Ahnapee River Watershed Nonpoint Source Assessment Report

Submitted by Jeffery Kirk & Mary Gansberg

Wisconsin Department of Natural Resources

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I. INTRODUCTION

As recommended in the *Twin-Door-Kewaunee (TDK) Water Quality Management Plan (1995)*, Lake Michigan District DNR monitored streams in the Ahnapee River watershed in 1994 to evaluate the impacts of nonpoint source pollution on water quality. This information, along with existing watershed data, was used to rank the priority of the watershed for selection in the Nonpoint Source Priority Watershed program.

The Ahnapee River watershed lies in southeastern Door and northeastern Kewaunee counties. The watershed primarily consists of the Ahnapee River and its Silver-Rio Creek tributary complex, the Three-Mile Creek and its tributaries, and the Mashek Creek (Figure 1). The approximate length and drainage area of these streams are given in Table 1. Surface-water drainage is mainly southeasterly, influenced by the slope of the bedrock (Poff and Threinen, 1965; Poff and Threinen, 1966).

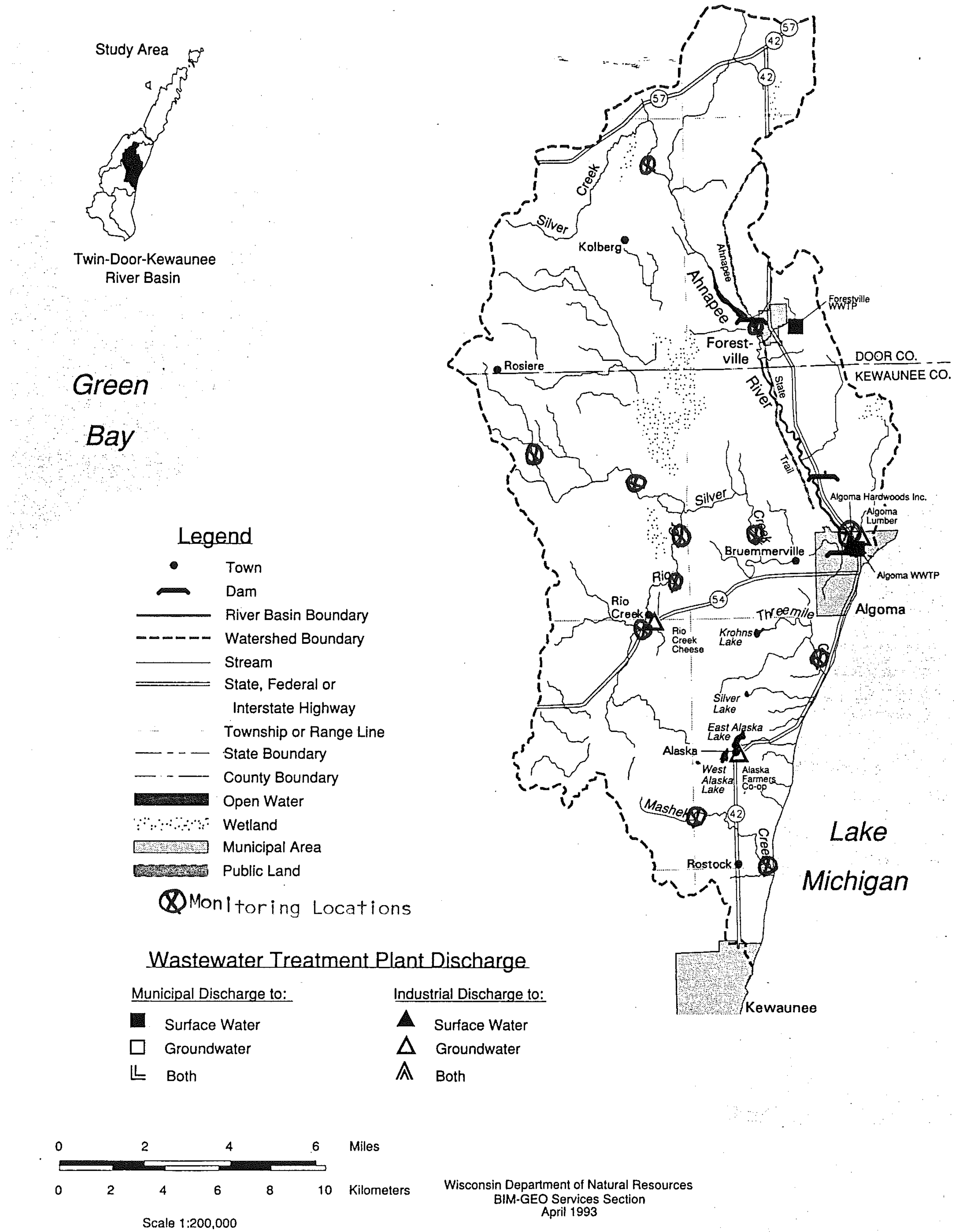
II. BACKGROUND

Niagara dolomite is the principle bedrock under the Door and Kewaunee Counties and also the Ahnapee River watershed. Since dolomite is a soft and brittle sedimentary rock and rich in calcium and magnesium carbonates, it's predominance accounts for the hard waters of this area (Poff and Threinen, 1965; Ibid, 1966).

