of the dissolved plant-available phosphorus load from the WWTP and its subsequent effect on stream dissolved oxygen.

Table D3 shows the alternative total phosphorus wasteload scenarios that were analyzed and the percent of stream length meeting water quality standards following each model run. Reductions in phosphorus continually increase downstream oxygen levels until 0.15 mg/l, where the percent of stream length in compliance is maximized. Below 0.15 mg/l, algal growth is suppressed to a point where photosynthesis is limited and oxygen levels suffer. At 0.5 mg/l, the entire downstream segment is in compliance with dissolved oxygen standards.

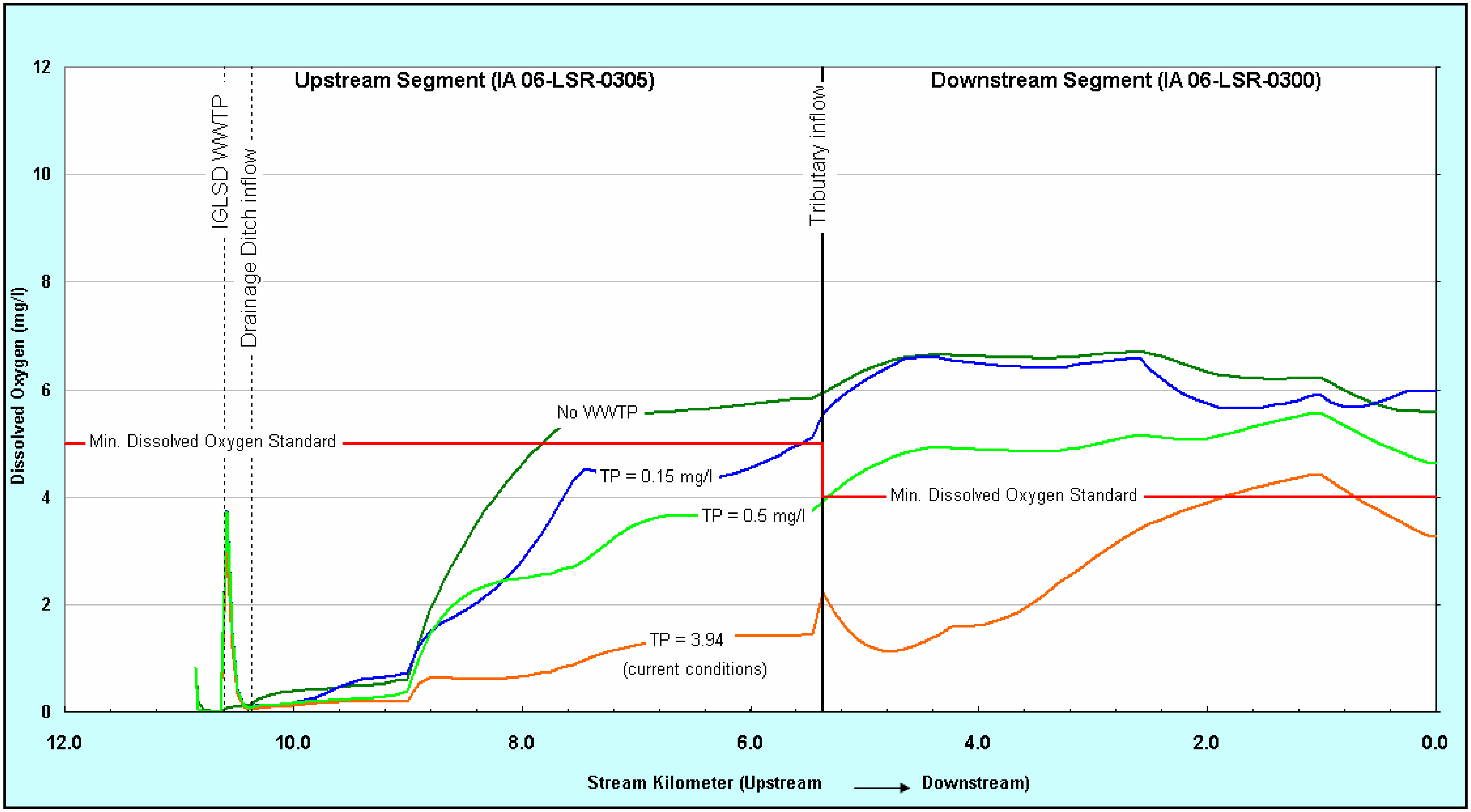


Figure D7. Qual2K modeling results: effect of alternative wastewater total phosphorus limits on downstream dissolved oxygen. Dissolved oxygen standard reflects current designated uses which are subject to change for upstream segment.

