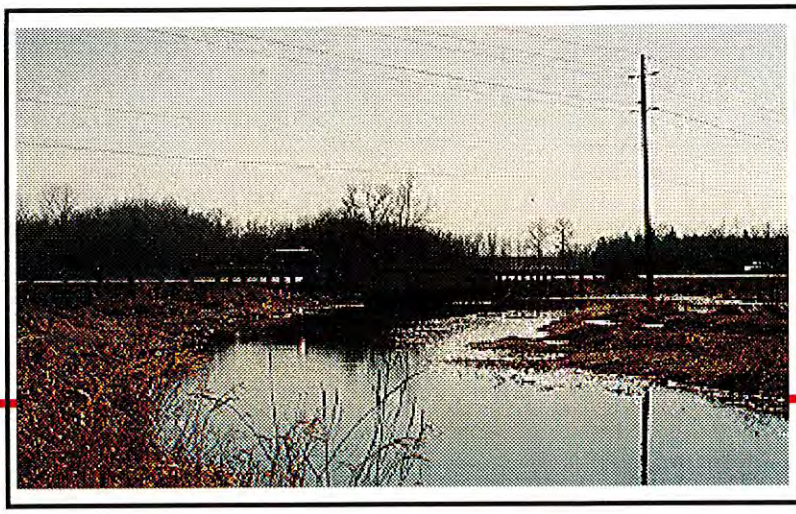

Ulao Creek
Stormwater Management Plan

Prepared for
Town of Grafton,
Ozaukee County Land Conservation Dept.
and
Wisconsin Department of Natural Resources

May 1998

BRAA Project No. 81624

Town of Grafton

WISCONSIN
DEPT. OF NATURAL RESOURCES

The Ulao Creek Partnership . . .

Protecting Ulao Creek
and preserving the unique rural character
of the Ulao Creek Watershed.

Ulao Creek
Stormwater Management Plan

prepared by

Bonestroo
Rosene
Anderlik &
Associates

Engineers & Architects

and

Northern Environmental[SM]

Hydrologists • Engineers • Geologists

ULAO CREEK
STORMWATER MANAGEMENT PLAN

FEBRUARY, 1998

ACKNOWLEDGMENTS

Bonestroo, Rosene, Anderlik & Associates, Inc. acknowledges the Town of Grafton, the Wisconsin Department of Natural Resources, the Ozaukee County Land Conservation Department, and the Ulao Creek Partnership for their time, effort, and assistance in the completion of this Plan.

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EXECUTIVE SUMMARY

BACKGROUND

The inventory of the Ulao Creek Watershed and completion of a comprehensive stormwater management plan stem from efforts by the Wisconsin Department of Natural Resources (WDNR) to control nonpoint source pollution through its priority watershed program. "A Nonpoint Source Control Plan for the Milwaukee River South Priority Watershed Project" and the Ozaukee Land Conservation Department's set of objectives provided the basis for the scope of services and plan recommendations found within this plan. Funding for this plan was supplied by the Wisconsin Department of Natural Resources (WDNR) Nonpoint Source Pollution Abatement Program (70 percent) and by the Town of Grafton (30 percent).

The plan was initiated by the Ulao Creek Partnership, formed in 1996, the Town of Grafton, and the Ozaukee Land Conservation Department. The study was conducted for three primary objectives: 1) to inventory the stormwater conveyance system and natural resources of the watershed, 2) to model water quantity and quality; and 3) to provide alternatives and recommendations for stormwater management in the area.

The 8,212-acre (12.8-square-mile) Ulao Creek Watershed drains north to south and spans three municipal boundaries before discharging into the Milwaukee River: the Village of Grafton, Town of Grafton, and City of Mequon. The Ulao Creek itself is 8.5 miles in length; a dominant feature of the watershed is the 418-acre Ulao Swamp. The Ulao Swamp has been identified as a Natural Area with local significance (NA-3) by the Southeastern Wisconsin Regional Planning Commission in its Natural Areas Plan (Planning Report No. 42). This Ulao Creek Stormwater Management Plan encompasses 6,294 acre of the watershed within the Town of Grafton.

This plan recommends the creation of a holistic view of the entire watershed accomplished through the creation of a Ulao Creek Watershed Stormwater Implementation Committee composed of the municipal engineer or director of public works from the Village of Grafton, Town of Grafton, and City of Mequon, and a representative from the Wisconsin Department of Natural Resources, the Ozaukee County Land Conservation Department, and the Ulao Creek Partnership. This committee should meet semi-annually for short one hour sessions to discuss the progress of implementation of the stormwater plan. These discussions will become increasingly important as all three communities move through the NR 216 Municipal Stormwater Discharge Permit Program.

OBJECTIVES

The primary objectives and general intent of the stormwater management plan were outlined by the Ozaukee County Land Conservation Department. The summarized objectives of this plan are as follows:

1. Reduce flood risks and damages
2. Preserve and improve water quality
3. Reduce erosion, sedimentation, and pollution from surface runoff flows
4. Assess existing and future pollutant loadings
5. Serve as a blueprint for municipal staff to incorporate best management practices for new development
6. Protect and enhance fish and wildlife habitat
7. Provide guidance for preventative measures and for retrofitting of existing drainage facilities to accomplish improved water quality and reduced flooding
8. Promote and improve groundwater recharge
9. Enhance the natural beauty of the watershed and the quality of the primary and secondary environmental corridors (including floodplains, woodlands, wetlands, wildlife and aquatic life habitats, and agricultural lands)
10. Assess existing and forecast future water quantity flows on the main stem.

These objectives were formulated by the Ozaukee County Land Conservation Department and the Ulao Creek Partnership and took into account goals of other stormwater studies and the rural nature of the study area.

PLAN RECOMMENDATIONS

The Ulao Creek Stormwater Management Plan relied upon targeted methods to accomplish these goals:

- an inventory of the watershed and stormwater conveyance system, water quality and quantity modeling,
- analysis of management alternatives, and recommendations to achieve the project objectives.

The watershed was divided into 58 sub-basins and an inventory of 92 drainage structures was taken. Present natural resources were also inventoried, including wetlands, woodlands, fisheries, and groundwater. Finally, existing land use in the watershed was determined from 1995 Southeastern Wisconsin Regional Planning Commission aerial photography; a determination of future land use was based on the Town of Grafton Planned Land Use Map.

Land Use	Land Use Percentages		
	Existing	Future	Recommended
Agricultural	52%	0	0
Open land *	14%	4.5%	4.5%
Residential	13%	69%	61%
Wetlands	12%	(12%)	(12%)
Wooded areas	4%	0	(8%)
Conservancy	(12%)	12%	20%
Commercial	2%	7.5%	7.5%
Industrial	2%	7%	7%

* Open land includes I-43, open fields, pastures, roads, and undeveloped residential and commercial areas.

(%) Values in parentheses represent over-lapped land use categories and are represented by another value for a different land use category.

The following paragraphs outline how the plan meets each of the 10 project objectives.

Flood Reduction

The stormwater management plan proposes to reduce flood and damage risks. It recommends structural water quantity Best Management Practices (BMPs) projects that will store the 100-year future development runoff and release it at the 10-year pre-settlement runoff rate. This plan assures a future, fully-developed Town with significantly reduced flooding and flood damage. Two types of structural quantity BMP are recommended: 1)Town of Grafton projects, and 2) Developer Driven projects. Town projects total $206,300, while developer driven projects total $7.2 million. Also recommended is the protection of existing and proposed 100-year ponding areas.

TABLE 9-1
PRIORITIZED TOWN STRUCTURAL WATER QUANTITY BMP RECOMMENDATION COSTS

POND	TYPE	Town Cost *	WDNR Cost**
PP-51	Modified	$19,500	$10,500
PP-12	Modified	$30,000	
PP-81	Modified	$30,000	
PP-64	Modified	$20,000	
PP-14	Modified	$20,000	
PPP-2	Modified	$86,800	
TOTAL		$206,300	$10,500

*Funding from future sub-basin special drainage fee assessments.
**WDNR cost based on non-point source cost share funding based on existing critical land use in sub-basin and is dependant on funding availability.

TABLE 9-2
DEVELOPER DRIVEN STRUCTURAL WATER QUANTITY BMP RECOMMENDATION COSTS

POND	TYPE	Developer Cost
PP-1a	Modified	$20,000
PPP-21	New	$520,000
PPP-1	New	$488,800
PP-13	Modified	$20,000
PP-29	Modified	$75,000
PPP-3	New	$408,000
Pond 1	Modified	$20,000
PP-27	Modified	$20,000
PPP-4	New	$846,400
PP-58	Modified	$20,000
PPP-20	New	$257,600
PP-91	Modified	$30,000
PP-59	Modified	$40,000
PPP-10	New	$302,400
PPP-11	New	$392,000
PPP-12	New	$408,000
PPP-13	New	$656,000
PPP-69	Modified	$20,000
PPP-30	New	$293,600
PPP-33	New	$332,000
PPP-35	New	$328,000
PP-90	Modified	$20,000
PPP-40	New	$416,000
PP-78	Modified	$30,000
PPP-50	New	$1,256,000
TOTAL		$7,219,800

Water Quality Improvement

The plan preserves and improves water quality by reducing erosion, sedimentation, and pollution of surface runoff. It provides a shopping list of water quality BMPs to be implemented as the land use in the Town of Grafton shifts from domination by agricultural to residential lands. The land use intensity will dictate the type of water quality BMPs to be implemented. For example, structural BMPs, like wet detention ponds for commercial and industrial land uses, constructed wetlands for one-acre lot residential land uses, and less intensive structural BMPs, like grassed swales, for three-acre lot residential land uses will be considered. The implementation of these recommendations will preserve the water quality of the Ulao Creek by configuring stormwater measure-to-filter pollutants in an acceptable level regardless of land use.