Soils in this watershed are level to very steep and are well drained to somewhat poorly drained. Soils in the southern half have a medium and moderately fine-textured subsoil underlain by medium and moderately coarse-textured subsoil (Link and Frings, 1980). Soils in the northern half have a loamy-sand to silt-loam subsoil over sandy loam or loam till (Link et al, 1978). The watershed is particularly susceptible to groundwater degradation due to its shallow soils and exposed, fractured dolomite bedrock. Recent monitoring revealed elevated levels of nitrates and bacteria in several wells (Yencha, 1993). This watershed consequently received a high groundwater ranking for selection as a priority watershed project. DNR and the district nonpoint source selection advisory committee have, therefore, been directed to consider the Ahnapee River watershed as a high priority for selection as a priority watershed project because of its 'high' groundwater ranking (TDK Water Quality Management Plan, 1995).

In addition, nonpoint sources of runoff water pollution are also likely degrading water quality in several streams within this watershed due both to the high prevalence of agricultural and pasturing practices and the frequent occurrence of stream bank crumbling (TDK Water Quality Management Plan, 1995). This report summarizes the results of nonpoint source stream basin monitoring activities in the Ahnapee River watershed and uses these data to rank the Ahnapee River watershed streams for

Figure 1. **Ahnapee River Watershed (TK04)**



possible selection in the Nonpoint Source Priority Watershed Program.

III. METHODS AND PROCEDURES

Stream habitat conditions were evaluated throughout the watershed in the spring, summer and fall and recorded on the Stream Habitat Evaluation Form (Ball, 1982). This rates the quality and quantity of habitat available for aquatic organisms.

Aquatic macroinvertebrates were collected in spring and fall throughout the watershed and sent to UW-Stevens Point for sorting and identification. Sample results were evaluated using the Hilsenhoff Biotic Index (HBI) which provides a relative measure of organic pollution loading to the streams (Hilsenhoff, 1987).

Dissolved oxygen and temperature on Silver Creek were measured every one half hour for three consecutive days during summer using a Hydrolab DataSonde 3 submersible water quality logger. Additional water chemistry samples were collected on each stream throughout the watershed in the spring, summer and fall seasons. Samples were chilled on ice and sent to the State Lab of Hygiene for analysis, following Field Procedures Manual protocol (1988).

Using criteria defined in the Department of Natural Resources Planner's Guidance (1991), water quality information on each stream were evaluated so the watershed could be prioritized for possible selection as a priority watershed project. Based on impacts on the water resources from nonpoint sources of pollution, each major tributary stream and the entire watershed was given either a high, medium or low priority ranking. High ranked watersheds will be eligible for selection as a priority watershed project.

IV. RESULTS AND DISCUSSION

The Ahnapee River watershed and monitoring locations are shown in Figure 1. Approximate length and drainage basin area for each of these streams are given in Table 1. A summary of habitat evaluation results, biotic index results and stream classifications for the major streams in the Ahnapee River watershed are also presented in Table 1. Water chemistry results are shown in Table 2.

Table 1: Characteristics of streams within the Ahnapee River Watershed.

Stream	Length (mi)	Watershed Area (mi^2)
Ahnapee River	15	117
Silver Creek	12.8	67

Rio Creek	*8*	*22.2*
Three Mile Creek	*3.2*	*5.7*
Mashek Creek	*5*	*5.9*

A) Ahnapee River, Mainstem

The mainstem of the Ahnapee River located in Door and Kewaunee Counties is a low gradient stream with a 72 acre impoundment at Forestville. It has been characterized as having good water quality and supporting a very good warmwater fishery. Anadromous fish runs have occurred as far upstream as the dam at Forestville. This watershed flows through predominantly agricultural land and wetlands in its 117 square mile watershed. Intensive agricultural practices and the increased prominance of cash crop agricultural communities have caused considerable amounts of nonpoint source sediment and nutrients pollution to reach the watershed's surface waters. In addition, intermittency and stagnation are also major use problems. Periodic shifts in flow due to Lake Michigan seiche effects are common in the lower reaches of this river (Poff and Threinen, 1965; Ibid, 1966; TDK Water Quality Management Plan,1995; Door County Soil and Water Department, 1996).