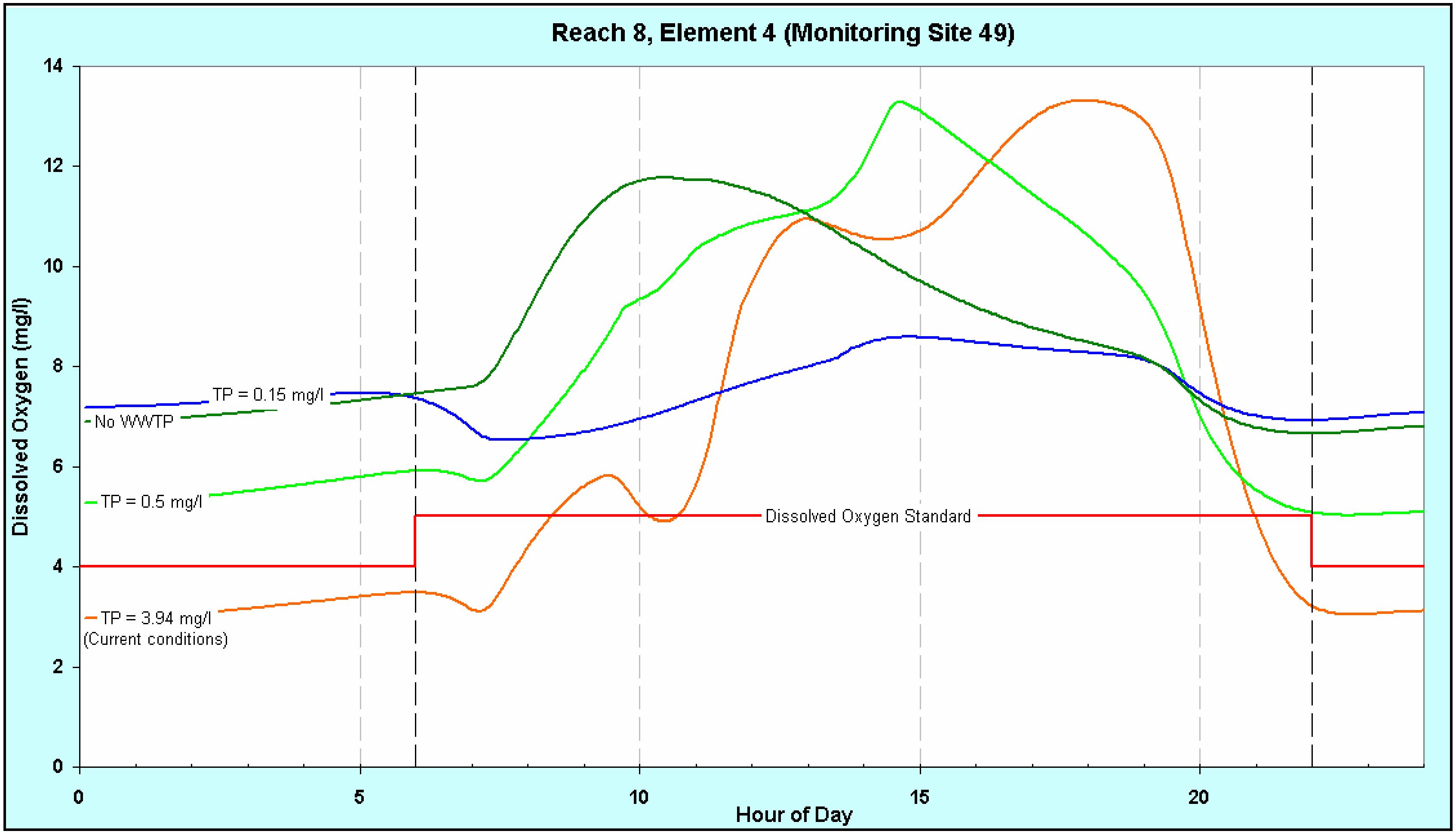


Figure D8. Qual2K modeling results: effect of alternative wastewater total phosphorus limits on 24-hour dissolved oxygen levels at monitoring Site #49.