The plan estimates an annual existing pollutant loading of 2.16 million pounds of sediment, 3,466 pounds of phosphorous, and 1,754 pounds of lead in the Town of Grafton watershed. Estimates were calculated using WDNR approved unit area loading values for modeled pollutants. Future land use changes will increase the quantity of pollutants entering Ulao Creek and enhance water quality. Planned water quality BMP recommendations, totaling $3.7 million of developer driven expenditures, would reduce the future loading values to less than the existing loading values. This reduction is represented in the following table:

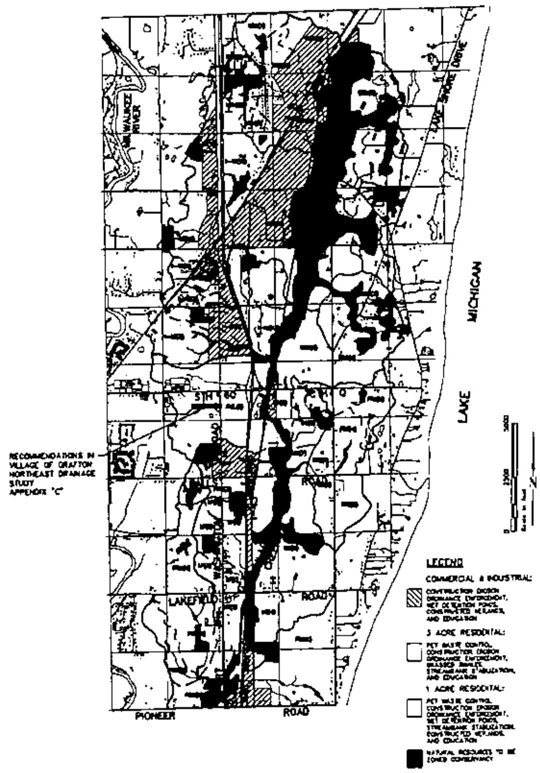
Condition	Sediment (lbs/yr)	Phosphorus (lbs/yr)	Lead (lbs/yr)
Existing	2,161,419	3,466	1,754
Future (% change)	2,873,674 (+33%)	2,705 (-28%)	4,366 (+149%)
With Recommended BMP's (% change)	574,734 (-73%)	1,082 (-69%)	873 (-50%)

Conservancy Zoning

Conservancy zoning designation serves compliance with water quality recommendations by preserving existing natural resources. Currently, 787 acres are designated as planned conservancy; this plan recommends increasing that area to 1285 acres. Included in this area are upland significant woods, primary environmental corridor, secondary environmental corridor, and all wetlands. Zoning to increase the total conservancy and area will protect and enhance fish and wildlife habitat, including the natural beauty of the watershed's water resources, environmental corridors, floodplains, and wetlands.

The plan identifies the Ulao Swamp as the watersheds prominent natural resource feature and recommends the protection of part, parts, or the entire Ulao Swamp. The area could be acquired as a park, nature preserve, WDNR wildlife area, or educational and research center. Stewardship grants, conservation easements, and the purchase of development rights could also be employed to preserve the Ulao Swamp.

The map below illustrates the area in the watershed recommended for conservancy zoning (in black), as well as the breakdown of the watershed by land use for the application of water quality BMPs.



Fish & Wildlife Habitat Protection

The plan outlines 14 special BMP projects for the Ulao Creek Corridor to restore and enhance fish and wildlife habitat. These project are geographically limited to the Ulao Creek and include streambank stabilizations, wetland restorations, and wildlife habitat ponds. The table below describes and ranks the Ulao Creek Corridor BMP projects. These projects will require $420,000 of expenditures by private landowners, developers, Town of Grafton, and WDNR and Federal cost sharing. WDNR cost sharing funds under the Nonpoint Program vary on an annual basis and are dependant on a project ranking in the priority watershed.

ULAO CREEK CORRIDOR BMPs COSTS

RANK	PROJECT	ESTIMATED COSTS
3	CC1 - Stream Rehabilitation at Ulao Creek & Port Washington Rd.	$15,000
4	CC2 - Stream Rehabilitation at Ulao Creek & family farm	$10,000
10	CC3 - Overflow Pond	$60,000
5	CC4 - Stream rehabilitation, clean out & buffer easement north of Lakefield Road	$16,000
6	CC5 - Plantings & streambank rehabilitation near Foxglove Estates	$32,500
9	CC6 - Two habitat ponds east of Foxglove Estates	$60,000
7	CC7 - Plantings along both sides south of CTH Q (Karin Manley farm)	$18,000
1	CC8 - Clean out culvert draining Mr. Z's & Tillman properties	$500

RANK	PROJECT	ESTIMATED COSTS
11	CC9 - Overflow pond on Tews property	$80,000
8	CC10 - Plantings upstream of CTH Q (Helms farm)	$15,000
2	CC11 - Cut back and clean out willows	$500
13	CC12 - Wetland restoration east of CC11	$18,000
12	CC13 - Two habitat ponds (Kaul property)	$60,000
14	CC14 - Wetland restoration of part of Ulao Swamp	$35,000
	TOTAL	$420,500

Drainage Retrofitting

The optimal amount of preventative measures and existing drainage retrofitting for improved water quality and reduced flooding are recommended. Fifty-eight percent of the structural stormwater quantity BMP recommendations are modifications of existing 100-year rain event storage areas. This allows the Town to make use of existing ponding areas. Plans include projects which retrofit culverts, change adjacent topography, or even combine storage areas to gain stormwater storage and reduce flooding. Implementation of these improvements will incorporate the latest in pond design applications to achieve water quality pollution reduction benefits, such as wet pond designs with multiple cells and forebays.

Groundwater Resources Preservation

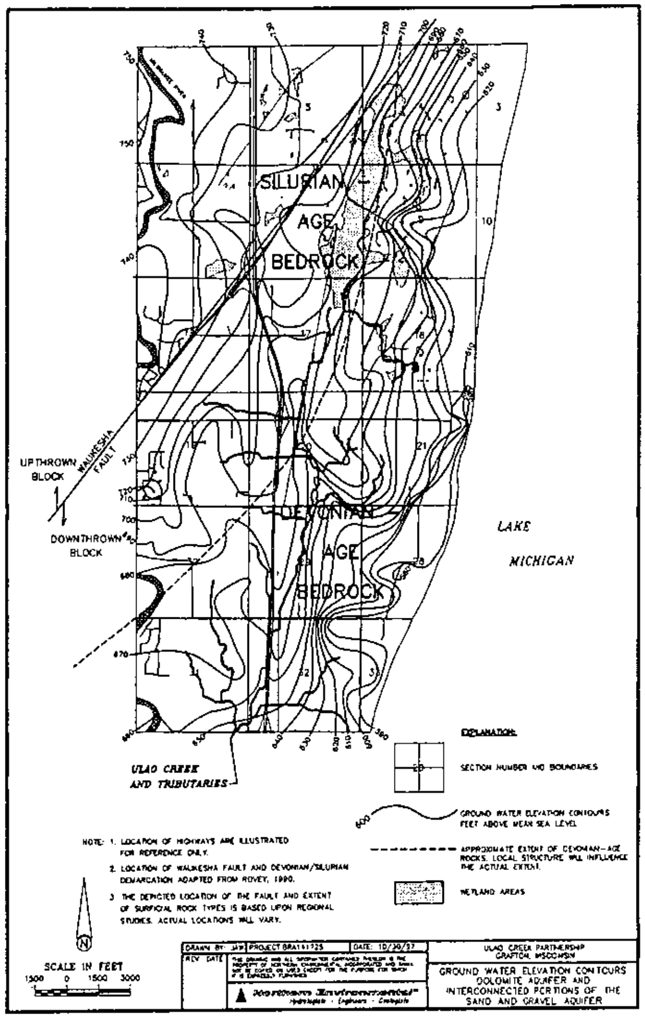
Northern Environmental Technologies, Incorporated, prepared a detailed report on the groundwater resources in the watershed and provides the following recommendations to preserve and improve groundwater resources. The groundwater study intended to increase the dry weather baseflow of the Ulao Creek. Data collected as part of this study revealed an important surface water/groundwater relationship – groundwater discharges to the surface in several areas:

1. The western flank of the Ulao Swamp, particularly north of Ulao Parkway
2. The lowland which parallels Interstate-43 north of Ulao Road
3. Small areas adjacent to Ulao Creek near the intersection of County Trunk Highways W and C

In the following areas, surface water features lose flow to groundwater:

4. Various stretches of the Milwaukee River, especially those upstream of dams and north of the Village of Grafton
5. Eastern portions of the Ulao Swamp
6. Northern-most portions of the Ulao Swamp
7. Ulao Creek between Ulao Road and Falls Road

The map below illustrates groundwater elevations in the watershed. "Groundwater valleys" can be seen draining the groundwater away from the watershed to Lake Michigan.



The plan recommends the Town of Grafton employ a phased approach to increase dry-weather baseflow. Primary attention should be given to options which minimize dry-weather loss of stream flow to groundwater. Specific management options will address:

- lessening the effect of gravel mining and agricultural drainage at the extreme north end of the Ulao Swamp,
- decreasing dry-weather infiltration under eastern portions of the Ulao Swamp, and
- assuring that newly constructed stream channel modifications, wetlands, and ponds are designed to prevent surface-water backflow and infiltrations during dry weather.

Surface-water backflow occurs in dry weather conditions when surface water is "pulled" away from the Ulao Swamp or the Ulao Creek towards the East and down to the water table below the wetland surface or ditch bottom.

In addition to preventing dry-weather loss of surface flow, attention should immediately be given to alternatives which detail flood water's transfer out of the watershed.

Detained stormwater should be released slowly to the creek: through storage in granular deposits paralleling Ulao Creek, a modification of agricultural drainage tile and ditch systems to promote temporary storage in low areas, and the infiltration of water in uplands west of Ulao Creek. Water can be transferred from the watershed by maximizing stormwater infiltration under areas east of Ulao Creek and the Ulao Swamp, and encouraging infiltration in the Ulao Creek floodplain between Ulao Road and Falls Road. After the implementation of management options which decrease dry-weather water losses from the creek and detain stormwater for slow release, the quantity and quality of water in Ulao Creek should be re-evaluated. If water is insufficient during dry periods to reach management objectives, artesian ground-water could be used to supplement Ulao Creek's flow. Most supplemental water is available in the lowlands north of Ulao Road. Wells, interceptor trenches, and/or discharging ponds/wetlands could be developed to promote groundwater discharge.

Implementation

The plan outlines in detail the measures which need to be implemented to achieve the stormwater quantity and quality objectives. These objectives will not be met if the recommendations are not implemented as lands develop. To assure that the Town of Grafton can uniformly implement these recommendations a Stormwater Management Planning Checklist has been created to serve as a blueprint for new development. The checklist will allow the Town to incorporate the recommended stormwater quantity and quality BMPs in the plan for new developments.