Water chemistry analysis on the Ahnapee River, conducted on samples collected monthly at CTH 'J' near the town of Forestville, found elevated levels of water pH, hardness and specific conductivity (Table 2). These elevated levels are likely due to both the shallow soils and high carbonate content of the underlying dolomite bedrock. Concentrations of both dissolved phosphorus and total phosphorus frequently exceed or approach the desirable levels, respectively, of 0.01 mg/l and 0.1 mg/l. These exceedences, most prevalent both during the spring-time period of intense snow and ice melt and in the September sampling which followed a heavy rainstorm, imply a high amount of nonpoint source pollution to the Ahnapee. Suspended solids (ss), Biochemical Oxygen Demand (B.O.D.) and bacteria (i.e. MFCC, fecal coliform) were consistently within acceptable levels, though each parameter had displayed the above-mentioned maxima during the spring and fall seasons (especially evident in the September sample when alarmingly high bacteria levels were observed). These seasonal maxima are again indicative of a high level of nonpoint source pollution.

Evaluation of stream habitat on the Ahnapee River (Table 3), conducted in the spring and fall seasons both at an upstream site located near CTH 'H' and a downstream site located at the foot of the town of Forestville millpond near CTH 'J', found habitat conditions to range between good to fair *conditions. The highest habitat ranking was obtained at the downstream site during spring sampling and is primarily due to the relatively high abundance of larger sized stone, rubble and gravel (as compared to the prevalence of sand, muck and silt at the upstream site), greater pool depth and more favorable ratio of pool-to-riffle sections of stream. In contast, the poorest habitat ranking and subsequent largest summer-time decline in stream habitat conditions was also observed at the downstream site, this time obtained during fall sampling, and is mainly due to a relatively large impact of the summer-time decline in stream flow rates and concurrent larger decline in habitat availability. This larger decline in habitat conditions is attributed to the downstream site's limited substrate variability due to its deeper and slower-moving pool-like conditions.*

The macro-invertebrate Biotic Index, evaluated both at the downstream site near CTH 'J' during the spring and fall seasons of 1994 and at the upstream site near CTH 'H' during the spring season, characterized water quality on the Ahnapee River to range between good to fair conditions, with some to fairly significant organic pollution likely. The most abundant invertebrate species in all samples were Ephemeroptera, Trichoptera and Diptera species (Table 4), organisms which generally are considered to be moderately intolerant to water pollution. Despite the similar index ranking, however, a greater impact of nonpoint source pollution loadings in the upstream than the downstream regions of the Ahnapee is indicated both in the relatively low invertebrate species diversity and the comparatively high prevalence of Amphipoda and Isopoda species within the upstream site's spring sampling; it is important to note that it is generally accepted that stream pollution reduces the number of species in that stream, while creating an environment that is favorable to a few (Odum, 1971), and that Amphipoda and Isopoda species are generally considered to be tolerant of and, as such, biological indicators of stagnant, degraded waters. The relatively large impact of nonpoint source pollution at the upstream site is probably due also to the upstream site's smaller channel dimensions and shallower mean depth. This suggestion of a relatively great impact of nonpoint source pollution in the upstream regions of the Ahnapee River is supported both in the observation of intense agricultural and pasturing practices within this area the day of spring sampling and also the inability to collect an invertebrate sample at the upstream site during fall sampling because of the overwhelming abundance of silt and muck. However, recent landuse inventory had suggested a smaller absolute pollution loading of both suspended solids and phosphorus to the upstream than the downstream sections of the Ahnapee (Brown County Soil & Water Conserv. Depart., 1996). The afore-mentioned degraded-water indicator species of Amphipoda, Isopoda and, also, the Simuliidae (black fly) family also contribute a substantial proportion of the invertebrate community at the downstream site during fall sampling; this *latter point is likely due to the Ahnapee's intermittent flow rate and subsequent stagnation.*

SUMMARY: Intermittency and stagnation are the principle factors that limit the ecological integrity of the Ahnapee River. The controllable factors of nonpoint source deposition of sediment and nutrients, likely stemming from this watershed's intense agricultural practices, also substantially degrade this stream's integrity and limit its potential to support trout and other desirable game fishes and other aquatic life. Water chemistry samples near the river's mouth had revealed that elevated levels of both suspended solids and phosphorus are being delivered to Lake Michigan, which are priority items of concern to the Green Bay Remedial Action Plan. The Ahnapee River, therefore, had received a medium priority ranking for possible selection in the Nonpoint Source Priority Watershed Program.