Table D3. Full summary of Qual2K modeling analysis.

Total phosphorus concentration in wastewater effluent under critical conditions	Reduction needed	% Stream length meeting dissolved oxygen standard in DOWNSTREAM SEGMENT
No WWTP	N/A	100%
3.94 mg/l (current conditions)	0%	22%
1.00 mg/l	75%	30%
0.750 mg/l	81%	60%
0.500 mg/l	87%	100%
0.250 mg/l	94%	100%
0.175 mg/l	96%	100%
0.150 mg/l	96%	100%
0.125 mg/l	97%	100%
0.100 mg/l	97%	100%
0.010 mg/l	99.7%	100%

0.500mg/l represents the first breakpoint, where the entire downstream segment attains dissolved oxygen standards.
0.150 represents the second breakpoint, where the percent of total stream length meeting standards is optimized.

TMDL, WLA, and LA determination. The steady-state or low flow TMDL is designed to protect the stream during the worst possible environmental conditions. For this project, it was determined by independently defining the WLA and LA under these conditions using available information and then summing them for a total load capacity.

For the WLA, the critical total phosphorus target was determined using the modeling results from Table D3 above. The percent stream length meeting WQS is maximized when the TP concentration from the IGLSD facility is at 0.5 mg/l. A target concentration of 0.500 mg/l total phosphorus in wastewater effluent was deemed appropriate to ensure that there would be no negative impact on the downstream segment.

The minimum daily flow value recorded at the IGLSD WWTP between the months of June through October (during which time critical environmental conditions apply) was used to calculate the critical condition WLA. This value, 1.645 MGD, was measured on 10/13/2000. Using this flow value and a target concentration of 0.5 mg/l, the critical condition WLA for Milford Creek is 6.9 lbs/day total phosphorus. To define the high flow daily maximum wasteload, 42.8 lbs/day, the plant's maximum wet-weather flow (10.22 mgd as specified in the 2007 construction permit) was used. The long term annual average wasteload allocation of 6,408 lbs/year on average was determined using daily AWW and ADW phosphorus wasteload allocations assuming four months per year of ADW days and eight months per year AWW days.

The nonpoint source load allocation was developed using monitoring data collected from the storm drainage ditch and tributary sites in 2005. The inflows and TP concentrations from these sources were used to confirm that, during critical conditions, very little phosphorus is delivered from nonpoint source areas. The sum of these loads, including dry atmospheric deposition, is 0.1 lbs/day.

The high flow condition nonpoint source load allocation was determined by estimating and summing the estimated loads from Lower Gar Lake and the immediate watershed to Milford Creek at a concentration of 0.5 mg/l. The Stenback and Crumpton (2006) study was used to determine the maximum flow rate from Lower Gar Lake between 1999-2005 (506.9 cfs), and the Rational Method was used to determine the maximum inflow from the watershed for a 2-year, 24-hour rain event (73 cfs). At 0.5 mg/l, these loads equaled 1,376.6 lbs/day and 197 lbs/day respectively, or 1,607.4 lbs/day total.

The long term LA was set arbitrarily by equating it to the phosphorus reductions called for in the 2003 Lower Gar Lake TMDL report, i.e. 50%. This is based on the assumption that a 50% reduction in phosphorus loading into Lower Gar Lake will equate to a similar reduction in phosphorus export from the lake to Milford Creek, along with a 50% reduction from direct watershed sources being needed.

Summary. The model shows that under critical stream conditions, reductions in point source phosphorus loading can make a direct impact on downstream dissolved oxygen levels in Milford Creek. However, flow alterations and physical limitations in the upstream segment affect the attainment of WQS through the implementation of a point source WLA alone; therefore additional management strategies may be needed in addition to both point source and nonpoint source phosphorus reductions. Such strategies might include riparian tree shading, aquatic plant biomass harvesting, and channel deepening.

Estimation of nonpoint source phosphorus loading

Nonpoint sources of phosphorus to Milford Creek were classified as follows: 1. Loads from the upper Iowa Great Lakes watershed, delivered from Lower Gar Lake during high flow periods; 2. Surface runoff loads estimated separately as dissolved and sediment-attached phosphorus; and 3. Natural background loading from atmospheric deposition.