Town of Grafton
Stormwater Management Planning Checklist
for New Developments

Property Owner: ____________________

Location: ____________________

Current zoning: ____________________

Planned zoning: ____________________

Sub watershed (size): ____________________

Property size: ____________________

- ❑ Are there any existing or planned 100-year ponding areas on the property and have they been incorporated into the development plan?
- ❑ Are there any zoned conservancy lands on the property (floodplain, corridor, wetlands)?
- ❑ Are the recommended water quality BMPs incorporated into the development plan (wet detention ponds, grassed swales, constructed wetland)?
- ❑ Are there any groundwater issues on the property (refer to Plate 2 - Appendix C) and have they been incorporated into the development plan?
- ❑ Are proper erosion control measures in development plan (silt fence, hay bales, temporary siltation basins)?
- ❑ Are any culverts proposed to be altered or installed on the property?
- ❑ Are there any eroded streambanks on the property?
- ❑ Will the natural drainage of the property be altered to discharge into a new sub-basin?
- ❑ Does the Ulao Creek or one of its eight main tributaries flow through, or abut, the property?

CONCLUSIONS

The Stormwater Management Plan outlines at length the specific steps to be taken to accomplish the project objectives. The implementation of proper stormwater management in the Ulao Creek watershed can be broken down into a series of tasks to be completed. In conclusion, the Ulao Creek Partnership, the Town of Grafton, and the Ozaukee Land Conservation Department should adhere to the following prioritized tasks with recommended schedules:

1. **Adopt the Ulao Creek Stormwater Management Plan as a stormwater planning document (from May, 1998 until the Town is fully developed under the planned land use map),**

2. **Coordinate with Ozaukee County a floodplain study of the portions of the Ulao Creek in the Town of Grafton (Application for WDNR funding has been submitted),**

3. **Adopt the WDNR Model Stormwater Zoning Ordinance, Appendix F (per NR 216 stormwater permit requirements),**

4. **Construct, as drainage problem arise, the Town of Grafton structural water quantity BMP projects (20 years),**

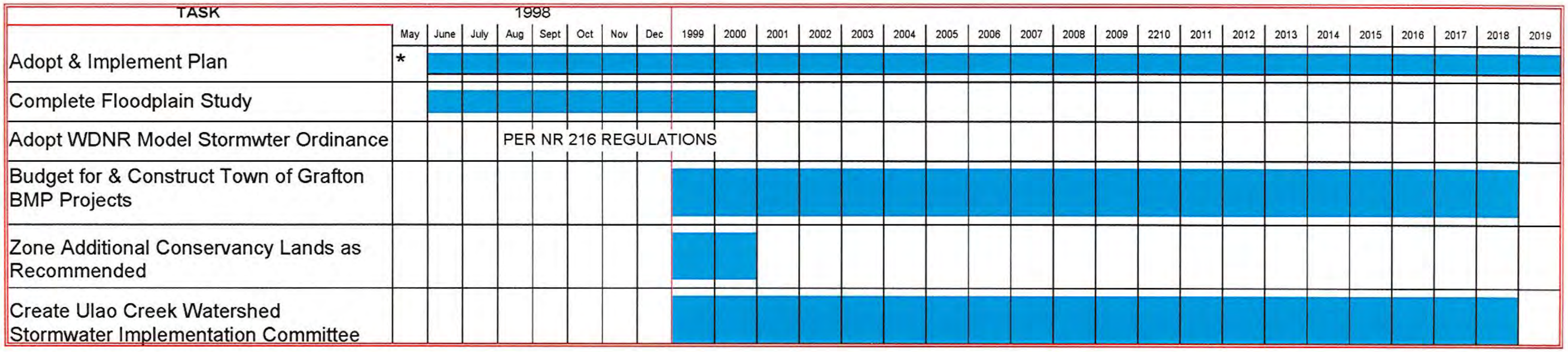
5. **Zone the additional conservancy lands recommended (two years),**

6. **Create the Ulao Creek Watershed Stormwater Implementation Committee (one year).**

The schedule for implementation of the recommendations is important because the funding for the Milwaukee River South Priority Watershed, which encompasses the Ulao Creek, is scheduled to expire on December 31, 1999.

* See schedule on the following page.

Ulao Creek Stormwater Management Plan Implementation Schedule



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F. WDNR Model Stormwater Zoning Ordinance

G. Town of Grafton Stormwater Management Planning Checklist

1) INTRODUCTION

In November of 1996, the Ozaukee County Land Conservation Department sent out a Request for Proposals for the Ulao Creek Stormwater Management Plan. In January of 1997 a contract was awarded to Bonestroo, Rosene, Anderlik, and Associates (Bonestroo) and in April of 1997 contracts were signed. May of 1997 brought about the full scale undertaking of the complete scope of services detailed by the Request for Proposals and the contract. Originally, the Request for Proposals outlined the scope of the plan to encompass the entire Ulao Creek Watershed; however, the final scope divided the watershed into municipal boundaries and corresponding studies (see Figure 1). The Village of Grafton portion of the Ulao Creek watershed was completed by Bonestroo and is attached in this report as Appendix D. The City of Mequon portion of the Ulao Creek watershed is being completed by Camp Dresser & McKee, Inc. and is anticipated to be completed by March of 1998. The Mequon report will be included with this report once it is completed as Appendix E.

The objectives of the stormwater management plan include a true *watershed approach*, a holistic method to stormwater management with an emphasis on protecting and enhancing the natural resources of the watershed. However, the Village and Town of Grafton are experiencing increased stormwater flows in a 6,718-acre watershed as land use shifts from an agricultural to rural residential base (See Map 1).

This stormwater management plan documents existing significant stormwater structures and land use conditions, provides the most accurate representation to date of existing natural resources, and models water quantity and quality for a number of different land use conditions. This plan also looks at the often overlooked groundwater resources that are integrally connected to the surface water resources in the Ulao Creek Watershed. The groundwater analysis and recommendations have been performed with Bonestroo's subsidiary Northern Environmental Technologies, Inc., and represented as Appendix C.

The best management recommendations section details the plan's recommendations for regional stormwater quantity ponds, stormwater quality measures, the Ulao Creek corridor, and a public educational program. The plan's implementation section outlines a timing schedule, cost estimates, financing alternatives, and the multi jurisdictional elements of the plan.

This plan was completed under the guidance of the Ozaukee County Land Conservation Department, the Town of Grafton, and the Ulao Creek Partnership with 70 percent funding provided by a grant from the Department of Natural Resources (WDNR) under the Nonpoint Source Pollution Abatement Program and 30 percent by the Town of Grafton.

The Ulao Creek watershed is part of the Milwaukee River South Watershed, a 157-square-mile basin. The Milwaukee River South watershed was designated a "priority watershed" in 1984 and a nonpoint pollution control plan was completed. Pollution reduction goals for the plan outline a 50 percent reduction in sediment loading, a 50 percent to 70 percent reduction in phosphorus loading, and a 50 percent reduction in heavy metal loading. Management actions, or Best Management Practices (BMPs), are funded by WDNR at different cost sharing levels. BMPs include street sweeping, detention ponds, infiltration devices, stormwater management plans, local enforcement staff for local stormwater ordinances, streambank erosion control, upland erosion control, barnyard runoff control, manure spreading management, education programs, and WDNR support.

This Ulao Creek Stormwater Management Plan takes into account the goals and objectives of the Milwaukee River South Nonpoint Source Control Plan and properly implemented, will achieve these goals and those more specific to the Ulao Creek Watershed.

2) GOALS AND OBJECTIVES

The following objectives were prepared by the Ozaukee County Land Conservation Department and the Ulao Creek Partnership for this plan. From this list, specific goals have been formulated:

A. Reduce flood risks and damages.
B. Preserve and improve water quality.
C. Reduce erosion, sedimentation, and pollution from surface runoff flows.
D. Assess existing and forecast future pollutant loading.
E. Serve as a blueprint for municipal staff to incorporate best management practices for new developments.
F. Protect and enhance fish and wildlife habitat.
G. Provide guidance for preventative measures and retrofitting of existing drainage facilities for improved water quality and reduced flooding.
H. Promote and improve ground-water recharge.
I. Enhance the natural beauty of the watershed and the quality of primary and secondary environmental corridors including floodplain, woodlands, wetlands, wildlife and aquatic life habitat, and agriculture lands.
J. Assess existing and forecast future water quantity flows on main stem.

The goals below were formulated through a series of Ulao Creek Partnership meetings.

A. Provide 100-year floodplain protection for all residents and structures, by storing the future land use condition 100-year storm event and discharging the flow of the 10-year pre-development storm event.
B. Develop a watershed wide water quality education program.
C. Prevent hazardous wastes from entering the stormwater drainage system and the Ulao Creek.
D. Develop a program to ensure the successful operation of the stormwater drainage system.
E. Promote the reduction of phosphorus and other pollutant loadings into receiving water bodies (ponds, ditches, streams, Ulao Creek).
F. Evaluate water quality and update stormwater management practices.
G. Limit phosphorus and other pollutants from development areas to natural concentrations.
H. Equitably finance the construction and maintenance of the stormwater drainage system.
I. Adhere to federal and state watershed policies and regulations.
J. Promote the protection of and improve ground-water resources.
K. Enhance quality of primary and secondary environmental corridors including floodplain, woodlands, wetlands, wildlife and aquatic life habitat.

This list of goals was refined over time and reflects input from a number of different disciplines, including stormwater engineers (Bonestroo), regulators (WDNR), landowners (Partnership members), municipal representatives (Village and Town of Grafton), and the Ozaukee County Land Conservation Department.

3) REGULATIONS

This stormwater management plan was prepared under a cost share agreement with the WDNR and the Ozaukee County Land Conservation Department. The terms of cost share agreements were set forth in the Nonpoint Source Control Plan for the Milwaukee River South Priority River Watershed prepared by the WDNR and the Department of Agriculture, Trade, and Consumer Protection. The Milwaukee River South Plan was prepared under the authority of the Wisconsin Nonpoint Source Pollution Abatement Program. This program, described under Section 144.25 of the Wisconsin Statutes and Chapter NR 120 of the Wisconsin Administrative Code, was set up to fulfill requirements of the 1987 Federal Water Quality Act. The Ulao Creek Stormwater Management Plan is part of "an integrated resource management strategy to protect or enhance our fish and wildlife habitats, aesthetics, and other natural resources."