B) Silver Creek

Silver Creek is the largest tributary to the Ahnapee River. It has one tributary, Rio Creek, and a 5.7 acre impoundment near Algoma. Silver Creek has fair to poor water quality due to nonpoint source impacts on its mainstem and on its Rio Creek tributary. Both Rio and Silver Creeks run through intensely agricultural watersheds. Cropland erosion and streambank pasturing have resulted in excessive sediment and nutrient loadings to these streams. Silver Creek has slightly stained water, the result of timber swamp drainage (Poff and Threinen, 1966; TDK Water Quality Management Plan, 1995). The lower 1.5 miles of Silver Creek supports a warmwater sport fishery, while an approximate one-mile portion of Silver Creek above the confluence with Rio Creek has the potential to become a Class II trout stream. Above that area, this creek's fishery potential is limited to a forage fishery due to nonpoint source impacts and flow variability. With control of pollution from nonpoint sources in the Rio and Silver Creek watersheds, however, it is likely that the fishery of Silver Creek has the potential to improve (TDK Water Quality Management Plan, 1995).

Water pH and specific conductance on Silver Creek (Table 5), determined on an hourly basis on two consecutive days in early June, 1994 at a site near Black Ash Road, were found to be rather high. These elevated levels, typical of the hard-water conditions in northern WI, are most likely due to this area's shallow soil and underlying dolomite bedrock. Levels of dissolved oxygen (DO) are rather high also, as compared to the state's warm-water quality standard of 5.0 mg/l. These elevated levels, especially apparent at a downstream location near CTH 'S' in the fall season during stream habitat assessment (Table 3), are likely the result of this stream's excessive nonpoint source nutrient pollution and subsequent establishment of dense aquatic vegetation. This point will be more fully developed in the *following paragraphs. Normal diel variation in oxygen levels is apparent, as both a mid-day maxima of nearly 11.0 mg/l DO and an evening minimum of about 8.0 mg/l are observed. Diel oxygen fluctuations occur as plants produce oxygen in the daylight during photosynthesis and consume oxygen in the evening during respiration.*

Stream habitat conditions on Silver Creek (Table 3), evaluated in the spring, summer and fall seasons at both an upstream location near Black Ash Road and a downstream site near CTH 'S', were found to range between good to fair conditions, characterized by a continuous summer-time decline in habitat conditions. This summer-time decline in habitat conditions is primarily due to a reduced flow rate and subsequent decreased water depth and, to a lesser extent, an increased stream bed and lower stream-bank deposition of silt and concurrent reduced bottom substrate cover availability. The upstream site had experienced the greatest summer-time decline in habitat conditions and is primarily due to the greater impact of stream bed and lower stream-bank deposition of silt, presumedly effectuated both in Silver Creek's excessive sediment and nutrient pollution loadings and the upstream's relatively small mean depth (as compared to the higher prevalence of deeper, pooled waters at the downstream site). The suggested greater impact of nonpoint source pollutant loadings in the upstream reaches of Silver Creek is supported in the poorer ranking of habitat conditions at a further-upstream location near Hawk Road, which again was primarily due to both a reduced flow rate and an increased stream bed and lower stream-bank deposition of silt. Furthermore, the existence of both stained water and extensive substrate-covering of periphyton and, most of all, the summer-time development of a thick mat of floating fragmented algae at the downstream site near CTH 'S', conditions which were not apparent at the upstream site, are likely due to the heavy nonpoint source nutrient loadings to Silver Creek and the influx of the degraded waters of Rio Creek and perhaps of Black Ash Swamp. Excessive nonpoint source nutrient loadings from cropland erosion may also be responsible for the elevated DO values recorded at the downstream site, presumedly due also to the still, pooled waters at this site and the afore-mentioned intense growth of periphyton and floating algae. The temperature value recorded at the upstream site is substantially lower than at the downstream site, which is likely due to this stream's spring-fed source and is representative of the headwater's trout-water classification.

The macro-invertebrate Biotic Index, collected in the spring and fall seasons of 1994 at the same locations described above in habitat assessment, found water quality in the upstream reaches of Silver Creek to range between very good to good conditions, with slight to some organic pollution loading likely. In comparison, the downstream reaches had exhibited poor water quality with significant pollution loadings likely. The upstream invertebrate communities were typically dominated by

Diptera, Trichoptera and Coleoptera species, generally considered to be moderately intolerant to pollution. The downstream populations were primarily composed of Amphipoda and Isopoda species, generally considered to be tolerant of and, as such, biological indicators of stagnant, degraded waters. Also note the relative level of invertebrate species diversity is substantially higher at the upstream site than at the downstream site as the higher abundance of clean-water organisms in the upper reaches of Silver Creek are a result of many species, while the populations in the degraded conditions in the downstream reaches of Silver Creek are dominated by only a few species, commonly indicators of degraded conditions. Again, it is widely accepted that pollution of a stream reduces the number of species found in that stream, while creating an environment that is favorable to a few (Odum, 1971). Therefore, the relatively low Biotic Index ranking and the concurrent low invertebrate species diversity at the downstream than the upstream site appears to mainly be due to the pooled, stagnant waters at the downstream site, rather than to nonpoint source water pollution.