To estimate loading from the upper Iowa Great Lakes watershed, information from an ISU study was utilized (Stenback and Crumpton, 2006). This study consisted of developing a mass-balance budget for total phosphorus and water movement throughout the Iowa Great Lakes, specifically for Lower Gar Lake. Results included exports of water and phosphorus to Milford Creek for the years 1999-2005 (Table D4), which is felt to cover a sufficient statistical range for characterizing phosphorus and flow exports based on annual precipitation. The total annual rainfall received between the years 1999-2005 ranged from the 18th percentile (20.4” in 2003) to the 95th percentile (37.7” in 2004) of long term data records (IEM, 2007).

A supplement to this study was done to compare the outputs from Lower Gar Lake to that of the IGLSD wastewater treatment plant. Results of this supplemental work are included in Appendix E.

To estimate event-driven nonpoint source loading, procedures from EUTROMOD's loading function were used (Reckhow, 1992). This method is commonly utilized in Iowa and in other states for estimating long term nonpoint source loadings of phosphorus. It estimates watershed total phosphorus loading as two separate fractions, dissolved and sediment-attached. The dissolved fraction is estimated by multiplying volumetric surface runoff estimates from unique land use categories by event mean concentrations (EMC's) also unique to different land use categories (Table D5).

The EUTROMOD method for estimating sediment-attached phosphorus is similar to the Iowa Phosphorus Index (Mallarino et al., 2005). Sheet and rill erosion is estimated using the Revised Universal Soil Loss Equation (RUSLE), and delivery to the stream is estimated using the Iowa NRCS Erosion and Sediment Delivery procedure. Based on watershed size and landform region, the sediment delivery ratio at the mouth of Milford Creek is 4.85%, meaning this is the fraction of gross field erosion which actually reaches the stream's mouth. The mass of soil loss is then multiplied by a soil phosphorus concentration and enrichment ratio according to land use type to get total sediment-attached phosphorus delivery.

Atmospheric deposition, or background loading, was estimated using measured rates of dry and wet total phosphorus deposition in the Iowa Great Lakes region. Stenback and Crumpton (2006) measured dryfall rates of TP to be 0.049 lbs/day, while wetfall TP concentrations were 0.0493 mg/l on average. At 28.3 inches of rain per year, this equates to 12.2 lbs/year. Annual deposition rates were multiplied by the surface area of the creek as determined from aerial photographs.

Table D4. Model lake total phosphorus (TP) budget summary for Lower Gar Lake (metric tons, (% of Total Inputs)) (taken from Stenback and Crumpton, 2006).

	Inputs					Outputs			Annual	Nutrient Mass In
Nutrient	Rain	Dry Dep.	Watershed	Adjacent Lake (Minn. L)	Sediment to Lake Flux	Adjacent Lake (Minn. L)	Lake to Sediment Flux	Milford Creek	Water Column Storage*	Lake Water Column at End of Year
1999	0.02 (<1)	0.04 (1)	1.16 (30)	1.43 (36)	1.27 (33)			3.93 (101)	-0.02 (-1)	0.11
2000	0.02 (5)	0.04 (11)	0.25 (70)		0.05 (14)	0.39 (109)		0.00 (0)	-0.03 (-9)	0.07
2001	0.02 (1)	0.04 (2)	2.08 (82)	0.08 (3)	0.33 (13)			2.51 (98)	0.04 (2)	0.12
2002	0.02 (1)	0.04 (3)	0.39 (31)		0.80 (64)	1.24 (100)		0.01 (1)	-0.01 (-1)	0.11
2003	0.01 (2)	0.04 (7)	0.52 (88)		0.02 (3)	0.59 (99)		0.00 (0)	0.01 (1)	0.11
2004	0.03 (1)	0.04 (2)	1.40 (55)		1.09 (43)	0.13 (5)		2.35 (92)	0.08 (3)	0.20
2005‡	0.02 (1)	0.02 (1)	1.00 (57)	0.70 (40)			0.13 (7)	1.57 (90)	0.04 (2)	0.06

* End of year minus beginning of year mass of TP in the lake water column.
† Two outlier TP concentrations of >0.5 mg/L (one in 2000 and another in 2004) were set to 0.2 mg/L to better match temporally adjacent measurements.
‡ 2005 results are from the more detailed study and are shown here for comparison.