STORMWATER REGULATIONS

The Federal Water Pollution Control Act of 1972 required industrial and municipal National Pollutant Discharge Elimination System permits. The result is stormwater regulation under Wisconsin Administrative Code Chapter NR 216. This urban stormwater permit program was developed by the Wisconsin Department of Natural Resources (WDNR) and became effective on November 1, 1994. NR 216 was necessitated by the federal Water Quality Act of 1987 to control pollutants in stormwater discharge. The federal regulations impose requirements on certain stormwater discharges from industries, construction sites, municipalities with populations over 100,000[1], and certain other municipalities as described below.

Like the federal program, Wisconsin's stormwater program regulates stormwater discharges from industrial, construction sites, and certain named municipalities. The state's program cannot be more stringent that the federal stormwater regulations.[2]

To date, the City of Milwaukee and the City of Madison (which each have a separate municipal storm sewer system serving an incorporated area with a population of 100,000) have obtained municipal stormwater permits. In addition, municipalities must apply for a stormwater permit if they have either:

1. a separate storm sewer system serving an incorporated area with a population of 50,000 or more and are located in a priority watershed. These municipalities are Eau Claire, Racine, Waukesha, and West Allis.

---

[1] Lawrie Kobza, 1995, *Wisconsin Environmental Law Journal*, reprint Article, "Controlling Stormwater in Wisconsin: Municipal Considerations and Strategies," (University of Wisconsin Law School), p. 2.

[2] Kobza, p. 5.

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2. located in a "Great Lakes Area of Concern." These municipalities are Green Bay, Allouez, Ashwaubenon, DePere, Marinette, Sheboygan, and Superior.

Additional municipalities also may be required to obtain a stormwater permit if one of the above municipalities petitions to have neighboring municipalities designated for coverage under the stormwater program. The WDNR must approve this designation.

Also, the WDNR on its own initiative, may require municipalities to obtain a stormwater permit if the DNR determines that the municipality either contributes to a violation of a water quality standard or is a significant contributor of pollutants to waters of the state.[3] Under this NR 216 provision, over 35 municipalities in southeast Wisconsin have recently been designated as required to submit a stormwater permit application to the WDNR. An incomplete list of Municipalities is as follows:

Brookfield	Glendale	South Milwaukee
Brown Deer	Greenfield	St. Francis
Butler	Menomonee Falls	Thiensville
Cudahy	Mequon	Wauwatosa
Elm Grove	Oak Creek	West Allis
Fox Point	River Hills	West Milwaukee
Germantown	Shorewood	Whitefish Bay

The Town of Grafton was designated for stormwater permitting on December 12, 1997, along with three other additional municipalities.

The following section will provide an overview of urban stormwater regulations.

NR 216

In 1990, federal regulations were enacted to control pollutants in stormwater discharge through permits aimed at promoting pollution prevention and best management practices. Acting on the federal regulation, the WDNR drafted Wisconsin Administrative Code Chapter NR 216. NR 216 defines who needs stormwater permits under the Wisconsin Pollutant Discharge Elimination System (WPDES).

The goal of NR 216 is to achieve reductions in runoff pollution on a watershed basis.

Based on federal regulations, there are three types of permits and legislation NR 216 contains a subchapter for each permit category:

1. Municipal
2. Industrial
3. Construction Site Soil Erosion Control

[3] Kobza. p. 6.

Each subchapter identifies where the permits are applicable, the application process, permit requirements, the annual fee for municipal and industrial permitees, and the application fee for construction site permitees.

The permits for municipalities emphasize information gathering, proposed management programs, monitoring, education, and implementation of management programs to prevent pollution.

Construction Site Soil Erosion Control Permits are required if the area of disturbance is five or more acres. The property owner is required to file a Notice of Intent and develop and comply with a plan that addresses erosion control and stormwater management. The plan must be in compliance with criteria outlined in the *Wisconsin Construction Site Best Management Handbook.*

Industrial facilities also are required to procure a permit. The permits are set up on a three tier basis depending on the type of industry. Industries also are required to prepare and implement a stormwater pollution prevention plan. The industry still will be required to secure any additional WPDES permits for non-storm discharges.[4]

Wetland Regulations

Wetlands are described as lands with hydric soils, hydrophytic plants, and hydrology that promotes the dominance of hydrophytic plants. Depending on size and location of the wetland to a navigable waterway, different regulations apply. A federal jurisdictional wetland is one that is on or adjacent to, including headwaters of, a navigable waterway. This includes isolated wetlands. The U.S. Army Corps of Engineers (COE) has jurisdiction of the dredging or placement of fill into navigable waters of the United States under Section 404 of the Clean Water Act. The WDNR has veto power over issuances of a COE Section 404 Permit to dredge or discharge under Section 401 of the Clean Water Act. In Wisconsin dredging and discharges are performed under the water quality certification process.

An alternative analysis must provide sufficient information to the WDNR to issue water quality certification and validate all COE permits. There are of course some exceptions to this process, like modification of existing structures, utility crossings, and cooperative projects with the Wisconsin Department of Transportation. In almost all cases however, if an area of land has met the requirements to be defined and identified as wetland, it will be regulated by the COE and/or the WDNR.

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[4] Wisconsin Department of Natural Resources, Bureau of Wastewater Management, *The Impact of Stormwater*: NR 216 Addresses the Problem, Wisconsin Department of Natural Resources Publication, July 1994.

Shoreland Zoning

NR 117: Chapter NR 117 of the Wisconsin Administrative Code requires municipalities in Wisconsin to place wetlands within shoreland areas under the shoreland/wetland zoning designation to ensure the preservation of many wetland areas within the region and throughout the state. By law, shorelands are defined as all areas located within 1,000 feet of the ordinary high-water mark of a navigable lake, pond, or flowage, or within 300 feet of the ordinary high-water mark of a navigable river or stream, or to the landward edge of the floodplain, whichever distance is greater. Shoreland/wetland zoning regulation and any subsequent proposed amendments are subject to review and approval by the DNR, thus making wetland zoning applicable both locally and statewide.

Other Regulated Activities

Grading constitutes another common activity regulated by the WDNR. Grading is regulated by the WDNR under a Chapter 30 Permit when in excess of 10,000 square feet and on the bank of a navigable waterway. A bank is defined as the unbroken slope to the navigable water. All construction projects affecting more than five (5) acres also are required to obtain an erosion control stormwater permit from the WDNR.

Zoning changes are regulated by the Town of Grafton and lands must be petitioned for rezoning. Future changes to zoning varying from the Town of Grafton Planned Land Use map will result in changes to the water quantity and quality results of this report. Changes to the quantity results would be negligible unless very large areas were proposed to be rezoned. Changes to the water quality results would be more significant and would require amending land use areas on Map 17, changing the water quality Best Management Practices recommendations for the rezoned area.

Floodplain filing is also a regulated activity of the WDNR and the Federal Emergency Management Association (FEMA). Any alternation of the floodplain requires a permit from both agencies as well as the local unit of government.

4) ULAO CREEK INVENTORY

PHYSICAL SETTING

The Ulao Creek Watershed encompasses 8,212 acres (12.8 square miles) and the Ulao Creek is approximately 8.5 miles in length (See Figure 1): 6,294 acres of the watershed is in the Town of Grafton (See Map 1, Appendix B), 425 acres in the Village of Grafton, and 1,493 acres in the City of Mequon. The Town of Grafton watershed (the Watershed) has been divided into three segments: north, middle, and south (See Maps 2,3,4 and Appendix B). The study area of the Village of Grafton Northeast Drainage Study constituted 560 acres. This study is presented in Appendix C. The differences in the Village areas are attributed to the fact that the Village's Northeast Drainage Study includes some areas that will be in the Village in the future and are not currently developed. The results of the City of Mequon - Ulao Creek Stormwater Management Study are not currently available, but will be presented in Appendix D once completed.

The Ulao Creek can be divided into four segments comprised of 1.75 miles in Mequon, 4.25 miles in the Town of Grafton, 1.25 miles through the Ulao Swamp, and 1.25 miles upstream from the Ulao Swamp. Also, a 1.5-mile major tributary to the Ulao Creek runs parallel to Interstate Highway-43 (I-43) and contributes flows to the Ulao Creek. Much of this tributary has been ditched and culverted under and along I-43. The I-43 area is mostly roadway and zoned commercial/industrial land use with some agricultural and residential. Most of the Watershed is rural in nature with currently a large percentage in agricultural production.

In terms of topography, the long narrow watershed sits on top of the Lake Michigan bluff with Lake Michigan 120 feet below to the East and the Milwaukee River 50 feet above to the West. The high point in the watershed is in the northwest corner at 805 feet and the low point is 660 feet at the confluence with the Milwaukee River. The Ulao Swamp is roughly at elevation 700. The Watershed is roughly bound by Sauk Road to the north, East River Road and River Bend Road on the west, County Trunk Highway C (CTH C) to the east, and Pioneer Road to the south.

EXISTING CONDITIONS - LAND USE

The existing land use conditions are presented in Table 1, Appendix A. These conditions reflect the land use as depicted by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) 1995 aerial photographs. The entire Watershed and sub-watersheds were measured using Ozaukee County digital topographic maps. The sub-watersheds were then broken up by land use categories and areas were individually measured using a planimeter to determine totals for each land use category. The following land uses were determined:

Table 4-1
Existing Land Use

Land Use	Percentage of Area
Agricultural	52%
Open land *	14%
Residential	13%
Wetlands	12%
Wooded areas	4%
Commercial	2%
Industrial	2%

* Open land includes I-43, open fields, pastures, roads, and undeveloped residential and commercial areas.

DRAINAGE STRUCTURES

A total of 92 structures were identified in the Watershed. The sbu-watersheds are further broken up into 52 smaller drainage areas called sub-basins. These structures (culverts, box culverts, bridges, etc.) are presented on Maps 5,6,7 Appendix B and in Table 1 of Appendix A. Seventeen structures were previously identified in the Village of Grafton Northeast Drainage Study, including the Ulao Creek bridge under County Trunk Highway (CTH) Q, and the railroad bridge immediately south of CTH Q (See Appendix C). The sub-watershed boundaries were delineated based on topography, roads, structure locations, and reference to the main stem of the Ulao Creek. Major hydrologic structures on the Ulao Creek include the bridges at Pioneer Road and Port Washington Road, bridge under I-43 south of Lakefield Road, bridge at Lakefield Road, the box culverts under Falls Road and CTH Q, and numerous crossings under the Chicago and Northwestern Railroad.