SUMMARY: Intermittency and stagnation are again the primary factors that limit the ecological integrity of Silver Creek. Excessive nonpoint source loadings of sediment and nutrients, likely stemming from both cropland erosion and streambank pasturing, and subsequent excessive growth of phytoplankton and macrophytes also severely impact this stream's ecological integrity and further limit its potential to support both trout and other desirable game fish and other aquatic life. Silver Creek, therefore, does not appear to be reaching its resource potential, because of the controllable influences of nonpoint deposition of sediments and nutrients, and consequently received a high ranking for possible selection in the Priority Watershed Program.

C) RIO CREEK

A wide, low gradient stream with brown water, which drains marsh deposits, woodland and cultivated land through the village of Rio Creek to Silver Creek. Rio Creek has very poor water quality due to excessive sediment and nutrient loadings from bothcropland erosion and streambank pasturing. Intermittent flow and low stream gradient are also major use problems and forage fishesno doubt comprise the present population (Poff and Threinen, 1966; TDK Water Quality Management Plan, 1995).

Evaluation of habitat conditions on Rio Creek, conducted in the spring of 1994 at both an upstream site located near CTH 'K' and a downstream site near CTH 'S' (Table 3), were categorized as good, with the only substantial difference between sampling sites being the slightly better conditions of stream bank protection, channel capacity and concurrent bottom scouring/deposition at the downstream site. Subsequent summer *habitat assessment at both the two stations described above and an intermediary site located near Lincoln Road found habitat conditions had declined to range between fair to poor, with the poorer ranking found only at the upstream site. Both the poor habitat ranking upstream and the concurrent decline in habitat conditions at both the upstream and downstream stream sites are primarily the result of both a reduced flow rate and subsequent reduced water depth and, to a lesser extent, a reduced availability of stream-bed cover. The poorest habitat ranking at the upstream site, then, is also the result of the upstream's relatively small mean depth (as compared to the higher prevalence of deeper, pooled waters at the downstream site). The latter impact of reduced availability of stream-bed cover is attributed to a relatively high rate of stream-bed and lower stream-bank deposition of silt and is probably due to both this stream's relatively small size and intermittent nature and also the afore-mentioned heavy sediment and nutrient loadings from surrounding cropland erosion and streambank pasturing. This point appears to be evidenced in the summer-time establishment of a thick mat of fragmented algae on the stream bed at the upstream locale and also the simultaneous development of large sediment islands or bars which extended into the stream banks. Further support is given in the relatively high levels of both DO and temperature that were recorded at the downstream site during summer sampling, which (similar to the previously-discussed Silver Creek) imply both slow stream movement and intense vegetative growth, which is characteristic of both heavy nonpoint source loading of nutrients and the slow-moving pool-like conditions at this site. The suggested conditions of limited stream flow, relatively great sedimentation rates and large nonpoint source loadings of nutrients and sediment are also presumed to be responsible for the fish die-off that occurred early June, 1994. Also note that relatively low pH values on Rio Creek were observed during summer sampling, which is most likely due to the nonpoint source input of acidic material from decaying vegetative matter from the surrounding forests and wetlands.*

Macro-invertebrate Biotic Index values on Rio Creek, conducted in the spring of 1994 on samples collected at both the upstream and downstream locations described above in stream habitat assessment, had characterized water quality to rank as poor, with significant pollution loadings likely. Isopoda and, to a lesser extent, Amphipoda species (generally considered to be tolerant of and, as such, biological indicators of stagnant, degraded waters) are responsible for a predominant proportion of every invertebrate sample. Poor water quality on the Rio is also indicated in the relatively low invertebrate species diversity, whereas a large proportion is contributed by a single species of Isopoda. A relatively large proportion of the invertebrate community at the downstream site was contributed by Ephemeroptera, Diptera and Trichoptera species, which are generally considered to be moderately intolerant of water pollution; this latter point appears to be due to a *comparatively small impact of the afore-mentioned relatively great nonpoint sediment and nutrient loadings and of water stagnation at the downstream site, likely due to this site's deeper, pooled conditions.*

SUMMARY: Intermittency, stagnation and stream size are the principle factors that limit the ecological integrity of Rio Creek. The controllable influences of excessive nonpoint source deposition of sediments and nutrients, subsequent development of large sediment sand bars and an intensive growth of phytoplankton and macrophytes also substantially degrade Rio Creek's ecological health. A fish kill was also attributed to this heavy nonpoint source pollution and intermitent flow. Primarily due to the substantial nonpoint pollution loadings, which may be controled, Rio Creek had received a high ranking for possible selection in the Priority Watershed Program.

D) Three Mile Creek

Three Mile Creek is a small, moderate gradient stream which intermittently drains from Krohns Lake to Lake Michigan and has fair water quality. The bottom is mainly sand and gravel and the water is slightly stained. About 110 acres of wooded wetland border the stream. Approximately 2.9 miles of the stream upstream from State Highway 42 are classified as Class II trout waters due to the experimental stocking of rainbow trout in Lake Michigan tributaries in recent years. Intermittent flows and nonpoint source impacts from agricultural runoff and streambank erosion are major use problems (Poff and Threinen, 1966; TDK Water Quality Management Plan, 1995).