Table D5. Input values for EUTROMOD Loading Function procedure.

2002 Land Cover	Runoff Coefficient	Dissolved TP in runoff (mg/l)	Soil P Concentration (mg/kg)
Open water	1.00	0.00	0
Wetland	0.90	0.00	0
Wet forest	0.15	0.01	500
Coniferous forest	0.15	0.01	500
Deciduous forest	0.15	0.01	500
Ungrazed grasslands	0.23	0.10	500
Grazed grasslands	0.25	0.25	500
CRP	0.23	0.10	500
Alfalfa	0.23	0.15	500
Corn	0.26	0.26	575
Soybeans	0.26	0.26	575
Other Agriculture	0.26	0.26	575
Roads	0.86	0.12	500
Commercial/Industrial areas	0.61	0.38	500
Residential areas	0.50	0.38	500
Barren	0.60	0.25	500

Appendix D --- Images and Maps

Figure E1. Photo of Milford Creek in July 2004 taken by IDNR.

Figure E2. Photo of Milford Creek in July 2005 (courtesy of Dan Eckert, Dickinson County Engineer).

Figure E3. Photos of fish kill in 2006 below Lower Gar Lake dam (courtesy of Glen Petersen, IGLSD superintendent).

Figure E4. Photo of fish kill in 2007 below Lower Gar Lake dam (courtesy of Glen Petersen, IGLSD superintendent).

Appendix E --- Supplemental Study on IGLSD Phosphorus Output (Stenback and Crumpton, 2006)

Brief Analysis of IGLSD and Lower Gar Lake TP Loads

Discharge from Lower Gar Lake was estimated on the basis of the USGS daily lake elevation data at West Okoboji Lake and a discharge equation based on the Lower Gar outflow structure dimensions and water head overtopping the spillway as described by Crumpton and Stenback, 2006.

1. The IGLSD discharge is generally a small fraction of the Lower Gar Lake discharge to Milford Creek when water is flowing. However, there are periods lasting from months to over a year when Lower Gar Lake discharge is zero. During these periods of no flow, the IGLSD (plus any other sources not accounted for here) makes up the entire flow to Milford Creek just below Lower Gar Lake (Figure 1). The difference between IGLSD and Lower Gar discharge TP load (Figure 5) is less extreme because the IGLSD TP concentrations are about one order of magnitude or more greater than Lower Gar Lake water column TP concentrations.

2. There is a correlation between IGLSD discharge and rainfall measured at the NOAA weather station at Milford, IA (Figure 2) with peak IGLSD flows generally occurring during the rainy period in late spring and summer.

3. IGLSD TP concentration is inversely related to IGLSD discharge (Figure 3). This observation in conjunction with item 2 suggests that during wet periods the IGLSD system may be receiving flow from leakage, storm sewers, sump pumps, etc. This can have serious consequences on estimation of TP loads based on the product of average TP concentration and discharge, as described below.

4. The product of discharge and concentration (adjusted for appropriate unit conversions) gives load. The load based on the Feb. 2005 to June 2006 IGLSD data shows a pattern that may be approximated reasonably well using an annually cyclical relationship (R^2 = 0.72, Figure 4; note that a slightly more complicated model that includes discharge together with the cyclical terms provides a minor improvement having R^2 = 0.77). This cyclical pattern may be expected for a population that follows an annual cyclical pattern. To the extent that the local population dynamics are similar from year to year, the cyclical approximation observed for the Feb. 2005 to June 2006 time period may provide a reasonable estimate of typical TP loading from the IGLSD for other years.

5. IGLSD TP load calculated as the product of average TP concentration and daily discharge will not accurately estimate the daily TP load. For the Feb 2005 to June 2006 IGLSD data, daily loads estimated this way are overestimated when flow is high and underestimated during the peak load months of July to September (Figure 4).