WATERWAYS

The Ulao Creek is 8.5 miles in length from the Milwaukee River to its headwaters 1.5 miles northwest of the Ulao Swamp. Photographs 4-1 through 4-6 below, visually depict the Ulao Creek from Port Washington Road to upstream of the Ulao Swamp. The entire length of the Ulao Creek was walked by Bonestroo field staff during April 1997. The creek was assessed to determine and identify areas of erosion, nonpoint source pollution, fish migration barriers, and the general nature of the creek's condition.

Photo 4-1 -- Ulao Creek Upstream of Port Washington Road
(Looking North)

Photo 4-2 -- Ulao Creek Upstream of Lakefield Road
(Looking North)

Photo 4-3 -- Ulao Creek Upstream of Falls Road
(Looking South)

Photo 4-4 -- Ulao Creek Upstream of CTH Q near Helms Property
(Looking North)

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Photo 4-5 -- Ulao Creek in the Ulao Swamp near the Kaul Property
(Looking North)

Photo 4-6 -- Ulao Creek Upstream of the Ulao Swamp
and Downstream of STH 32 (Looking West)

There are 13.4 acres of surface water bodies in the watershed.

Eight major tributaries, totaling approximately 9.3 miles of streams, that flow into the Ulao Creek (See Maps 5, 6, and 7). The largest of these is a two-mile, two-forked stream north of Pioneer Road and west of Port Road. Smaller in length are the I-43 stream immediately east of I-43 and the agricultural stream north of Pioneer Road and east of I-43, both of which are 1.5 miles long.

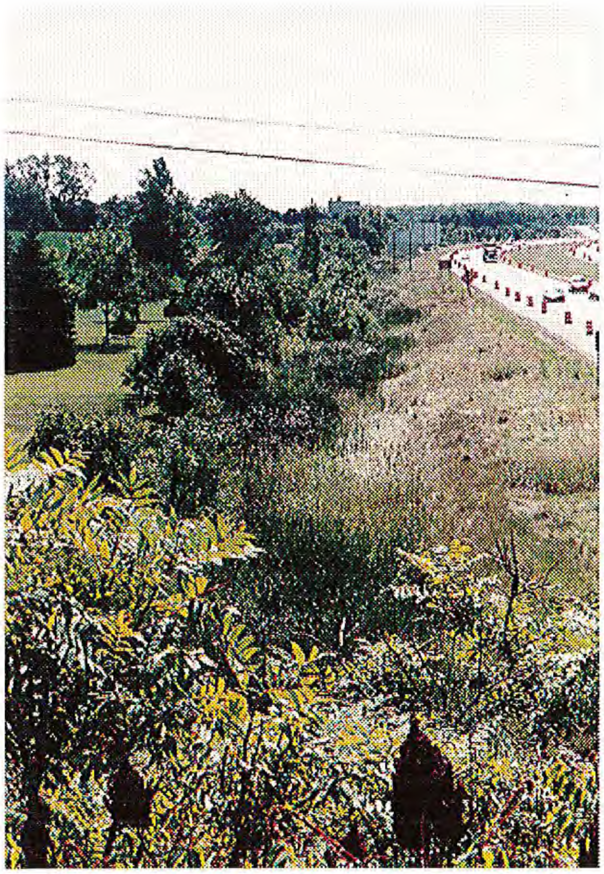

Photo 4-7 – I-43 Tributary to Ulao Creek
(looking south from Arrowhead Rd. Overpass)

Photo 4-8 -- Pioneer Road Tributary to Ulao Creek
(Looking East from RR)

The remainder of the tributaries range from 0.7 to 1.1 miles in length. All of these tributaries have undergone significant ditching and straightening confirmed during the creek inventory walk. Significant bank erosion and loss of bank vegetation on all tributaries to the Ulao Creek have resulted. These tributaries are also in areas that will develop in the future and be significant sources of sediment loading to the Ulao Creek during construction activities. Best Management Practices for construction sites and inspection of sites during construction is the single best available measure to reduce sediment loading to the Ulao Creek from new construction activities. Steps can be taken to reduce the impacts to the Ulao Creek, as well as to enhance the tributaries themselves. These steps are outlined in the Creek Corridor section of the Best Management Practice Recommendations.

Navigable tributaries and navigable bodies of water are identified on Maps 5, 6, and 7 in Appendix B. Identified points of navigability were taken from an Ozaukee County Environmental Health Department working base map for shoreland zoning and navigable waters; however, these data should not be considered absolute or complete. Additional navigable tributaries may be present in the watershed.

FLOODPLAIN

Analysis of the Ulao Creek WDNR floodplain model has been eliminated because it was not a complete floodplain model. The incomplete nature of the model resulted in the Village of Grafton funding, with developer's contributions, a floodplain study to determine the floodplain of the Ulao Creek within Village limits. Funding to complete the remainder of the Ulao Creek floodplain study, within the Town limits, has not occurred but is highly recommended.

As part of the Northeast Drainage Study for the Village of Grafton, the floodplain of the Ulao Creek was studied for the effects on proposed stormwater management practices. When the process to prepare the Northeast Drainage Study began in January 1997, a WDNR model to calculate the floodplain in the Ulao Creek was well underway. Because of technical complications, the WDNR floodplain model was never completed.

In June of 1997, the Village of Grafton hired Bonestroo and Associates to complete a floodplain analysis of the portion of the Ulao Creek passing through Village limits as an addendum to the Northeast Drainage Study. The preliminary results of this study have been presented to Village officials and adjacent landowners. Discussions are progressing with the WDNR as they pertain to the use of flow data generated with the Best Management Practices outlined in this report for acceptance as the floodplain model. After accepted flows are agreed upon, the floodplain model will be completed and the Village of Grafton Northeast Drainage Study can be finalized. Please refer to Appendix D for a draft copy of the Floodplain Study in the Village of Grafton Northeast Drainage Study.

SOILS

Soils in the Ulao Creek Watershed belong to two major soil associations: the Kewaunee-Manawa association in upland areas and drainage ways and the Houghton-Adrian association along the Ulao Creek. The most dominant soil type in the watershed is KnB-Kewaunee silt loam, 2-6 percent slopes. Other members of the Kewaunee series also account for significant upland acreage.

The Kewaunee series soils are nearly level to steep, well drained, composed mostly of loam, and are indicative of uplands. The Kewaunee soils do have poorly and very poorly drained soils as inclusions, which can be seen by the many perched wetlands in upland woods or fields.

The Manawa series soils, MaA-Manawa silt loam, are nearly level to gently sloped, somewhat poorly drained, and indicative of drainage ways. The Manawa series soils have historically been drained for agricultural activities in Ozaukee County.

The Houghton-Adrian association compose most of the soils in the north half of the Ulao Creek floodplain. The two soils that make up this association, Hu-Houghton mucky peat and Ak-Adrian mucky peat, are very poorly drained organic soils.

The south half of the Ulao Creek floodplain is dominated by soils in the Fabius series and Sebewa series. Fabius loam-FaA is a somewhat poorly drained soil associated with drainage ways and outwash terraces. Sebewa silt loam-Sm is poorly drained and occupies drainage ways and depressions.

The hydric soils in the Watershed are depicted as the blue shaded soils on Map 8, Appendix B. This map and soil information was compiled using the United States Department of Agriculture Soil Survey of Ozaukee County and a list of hydric soils for Ozaukee County produced by Dave Roberts of the Natural Resource Conservation Service.

The majority of the hydric soils are not suitable for development, especially poorly drained urban sub-classes. Some what poorly drained soils are suitable, if not wetland, for many rural development applications.

Northern Environmental analyzed the granular soils in the watershed for the groundwater study. Appendix C, and Plate 2 detail the location of these soils.

WETLANDS

The wetlands in the Watershed are a result of two major factors: 1) the drainage and soils associated with the Ulao Creek and its tributaries, and 2) isolated shallow sloped poorly drained soils in woods, agricultural fields, and open areas. Wetlands in the Watershed were identified through a combination of information from the Wisconsin Wetlands Inventory map, USDA Soil Survey, SEWRPC 1995 Land Use Inventory aerial photographs, and the Ozaukee County digital two foot contour topographic maps. This information was then field checked during the inventory of the Ulao Creek. The results of this analysis are presented in Maps 9, 10, 11 in Appendix B as the wetlands in the Watershed.

These maps are the most accurate depiction of the wetlands in the Watershed without completing a detail wetland inventory or field delineating each wetland. These wetlands were identified primarily by air photo interpretation based on vegetation, visible hydrology, and hydric soils information. Some areas were field-checked, however other boundaries may be depicted slightly differently when field delineated. Field delineated wetlands surveyed by a registered land surveyor would be the most accurate depiction of a jurisdictional wetland which can be regulated by the government. These wetlands represent wetland boundaries at the time of the inventory and are not meant for regulatory purposes.

Wetlands account for 769 acres of the 6294 acres in the Watershed, or 12 percent of the Watershed. Comparatively, the entire Milwaukee River South watershed has only 4 percent wetlands. This demonstrates the high concentration of wetlands in the Ulao Watershed, and the need for preservation or protection of these resources.

The continental United States has on average lost 53 percent of its wetlands. Wisconsin is no exception to this average and has about 46 percent of its wetlands remaining (Dahl, 1990). Wetlands perform important functions and provide significant values for the Watershed. Important wetland functions include:

- storm and floodwater conveyance and storage,
- groundwater discharge and recharge,
- reduction and storage of pollutants,
- shoreline and streambank erosion protection, and
- fish and wildlife habitat.

Wetland values include:

- recreational opportunities,
- educational and research opportunities, and
- open space and aesthetics.

Hunting and fishing, as recreation, are important sources of revenue in Wisconsin from residents and tourists.

The largest of these wetlands is the Ulao Swamp in the northern portion of the Watershed. The Ulao Swamp area is very flat and in close contact to the water table. Photographs 4-9 and 4-10, following, show two views of the Ulao Swamp, south of Ulao Parkway.

Photo 4-9 -- Dense Cattail Stand with Young American Elm and Green Ash in the Ulao Swamp.