Evaluation of stream habitat on Three Mile Creek, completed at a downstream site near 10th Road in the spring, summer and fall of 1994, found habitat conditions to vary between good to poor conditions, characterized by a continual summer-time decline. This habitat decline is primarily due to a reduced flow rate and subsequent decreased water depth and, to a lesser degree, an increased stream bed deposition of silt and concurrent reduced availability of stream-bed cover. Relatively low temperatures and elevated DO levels were recorded during habitat evaluation, which is representative of this creek's designation as trout waters. A relatively high pH level was apparent during the first day of habitat evaluation, which is likely due to the high carbonate content of this stream's sand substrate.

Macro-invertebrate Biotic Index values on Three Mile Creek, conducted during the spring and fall of 1994 at the same downstream site described above in stream habitat assessment, had found water quality to be very good, with slight organic pollution likely. Trichoptera species, generally considered to be moderately intolerant of pollution, account for a predominant proportion of the collected invertebrate *communities. Plecoptera and Megaloptera species, generally considered to be very intolerant of pollution loadings, were also present in the fall sampling, which is another indication of this stream's high water quality. However, Amphipoda and Isopoda species (generally considered to be moderately tolerant of and, as such, biological indicators of stagnant, degraded waters) also account for a large portion of the current invertebrate populations. This large representation, which is also reflected in relatively low values of invertebrate species diversity, is likely due to the relatively low flow rate and the subsequent prevalence of stagnant, pooled waters.*

SUMMARY: Intermittency and stagnation are the principle factors which limit the ecological integrity of Three Mile Creek. The controllable influences of nonpoint source loadings of sediment and nutrients, likely due to both cropland erosion and streambank pasturing, also substantially degrade this stream's ecological integrity and limit its potential to support trout and other desirable game fish. Three Mile Creek received a medium ranking for possible selection in the Priority Watershed Program.

E) Mashek Creek

Mashek Creek is a very small, high-gradient stream which drains into Lake Michigan near the Green Bay aqueduct. The stream bed is mainly gravel and its water is good quality and clear. Presumedly forage fishes are the stream's primary inhabitants, though anadromous fish runs from Lake Michigan occur in the lower reach as far as three quarters of a mile above Highway 42. Intermittency is a major use problem (Poff and Threinen, 1966; TDK Water Quality Management Plan, 1995).

Evaluation of stream habitat conditions on Mashek Creek, completed both at a downstream site located near Lakeshore Drive during the spring, summer and fall of 1994 and an upstream site near Meadow Road in the summer of 1994, identified habitat conditions to range between good to poor conditions, with the poorest ranking being observed only at the upstream site during summer sampling. Both the overall poorest habitat ranking at the upstream site and the poorer downstream habitat ranking were recorded during the summer season and are primarily the result of a substantially reduced flow rate and subsequent reduced water depth. Similar to Three Mile Creek, this condition is likely due to Mashek Creek's relatively small size and intermittent nature. The poorest habitat ranking upstream is also largely due to a relatively great amount of streambed and lower stream bank deposition of silt and other fine matter, suggesting a rather large amount of nonpoint source pollution. The lower amount of streambed and lower stream bank deposition of silt and other fine material at the downstream site may also be due to a relatively high rate of streambed flushing, a reflection of the aforementioned high gradient.

Assessment of the macro-invertebrate Biotic Index on Mashek Creek on samples collected in the spring and fall seasons of 1994 at the downstream site near Lakeshore Drive, had found water quality to be good, with slight organic pollution loadings likely. Ephemeroptera, Diptera, Trichoptera and Coleoptera species, generally considered to be moderately intolerant to pollution, were responsible for a predominant proportion of the invertebrate communities. A relatively large portion of the invertebrate samples, though, is contributed by Amphipoda and Isopoda species, generally considered to be moderately tolerant of and, as such, biological indicators of degraded, stagnant waters. Similar to conditions on both Silver Creek and Three Mile Creek, the rather high abundance of Amphipoda and Isopoda species is likely due to Mashek Creek's relatively small size, intermittent nature and resultant high prevalence of pooled, stagnant waters.

SUMMARY: Similar to Three Mile Creek, the primary factors that limit the ecological integrity of Mashek Creek are intermittency, stagnation and stream size. The controllable influences of nonpoint source deposition of sediments and nutrients are also substantially degrading this stream's ecological integrity. However, the relatively steep gradient of Mashek Creek and resultant streambed flushing appear to substantially improve this stream's water quality. Mashek Creek received a medium ranking for possible selection in the Priority Watershed Program.