6. Daily TP load discharged from Lower Gar is difficult to estimate accurately because there are generally less than seven or eight lake water samples available (to us) per year

and few, if any, were collected during the late fall, winter, or early spring. Lower Gar sample data show lake water column TP concentrations ranging between 0.05 to near 0.3 mg/L during 1999 to 2004, with an estimated flow-weighted average (FWA) of 0.155 mg/L (based on Crumpton and Stenback 2006 nutrient budget modeling). The product of this FWA concentration and daily discharge from Lower Gar gives the estimated TP discharge from Lower Gar to Milford Creek illustrated in Figure 5.

The IGSLD cyclical model and the product of IGLSD discharge and average TP concentration show a similar overall pattern, but the average TP concentration times discharge may severely overestimate load during time periods when the IGLSD discharge is high and may underestimate TP load during other time periods (Figure 5).

<u>Reference</u>

Crumpton, W.G. and Stenback, G.A., 2006, "Estimating Phosphorus Loads for Shallow Lakes: Case Study for Lower Gar Lake, Iowa", Final report submitted to the Iowa Department of Natural Resources, August 2006.

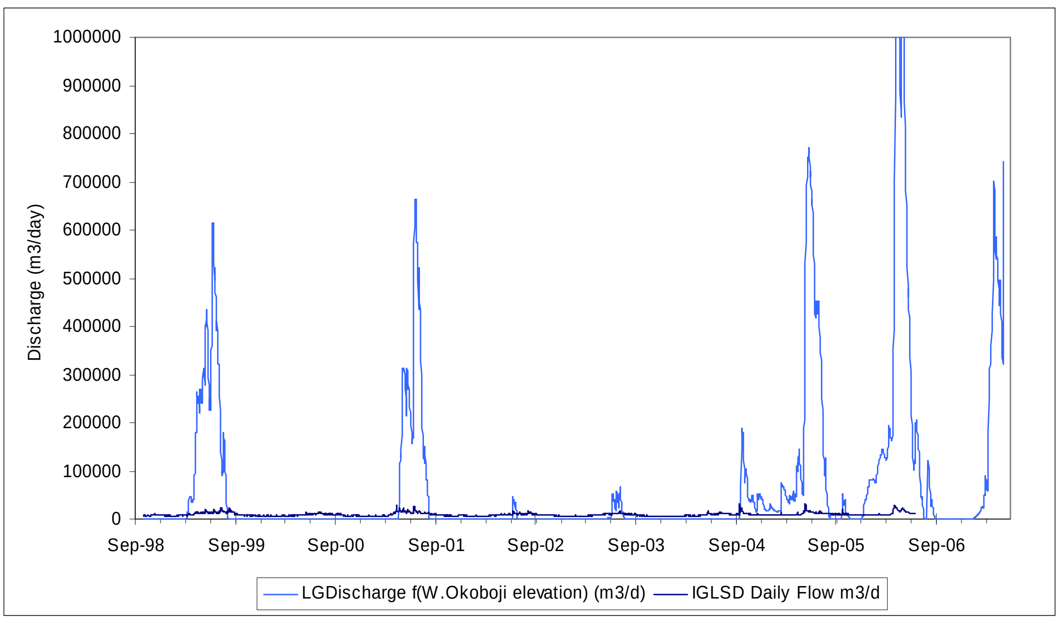


Figure 1. IGLSD discharge (source: Joe Herring, IDNR, 5/8/2007 email) and estimated Lower Gar discharge to Milford Creek based USGS West Okoboji Lake daily surface elevation and a weir discharge equation based on the Lower Gar Lake outflow structure dimensions.