Photo 4-10 -- Ulao Swamp Survey Transect through Cattails, Marsh Marigold, and Dead American Elm

The Ulao Swamp also receives significant groundwater discharge evident by numerous springs on the west side. Northern Environmental completed a detailed groundwater report, Appendix C. A spring can be seen in photograph 4-11.

Photo 4-11 -- Spring Discharging on the West Side of the Ulao Swamp and West of the Railroad on WEPCo Property

The Ulao Swamp has an abundance of groundwater indicator plant species such as marsh marigold, sneezeweed, angelica, and skunk cabbage. The Ulao Swamp is 418 acres in size, accounting for 52 percent of the 769 acres of wetlands in the Watershed. Ten sub-watersheds, or 17 percent of the sub-watersheds, account for 626 acres (81 percent) of the total wetlands in the Watershed.

The south part of the Ulao Swamp was surveyed to help determine the feasibility of releasing water from artesian wells or springs on the Wisconsin Electric Power Company (WEPCO) ash landfill property. The WEPCO property is located west of STH 32, east of the CN&W Railroad, and south of Ulao Parkway. The survey was performed through compilation of data from numerous east-west transects across the Ulao Swamp. The survey area itself was immediately east of the WEPCO property to the southern terminus of the Ulao Swamp and included about the first half-mile of the Ulao Creek south of the Ulao Swamp. The results of this survey are presented in Map 12, Appendix B. The augmentation of base flow in the Ulao Creek was the driving force behind the feasibility study. Analysis determined that reducing dry weather base flow loss is more feasible than augmentation. Also, base flow augmentation may only result in increased dry weather losses.

Analysis indicates that piping the water from the springs to the bank of the Ulao Creek and releasing it through a float controlled valved would be the most efficient mechanism to convey groundwater to the creek in time of low flow. This alternative may prove to be costly and require significant regulatory approval and environmental documentation.

A total of 51 wetlands have been restored in the watershed since 1990, according to the Ozaukee County Land Conservation Department's working wetland restoration map. Most of these are small, 1-5 acre, shallow marsh and wet meadow restorations on agricultural lands. About half of the total projects are on lands under the Crop Reduction Program (CRP). Photo 4-12 shows one wetland restoration in a group of six restored by one landowner just north of Pioneer Road in sub-watershed PRE(1). The continued restoration of small wetlands by private land owners will improve water quality and wildlife habitat but will not provide storage in large rain events due to design constraints. Restorations will also provide valuable open space area in the Town.

Photo 4-12 -- A Restored Shallow Marsh Wetland

WOODLANDS, CORRIDORS, AND NATURAL AREAS

SEWRPC identified natural resource features as part of the Area Wide Water Quality Management Plan for Southeastern Wisconsin. The plan intends to achieve clean "fishable and swimmable" surface waters within the seven county area of Southeastern Wisconsin. These natural resource features are divided into primary environmental corridors, secondary environmental corridors, and isolated natural areas. SEWRPC's isolated natural areas include open areas, upland woods, and wetlands. Primary environmental corridors, secondary environmental corridors, and wooded areas in the Watershed have been identified on Maps 13, 14, 15 in Appendix B. The wooded category includes 13 upland woods not associated with a major wooded wetland or an environmental corridor. A total of 667 acres of primary environmental corridor and 225 acres of secondary environmental corridor, as well as 283 acres of woods are in the watershed.

There have been recent discussion by the Ulao Creek Partnership and Ozaukee County as to why the middle portions of the Ulao Creek are not designated as primary environmental corridor. Size limitations such as to what can be designated as primary environmental corridor, one of which is width. A primary environmental corridor must have a minimum width of 200 feet. Many middle portions of the Ulao Creek have a natural resource feature of less than 200 feet, resulting in a secondary environmental corridor determination.

Second, a portion of the secondary environmental corridor immediately north and south of CTH 'Q' where floodplain information did not include the corridor determination. SEWRPC is in the process, at the WDNR's request, of re-analyzing the corridor in that location pending the results of the Village of Grafton floodplain study and this report.

Many of the wetland areas are forested wetlands and can be classed as bottomland hardwoods (wet-mesic hardwoods) with some swamp hardwoods (wet-hardwoods). Bottomlands are associated with riparian systems and swamps are associated with wet soils, usually old river or lake beds. Tree species associated with the wooded wetlands in the Watershed include green ash, silver maple, American elm, black willow, swamp white oak, cottonwood, black ash, red maple, and river birch. Green ash dominate the wet areas and silver maple the wetter areas. American elm, to a lesser extent, can dominate wet areas but is more susceptible to die off from Dutch elm disease. Green ash will experience top die off if water levels rise and become intolerable.

Even though these plant communities are wetlands, bottomland hardwoods have limits to the amount of flooding they can withstand before a shift to a wetter plant community establishes itself, like a alder thicket or shallow marsh. A drastic change in water levels did not allow time for establishment of more water tolerant trees or a well diversified shallow marsh community. Often, aggressive reed canary grass will dominate the dead tree stands.

Thirteen (13) of the largest woods have been identified on the Environmental Corridor Maps and are recommended for preservation and management. The majority of these twelve identified woodlands are upland hardwoods and can be classed as northern hardwoods. Northern hardwoods have an average tree composition which is a mix of hardwoods with some conifers. Tree species typically include sugar maple, basswood, white ash, beech, white oak, red oak, cherry, hickory, white pine, white cedar, white birch, aspen, musclewood, ironwood, and often a dense understory growth of honeysuckle and buckthorn. Most often the shade tolerant sugar maple, basswood, white ash, and beech dominate the all-aged stands. Regeneration is an on-going process in these woods. As one tree dies, a sapling is ready to quickly establish itself in the newly formed sun opening.

On-going plantings in the watershed are being done both as a part of Managed Forest Lands, under the WDNR Managed Forest Law, and as general plantings by private landowners. Ten Town of Grafton participants in the Managed Forest Law receive reduced property taxes. For the most part plantings are conifers or as mixed conifer/hardwood. Species being used are white pine, white spruce, Norway spruce, red oak, white oak, white cedar, and walnut. Tree plantings are generally done at a rate of 800 trees per acre, and usually in row format on large scale plantings. This rate is recommended for future plantings, however staggered rather than raw plantings are more desirable both for aesthetics and wildlife.

According to SEWRPC's Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin pre-settlement vegetation map much of the Ulao Swamp was conifer swamp/bog, and most likely a combination of cedar and tamarack swamp. This map was compiled using records from the U.S. Public Land Survey of 1835-36. The Ulao Swamp is the highest quality of the Watershed wetlands despite numerous impacts since settlement of the Watershed. These impacts include drainage for agricultural production, water level changes due to ditching and increased flows from development, and filling for railroad and road construction. The SEWRPC Natural Areas Management Plan classifies the Ulao Swamp as a NA-3, natural area of local significance, and recommends it for acquisition by a private conservancy organization.

FISHERY

Analysis of the fishery of the Ulao Creek was completed by compiling WDNR information with field observations during the inventory portion of the plan. The fishery of the Ulao Creek has been classified by the WDNR as capable of supporting a warm water sport community. Cold water fish communities include trout, while warm water sport communities include pike, bass, sunfish, bluegill, and crappie. Based on past WDNR fish survey data, the community is composed of 13 species of intolerant to very tolerant forage fish. Warm water sport fish collected from the Creek include northern pike, green sunfish, bluegill, white crappie, and largemouth bass. The habitat of the Creek is degraded due to straightening, embeddedness, loss of bank vegetation, and low flow conditions. This was confirmed by field observations of silt plumes, eroding banks, lack of shrub or woody cover on most banks, and isolated deeper pools associated with bridge crossings. Photographs 4-13 through 4-15 document these conditions. These conditions are indicative of a degraded and channelized rural stream. These conditions contribute to degradation of habitat through increased stream temperatures, sedimentation of gravel spawning areas, lowered dissolved oxygen levels, and loss of biotic diversity both in aquatic plants and insects.