V) CONCLUSIONS

Nonpoint sources of pollution are evidently impacting each of the watershed streams and limiting the abundance and diversity of aquatic communities. The Ahnapee River, Three Mile Creek and Mashek Creek received medium priority ranking because of localized effects from nonpoint source pollution. Silver Creek and Rio Creek received high priority rankings because of the obvious and significant impacts on the water resources from controllable sources. Applying the priority watershed ranking procedures outlined in the Planner's Guidance (1993), the Ahnapee River Watershed ranked high priority for stream selection in the Nonpoint Source Priority Watershed Program.

VI) REFERENCES

Ball, Joe, 1982. Stream Classification Guidelines for Wisconsin. Wisconsin Department of Natural Resources.

Brown County Soil and Water Conservation Department. 1996. Interim Project Status, Wisconsin Lake Management Planning Grant for the Forestville Millpond.

Hilsenhoff, William. 1987. An Improved Biotic Index of Organic Stream Pollution.

Link, E.G., S.L. Elmer and S.A. Vanderveen. 1978. Soil Survey of Door County, Wisconsin. USDA Soil Conservation Service.

Link, E.G. and S.W. Frings. 1980. Soil Survey of Kewaunee County, Wisconsin. USDA Soil Conservation Service.

Odum, Eugene. 1971. Fundamentals of Ecology. 3rd Edition. W.B. Saunders Co. Philadelphia.

Poff, Ronald J. and C.W. Threinen. 1965. Surface Water Resources of Door County. Wisconsin Department of Natural Resources.

Poff, Ronald J. and C.W. Threinen. 1966. Surface Water Resources of Kewaunee County. Wisconsin Department of Natural Resources.

Wisconsin Department of Natural Resources, 1995. Twin-Door-Kewaunee Water Quality Management Plan.

Wisconsin Department of Natural Resources. Lake Michigan District: Water Quality and Lake Management files.

Wisconsin Department of Natural Resources, 1988. Field Procedures Manual. Draft 2nd Edition.

Wisconsin Department of Natural Resources. 1991. Planner's Guidance: Water Quality Management Plans. Chapter Six.

Yencha, A. 1993. Letter to D. Watermolen, Water Quality Planner. WI Department of Natural Resources, Lake Michigan District Water Quality Management files.

Table 2: Monthly Water Chemistry Analysis on the Ahnapee River during 1994.

Location, Date	Hwy J, 1/24	Hwy J, 2/16	Hwy 42, 3/22	Hwy 42, 4/19	Hwy J, 5/03	Hwy J, 6/09	Hwy J, 7/20	Hwy J, 8/25	Hwy J, 9/27	Hwy J, 10/26	Hwy J, 11/17	Hwy J, 12/27	Mean
pH	9.0	9.5	8.4	8.9	9.0	8.7	8.5	8.4	8.5	8.6	8.6	8.5	8.72
Hardness	410	400	230	290	270	310	270	270	210	340	370	390	313.3
Biochemical Oxygen Demand (mg/l)	1.2	1.2	2.6	2.2	1.2	4.1	3.4	3.0	2.0	< 1	< 1	< 1	2.19
Ammonia Nitrogen (mg/l)	.425	.390	.106	.085	.065	.109	.082	.065	.031	.051	N.D.	.038	.139
Nitrate & Nitrite Nitrogen (mg/l)	4.49	4.40	1.33	0.75	1.57	1.24	0.74	0.56	0.06	2.26	2.64	4.32	1.595
Total Kjeldahl Nitrogen (mg/l)	1.1	1.0	0.8	1.1	0.9	1.1	1.25 *	1.07 *	1.41 *	1.0	0.80	0.64	1.013
Total Phosphorus (mg/l)	0.03	0.04	0.08	0.06	0.03	0.06	0.07 *	0.05	0.088 *	0.025 **	0.02	0.01	0.042
Dissolved Phosphorus (mg/l)	.010	.022	.039	.012	.006	.004	*	.002	.039	N.D.	N.D.	N.D.	.0168
Suspended Solids (mg/l)	2.0	< 2	5.0	10.0	2.0	6.0	9.0	4.0	12.0	N.D.	N.D.	N.D.	6.25
MFCC	< 10	< 10	10	10	< 10	20	*	30	59000	20	10	< 10	8443
Fecal Strep.	< 10	< 10	160	< 10	< 10	< 10	*	10	59000	10	10	60	9875
Conductivity	786	743	420	482	463	575	500	552	285	650	660	730	570.6

N.D - Not detectable; * Holding time exceeded, result approximate; ** Exceed standard of 0.013.

TABLE 3: Water Resource Conditions on streams in the Ahnapee River Watershed during Summer, 1994.