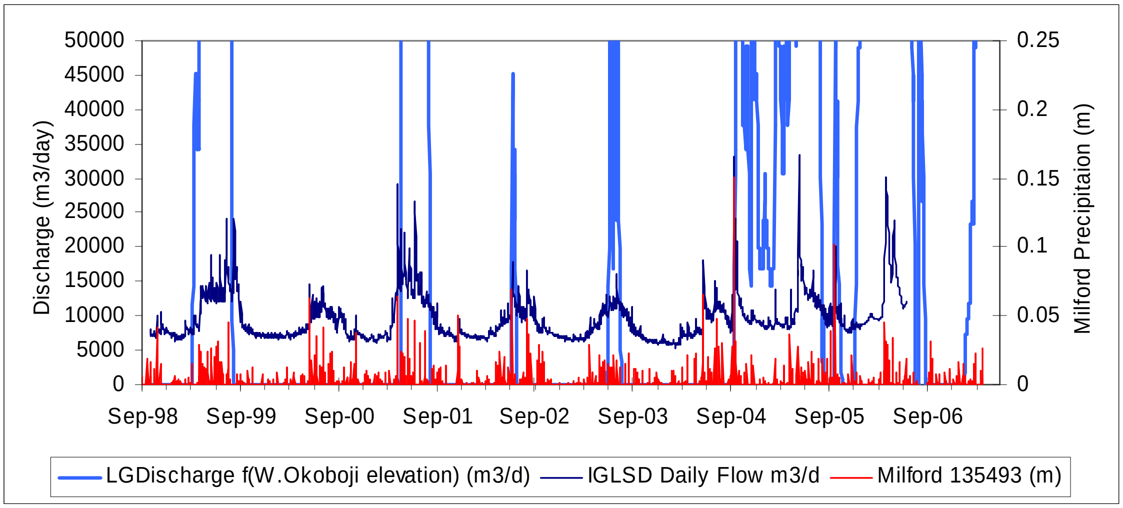
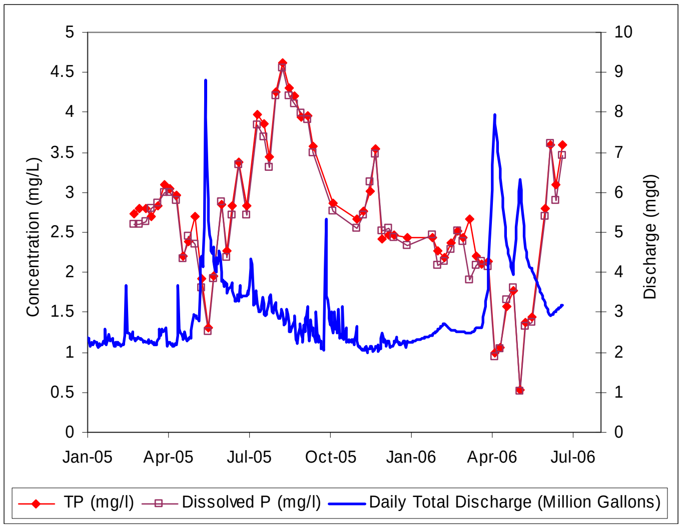


Figure 2. IGLSD discharge, Lower Gar discharge (mostly off-scale) and precipitation at Milford, IA from the NOAA/National Climate Data Center station 135493.



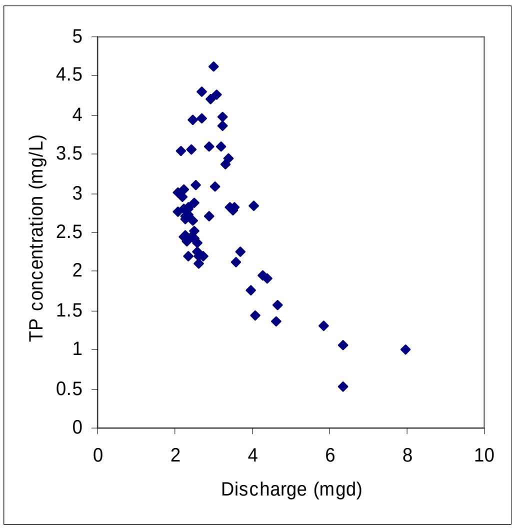


Figure 3. IGLSD TP (and dissolved P from Joe Herring via e-mail) concentration tends to decline as flow increases (left panel) resulting in an inverse relationship to IGLSD discharge (right panel).