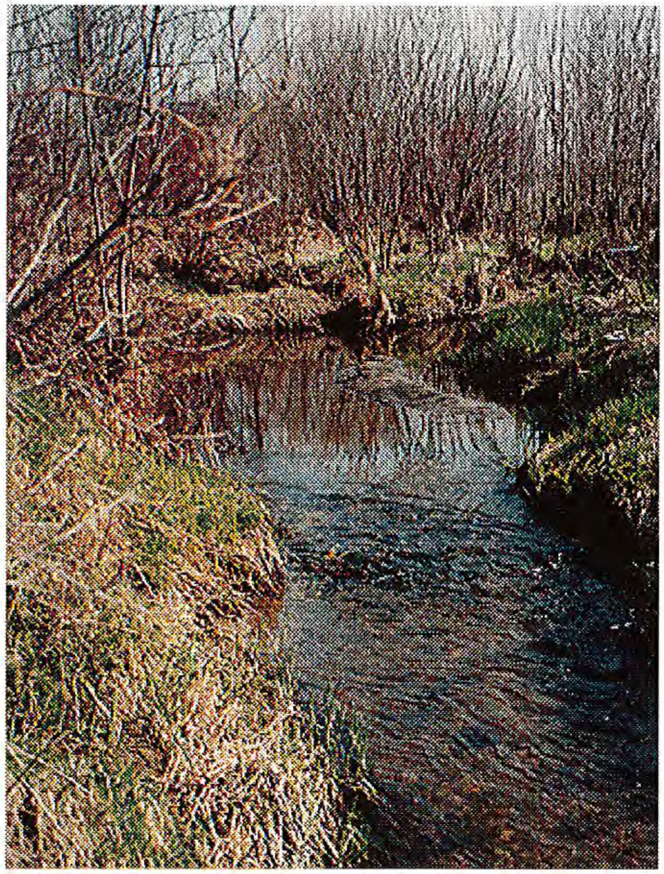

Photo 4-13 -- Siltation in the Middle of the Ulao Creek Upstream of a Riffle

Photo 4-14 -- Bank Erosion of the Ulao Creek

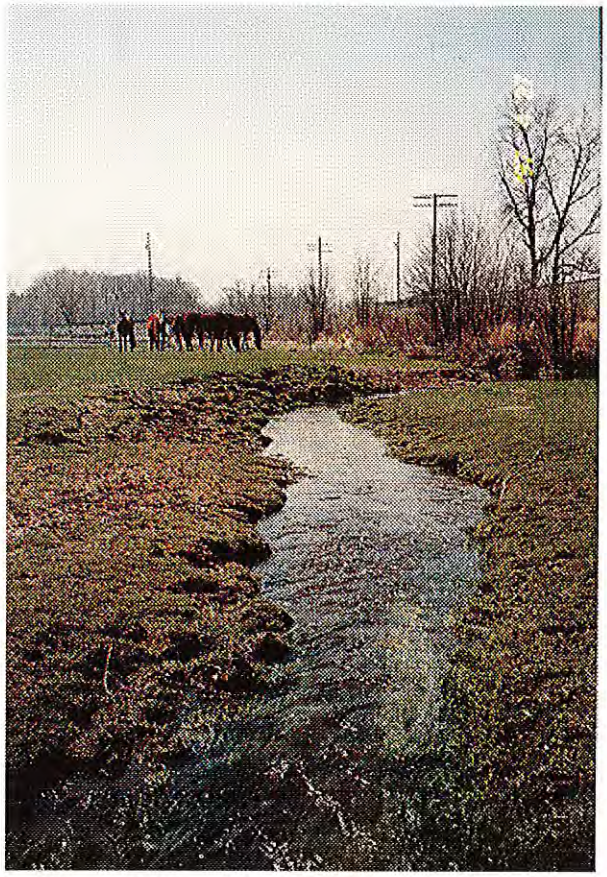

Photo 4-15 -- Livestock Access Showing
Bank Effects on the Ulao Creek

Areas of the Ulao Creek can be categorized into three groups with reference to the fishery. During the field investigation, the lower one-third of the Ulao Creek had a pool and riffle bottom with silt deposits and eroding banks. The water depths were consistently between 6" and 24", with no dry areas in the creek bed. The middle one-third of the Creek had a narrower bed and the substrate had a much larger percentage of sand and gravel than the other two-thirds. Streambank erosion was not as evident; areas of the Creek were dry at a water depth less than 6". These areas were beginning to show signs of becoming fish migration barriers, even in the wet hydroperiod of April. The sand and gravel areas may be places, especially in summer, where the creek is flowing under the surface bed within the sand and gravel layer. The northern one-third of the Creek is mostly a ditch through the lower Ulao swamp area. This stretch of the Creek begins just north of CTH Q after its junction with the I-43 tributary. The bottom of the Creek is mostly muck with some silt, sand, and gravel. The banks are less eroded and water depths were between 6" and 18".

The U.S. Fish and Wildlife Service and the WDNR agree that gravelly substrate and woody bank vegetation provide important food and cover for the native forage fish in creeks, similar to the Ulao Creek. Table 3, Appendix A, illustrates the fish distribution data for the Ulao Creek from WDNR fish surveys. The majority of the recommendations in the Creek

Corridor Section of the Best Management Practices Recommendations focus on restoring and enhancing the two stream traits of gravelly substrate and woody bank vegetation. Projects also include habitat over flow ponds for rearing and spawning along the Creek. Areas of stream blockage, or fish barriers, were located and identified as stream rehabilitation and cleanout projects. Specifically, blockage areas include those immediately upstream from Port Road, at Lakefield Road, at Falls Road, at CTH "Q", and at the south end of the Ulao Swamp.

GROUNDWATER ANALYSIS

The goal of promoting the protection and improvement of groundwater resources is unique for a stormwater management plan. The occurrence of low or no flow conditions in the Ulao Creek has drawn attention to groundwater and how it may interact with surface water during these flow conditions.

Northern Environmental Technologies, Inc. (NETI) has prepared a detailed groundwater study for the Ulao Watershed. This report is attached as Appendix C. The section below summarizes groundwater information for the Ulao Watershed. Recommendations for the promotion and improvement of the Ulao Creek's groundwater resources are found in the Best Management Practices recommendation section.

Groundwater is water that lies below the ground surface, filling the cracks, crevices, and pour space of rocks and soil. The water table is the top of the zone of saturation in rock or soil. When the water table rises above the surface, it becomes surface water and its point of exit on the land surface becomes groundwater discharge. On the otherhand, groundwater recharge occurs in upland and wetland where soils are permeable all the way, or along a seam, to the water table. Of course, there are exceptions to all rules, and it is possible that groundwater may not be connected to the water table, and the two separated by an impermeable layer. This situation is called a perched water table.

The Watershed is complex, interlayered fine-grained and coarse-grained unconsolidated sediments. The unconsolidated deposits are composed primarily of till, lacustrine sediments, and fluvial sediments deposited by glacial action approximately 12,000 to 16,000 years ago. Relatively thin veneers of post-glacial alluvium and organic deposits are found along major water courses and wetlands. Small deposits of pre-glacial sediment also may fill some bedrock valleys. In general, the unconsolidated sediments are finer grained and thicker near Lake Michigan.

Furthermore, many areas northwest of State Highway 32/County Highway V are underlain by substantial thickness of sand and gravel. Glacial sediments rest unconformably upon Devonian-age dolomite and shaly dolomite in the southeastern half of the Watershed, and upon Silurian-age dolomite in the northwestern part of the Watershed. A regionally-recognized fault crosses the Watershed with approximately 80 feet of relief expressed in bedrock underlying the Watershed. Bedrock surface topography is quite irregular, with prominent bedrock valleys and ridges found in some areas, particularly in the northern half of the Watershed near the fault.

Some important conclusions from the NETI report are described in layperson's terms below. First, it has been determined that the Milwaukee River has an impact on the Ulao Creek. Portions of the Milwaukee River can be called a "losing river" – one that loses water to the zone of saturation. At times the Milwaukee River, especially near the Saukville/Cedarburg/Grafton Area, loses water to the bedrock below the river, and the groundwater travels southeast to seep out along the bluffs of Lake Michigan and through the Lake bottom. In the northern part of the watershed these permeable layers are connected to the Ulao Swamp, and water from the bed of the Milwaukee River discharges through seeps and springs into the western portions of the Ulao Swamp.

These effects of the Milwaukee River and similar permeable soil, glacial till, and rock conditions cause surface and groundwater to be lost from the middle of the Ulao Creek. This condition is mostly a function of the surface layers of rock and soil above the bedrock. More permeable materials allow the connection between the surface waters and bedrock groundwater. These more permeable layers are found in the middle one-third of the Ulao Watershed in general, whereas the northern one-third is an area of high groundwater discharge. The middle one-third of the Ulao Creek is a "losing creek" because the south one-third has less permeable surface materials (soil and rock), the Creek is not losing water and therefore has an upward gradient, favoring discharge into the Creek. These indications coincide with the water depths inventoried in the Ulao Creek.

This condition is also, to a lesser extent, a function of hydraulic head. Hydraulic head is the amount energy water has between two points at different elevations, which is dependent on the amount of surface water and the distance to groundwater. In early spring and during summer rains, the volume of water is greater, moving water downstream more quickly and with more hydraulic head. In mid-summer, dry conditions affect the amount of water moving downstream from north of CTH Q resulting in less hydraulic head. When there is less hydraulic head, the Ulao Creek is more likely to be a "losing creek."

Some of the groundwater in the north and east part of the Watershed, around the Ulao swamp, has been discovered to flow north and east towards Mineral Spring Creek. This flow direction decreases the downstream hydraulic gradient towards the lower Ulao Creek, and in turn may be contributing to low flow conditions in the Ulao Creek in mid-summer.

Data collected as part of the Northern Environmental groundwater study (Appendix C) revealed the following important surfacewater/groundwater relationships. Groundwater discharges to the surface in several areas. Important groundwater discharge areas include:

- The western flank of the Ulao Swamp, particularly north of Ulao Parkway.
- The lowland parallel to Interstate-43 north of Ulao Road.

- Small areas adjacent to Ulao Creek near the intersection of County Trunk Highways W and C.

In other areas, surfacewater features lose flow to groundwater. Such features include:

- Various stretches of the Milwaukee River, especially those upstream of dams and north of the Village of Grafton
- Eastern portions of the Ulao Swamp
- Northern-most portions of the Ulao Swamp
- Ulao Creek between Ulao Road and Falls Road

5) WATER QUALITY ANALYSIS

The WDNR *Nonpoint Source Control Plan for the Milwaukee River South Priority Watershed* sets forth goals to reduce nonpoint source pollutant loading in the watershed. Nonpoint source pollutants of concern include sediment, nutrients, bacteria, heavy metals, oil and grease, and excessive stormwater. Heavy metal pollutants include lead, copper, zinc, cadmium, and chromium. Lead, copper, and zinc are most commonly modeled. Sources for lead include vehicle service areas, batteries, automotive parts, rust, industrial emissions, incinerators, and air-borne dust from pre-1978 buildings, metal bridges, and structures. Sources for copper include wiring, electronics and computers, copper piping, and automotive parts. Sources for zinc include any galvanized steel product form cars, trucks, roofs, culverts, bridges, buildings. Estimating existing and proposed pollutant loading is important for identification of recommendations in the form of BMPs. When implemented, the BMPs will achieve the Priority Watershed Plan goals for nonpoint source pollutant reductions.

Water quality analysis for the Watershed, and the Village of Grafton and City of Mequon, was performed using a tabular spreadsheet model. This method is based on unit area loading values for certain indicator pollutants. Pollutants modeled by Bonestroo in the water quality analysis for the study area include sediment, phosphorus (nutrient), lead, copper, and zinc (heavy metals). The unit area loading values are multiplied by the area of a given land use in each sub-watershed. The WDNR has approved the unit area pollutant loading values presented in Table 7, Appendix A.

The land use values from the existing conditions section were applied to the unit area loading values and detailed results are presented in Tables 8, 9, 10 Appendix A for sediment, phosphorus, and lead, respectively. The same process was applied to the proposed conditions as dictated by the planned land use map provided by the Town of Grafton. Detailed future condition model results are presented in Tables 11, 12, 13 Appendix A for sediment, phosphorus, and lead, respectively. The third step in the modeling of water quality was the combination of planned land use, existing natural resources, and planned BMP recommendations. These results are presented in Table 5-1 for sediment, phosphorus, lead, copper and zinc respectively.