Stream	Location	Date	Stream Habitat Condition	Temperature (°C)	Dissolved Oxygen (mg/l)	pH
Ahnapee River	CTH H	04/14	139, Fair	6.8	11.0	9.11
		09/19	163, Fair	12.5	10.3	
	CTH J	05/02	87, Good	10.2	12.1	
		09/20	176, Fair	22.0	11.8	
Silver Creek	Black Ash Road	03/29	91, Good	1.8	10.4	8.5
		06/14	173, Fair	16.2	9.5	
		09/20	198, Fair	16.6	9.7	
	CTH S	03/29	107, Good	1.3	9.2	8.2
		06/14	122, Good	21.0	> 20	
		09/20	146, Fair	22.0	> 20	
	Hawk Road	09/20	210, Poor			
Rio Creek	CTH S	03/29	103, Good	1.1	9.5	7.8
		06/14	187, Fair	20.0	10.0	
	CTH K	03/29	111, Good	0.4	8.5	
		06/14	211, Poor	20.6	16.4	
	Lincoln Road	07/25	154, Fair	21.4	7.6	
Three Mile Creek	10th Road	04/14	110, Good	9.2	11.3	10.0
		07/25	157, Fair	17.9	7.2	
		09/20	205, Poor			
Mashek Creek	Lakshore Drive	03/29	94, Good	1.2	10.9	8.9
		07/25	158, Fair	18.4	8.7	
		09/20	140, Fair	18.0	9.5	
	Meadow Road	07/25	209, Poor	16.4	7.5	

Table 4: Biotic Index, Species Diversity and Percent Composition of Invertebrate Populations on Select Streams in the Ahnapee River Watershed during Summer, 1994.

River	Ahnapee River			Silver Creek				Rio Creek		Three Mile Creek		Mashek Creek	
Location, Date	CTH J, 05/02	CTH J, 09/20	CTH H, 04/14	Black Ash Rd., 03/29	Black Ash Rd., 09/20	CTH S, 03/29	CTH S, 09/20	CTH K, 03/29	CTH S, 03/29	04/14	09/20	03/29	09/20
Hilsenhoff Biotic Index Rating	5.62, Fair	5.39, Good	5.76, Fair	5.34, Good	4.29, Very Good	7.86, Poor	7.87, Poor	7.94, Poor	7.86, Poor	3.66, Very Good	4.18, Very Good	5.05, Good	4.59, Good
Benthos Species Diversity	1.26	1.02	0.84	1.31	0.99	0.23	0.35	0.58	0.19	0.92	0.82	0.97	0.92
% Ephemeroptera	20	44	27	7	5				6	5	5	6	10
% Diptera	70	10	13	18	5	4		2	9	9	9	11	4
% Trichoptera	6	33	1	35	42	1		2	4	47	24	25	20
% Coleoptera	4	11	5	14	45	5	3			2	8	12	25
% Amphipoda		2	35	10	2		26	5	9	30	50	31	30
% Isopoda		2	13	17		90	69	92	70	3	4	13	11
% Odonata			1									1	
% Gastropoda												1	
% Oligochaeta					1	1			1			1	
% Collembola												1	
% Neuroptera		1											
% Pelecypoda								1		4			
% Hirudinea										1			
% Plecoptera											1		
% Megaloptera											1		
% Hemiptera							2		1				
% Turbellaria								1					

TABLE 5: Diel Water Quality Parameters on Silver Creek during Summer, 1994.

Date	06/07	06/08	06/09	06/10
Number of observations (n)	7	24	24	9
Temperature (°C): Mean (Standard deviation, s)	16.82 (1.16)	15.32 (2.10)	15.33 (2.42)	13.63 (0.64)
Temperature: Maximum/Minim.	18.42/15.09	18.78/12.43	18.99/11.92	14.71/12.84
pH: Mean (Stand. dev.)	8.38 (0.04)	8.41 (0.06)	8.44 (0.07)	8.38 (0.01)
pH: Maximum/Minim.	8.45/8.32	8.51/8.32	8.54/8.35	8.41/8.37
Specific conductivity (uS/cm): Mean (Stand. dev.)	773.9 (5.96)	783.3 (4.19)	790.2 (6.35)	801.0 (3.54)
Specific conductivity: Maximum/Minimum	781.9/765.5	788.8/776.4	799.0/779.7	796.0/805.0
Dissolved oxygen (mg/l): Meam (Stand. dev.)	8.82 (0.74)	9.54 (1.13)	9.43 (1.10)	8.78 (0.57)
Dissolved oxygen: Maximum/Minimum	10.22/8.15	11.46/8.12	11.20/7.90	8.19/9.87
Dissolved oxygen-Percent saturation: Mean (Stand. dev.)	90.41 (10.66)	94.62 (13.36)	93.68 (13.47)	83.79 (4.81)
Dissolved oxygen-Percent saturation: Maximum/Minimum	108.0/80.9	117.8/80.0	116.5/78.5	93.9/79.8