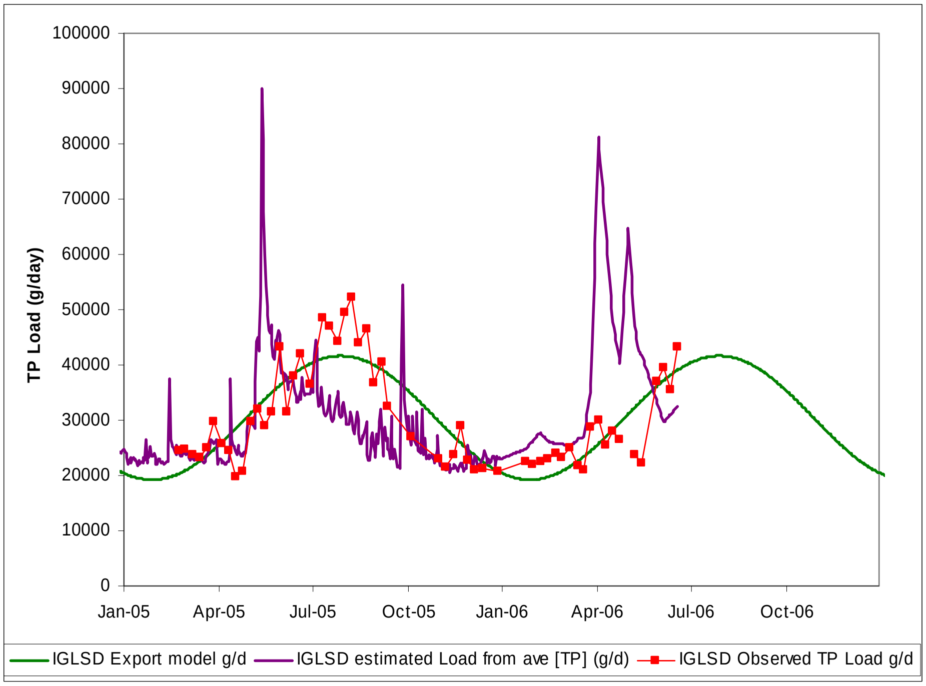


Figure 4. Feb. 2005 to June 2006 IGLSD TP load follows a pattern that is approximately cyclic with an annual period (R^2 = 0.72). TP load calculated as the product of average TP concentration and discharge does not accurately estimate the daily loads as illustrated by load overestimation when flow is high, generally April and May, and load underestimation during July to September.

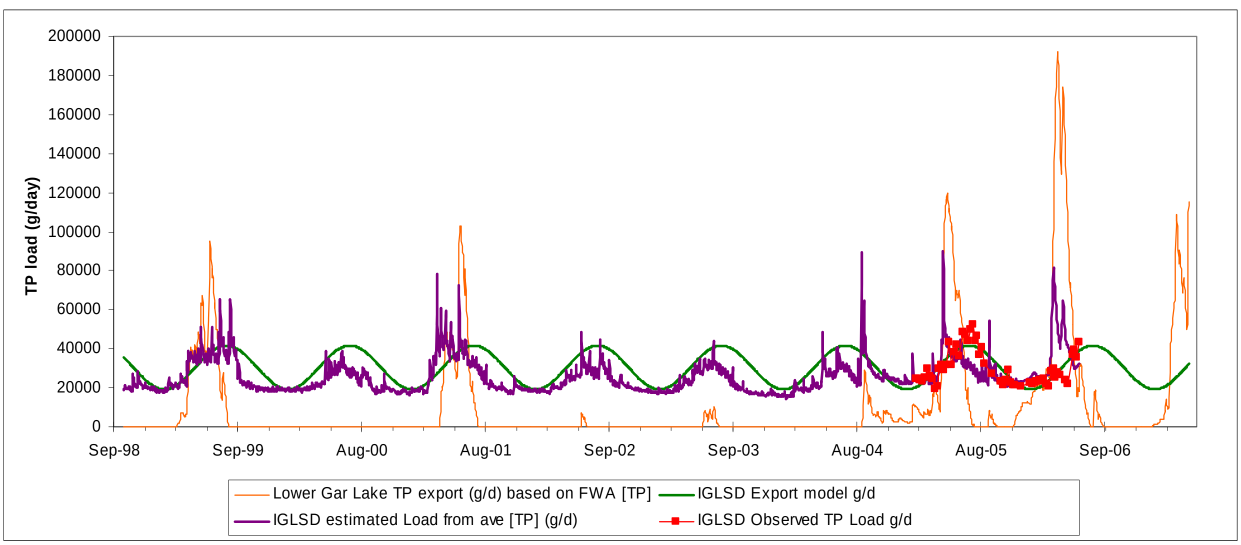


Figure 5. Estimated TP load discharged from Lower Gar Lake (based on model discharge and FWA TP concentration), IGSLD cyclical model extended backward and forward in time, and the product of IGLSD discharge and average TP concentration.

Appendix F --- Public Comments