The water quality results for the 6293.8 acre study area are:

Table 5-1

Condition	Sediment (lbs/yr)	Phosphorus (lbs/yr)	Lead (lbs/yr)	Copper (lbs/yr)	Zinc (lbs/yr)
Existing	2,161,419	3,466	1,754	841	2432
Future (% change)	2,873,674 (+33%)	2,705 (-28%)	4,366 (+149%)	1203 (+43%)	5389 (+122%)
With BMPs (% change)	775,892 (-73%)	838 (-69%)	2183 (-50%)	601 (-50%)	2694 (-50%)

EXISTING POLLUTANT LOADING

Existing land use conditions discussed earlier were applied to the unit area loading values to determine existing pollutant loading. The existing water quality pollutant loading for sediment, phosphorous, and lead in the Watershed is presented in Tables 8, 9, and 10 Appendix A. Areas classified as open space in the existing condition containing I-43 land use were modeled with a higher lead unit area loading value. This value was weighted based on the percent of I-43 area versus open space for each appropriate sub-watershed, and is most similar to the industrial loading value for lead.

PROPOSED FUTURE POLLUTANT LOADING

The planned land use map, provided by the Town of Grafton, was used to determine future land use conditions in each sub-watershed. These values were then applied to the unit area loading values to determine the proposed future pollutant loading. The future water quality pollutant loading for sediment, phosphorus, and lead in the Watershed is presented in Tables 11, 12, and 13, Appendix A. The indicated drop in proposed phosphorus loading can be attributed to a shift from agricultural to residential land use in the future conditions.

PROPOSED FUTURE POLLUTANT LOADING WITH IMPLEMENTED RECOMMENDATIONS

Estimated levels of pollutant reduction are based on past experience in water quality modeling and analysis on ponds that Bonestroo has designed. These ponds are functioning at their predicted pollutant reduction levels of: 70 percent to 80 percent reduction of sediments, 60 percent to 80 percent reduction of phosphorus, and 50 percent to 70 percent reduction of lead. The levels of reductions modeled for the proposed condition with the proposed recommendations are shown in Table 5-1 and represent a 73 percent reduction in sediment, a 69 percent reduction in phosphorus, and 50 percent reduction of lead. These reductions are in conformance with the recommendations of the Milwaukee River South Priority Watershed Plan. The total pollutant loading for the future condition was reduced by these percentages to determine the pollutant loading for the study area with the implementation of the proposed recommendations.

6) WATER QUANTITY ANALYSIS

WATER QUANTITY MODELING

METHODOLOGY

Stormwater runoff is defined as that portion of precipitation that flows over the ground surface during, and for a short time after, a storm. The quantity of runoff is dependent on the intensity of the storm, the amount of antecedent rainfall, the length of storm, the type of surface and the slope of the surface.

The intensity of a storm is described by a return storm interval, which designates the average period of years during which a storm of a certain magnitude is expected to occur one time. Thus, the degree of protection is determined by selecting a return storm interval to be used as a basis for design.

Based on historical data prepared by the SEWRPC and U.S. Weather Bureau Technical Paper 40 charts rainfall events for the watershed can be categorized as:

- 2-year frequency storm is 2.6 inches of rain in a 24-hour period.
- 10-year frequency storm is 3.9 inches of rain in a 24-hour period.
- 100-year frequency storm is 5.5 inches of rain in a 24-hour period.

Hec-1 models drainage basins and reservoirs utilizing the methodology developed by the Soil Conservation Service (SCS) for their TR-20 program. Input data consists of the drainage area, basin slope, SCS runoff curve number that is based on land use, hydraulic watercourse length, time of concentration, and the 24-hour rainfall precipitation. SCS Type II rainfall distribution was used. Rainfall precipitation for the 2, 10, and 100-year recurrence interval was selected from SEWRPC and U.S. Weather Bureau Technical Paper No. 40.

Table 6-1 indicates the runoff curve number used in the hydrologic modeling of the Ulao Creek Study.

Table 6-1
Runoff Curve Numbers Used in Modeling

Land Use Type	Runoff Curve Numbers (TR-55, Soil Conservation Service, type C-soils)
A1 – Exclusive Agriculture >35 Ac	85
A2 – Agricultural/Rural Residence >10 Ac	82
R1 – Five acre lots	74

Land Use Type	Runoff Curve Numbers (TR-55, Soil Conservation Service, type C-soils)
R2 – 3 acre lots	76
R3 – 1 acre lots	79
B-1 – Commercial	92
M-1 – Industrial	90
C-1 – Conservancy	84
SW – Surface Water	100
Freeway	92

DESIGN CRITERIA

To model the existing conditions for the Ulao Creek study, a runoff curve number of 71 was used for the entire study and represens pre-settlement land use with Type-C soils. This value will result in a lower existing runoff and a more stringent allowable proposed discharge. To meet the WDNR goals for pollutant reductions into Ulao Creek and to restore the Ulao Creek Watershed to a beneficial component of the ecological system, it is necessary to analyze the study area in its more natural condition. The majority of the existing land in the study is row crops. Row crop land use can be shown to have high runoff; therefore when comparing pre-development runoff to post-development runoff, it can be argued that little if any stormwater detention is required because post-developed runoff is only slightly more or even less than pre-development runoff.

The existing conditions for each subwatershed were modeled as a combination of land area, land use, and existing detention areas caused by culverts and bridges in place today. Maps 16, 17, and 18 show the location of existing detention areas caused by a culvert or other obstruction. The number associated with each pond correlates to the structure that acts as the control during a storm event. These structures are identified in the inventory section of this report. The results of running a model for a 10-year storm event with a pre-settlement runoff curve number of 71 are listed below. These results include the peak discharge rate of the subwatersheds and the existing ponds.

Proposed conditions for each subwatershed were modeled as a representation of the Town of Grafton Future Land Use Map. The runoff curve number for each subwatershed was revised to reflect the changes in the amount of impervious area. Revised runoff curve numbers(CN's) in each subwatershed are presented in Table 14, of Appendix A. A model was run with future land use conditions but with no changes to existing structures taken into account.

RESULTS

Table 6-2 is a listing of the future peak discharge rates for the subwatersheds and existing ponds for the 2, 10, and 100-year storms. This table also lists the discharge rates for the 10-year pre-settlement flows.

Table 6-2

Subwatershed	10-Year Pre-Settlement Flow	Future Land Use Conditions		
		2-Year Flow	10-Year Flow	100-Year Flow
USN-7	112	89	200	353
Pond 1	7	4	9	17
EP-13	5	3	6	11
USN-8	68	24	52	93
EP-14	5	3	8	14
USN-9	142	79	182	326
COM-1	145	80	187	336
EP-12	25	14	32	53
USN-6	215	224	413	653
COM-2	228	230	432	687
EP-5	123	125	212	328
USN-3	74	94	161	243
COM-3	160	177	287	433
EP-6	80	83	145	224
USN-4	90	71	148	251
EP-7	30	23	47	64
EP-18	13	10	21	35
USN-5	135	174	299	453
EP-1	27	38	58	82
USN-2	32	40	67	102
USN-1	420	331	687	1162
COM-4	501	435	863	1425
SWMP-N	29	11	21	30
USS-4	212	125	292	523
EP-35	21	13	28	43
USS-3	191	113	262	470
COM-6	198	117	274	494
EP-34	15	9	20	32
USS-1	797	748	1440	2331
USS-2	225	144	321	562
COM-5	1011	880	1747	2881
USS-6	105	63	142	252
EP-44	80	47	110	198
USS-5	209	124	282	499
COM-7	1275	1035	2117	3552
SWMP-S	92	68	133	212

Subwatershed	10-Year Pre-Settlement Flow	Future Land Use Conditions		
		2-Year Flow	10-Year Flow	100-Year Flow
I-43-12	175	216	378	579
EP-27	120	140	226	337
I-43-11	156	115	248	426
COM-9	332	249	451	717
EP-20	53	53	78	105
I-43-10	219	195	388	638
EP-29	70	65	97	127
I-43-9	58	37	82	142
EP-55	34	26	40	50
I-43-8	107	94	184	300
EP-51	43	52	71	99
COM-10	74	76	110	148
EP-53	37	34	58	87
I-43-7	87	60	127	218
EP-50	54	30	44	57
I-43-6	21	28	46	68
I-43-1	108	103	202	330
COM-11	299	275	456	668
I-43-3	173	127	270	461
EP-38	122	99	166	225
I-43-2	47	58	99	150
I-43-5	33	37	66	102
EP-39	32	35	58	90
I-43-4	44	63	104	154
COM-13	77	98	162	244
EP-56	11	16	29	44
I-43-13	51	43	99	175
COM-40	81	103	201	330
UC-TRB	79	96	196	320
COM-12	199	189	332	505
UCRK-1	199	184	334	495
WASH-1	146	See Village of Grafton Northeast Drainage Study Appendix D		
COM-14	345			
UCRK-2	341			
WASH-2	213			
COM-15	554	312	570	878
U-CREEK-4	553	313	576	884
FRE-5	178	98	229	411
POND-10	18	10	24	51
FRE-4	117	65	151	270
COM-19	125	69	163	295
EP-58	26	15	33	58
FRE-2	91	50	116	208
FRE-3	115	64	148	266

Subwatershed	10-Year Pre-Settlement Flow	Future Land Use Conditions		
		2-Year Flow	10-Year Flow	100-Year Flow
COM--18	206	114	285	474
EP-59	17	10	23	40
FRE-1	67	37	88	159
COM-17	84	46	110	198
UC-7	119	82	178	307
FRW-4	112	131	233	360
EP-64	8	9	14	21
FRW-1	24	32	53	79
COM-20	29	37	61	91
EP-63	11	16	25	31
UC-8	86	51	116	206
UC-9	111	61	144	259
COM-16	388	239	541	948
U-CREEK	377	231	531	939
FRW-3	78	69	137	224
EP-84	44	39	75	103
FRW-2	19	25	41	62
COM-21	53	53	101	143
EP-83	18	18	25	34
COM-22	390	245	550	961
UCRK-6	368	237	536	931
UC-6	369	219	504	898
UC-5	41	53	89	133
COM-23	748	468	1060	1863
UCRK-7	721	454	1046	1834
LF-5	82	56	122	210
EP-70	31	21	42	57
LF-3	55	37	80	136
EP-71	23	16	35	62
COM-26	51	35	75	112
LF-1	43	29	64	110
LF-6	25	17	36	62
LF-2	89	70	143	241
LF-4	26	18	38	64
COM-25	158	117	246	417
EP-81	68	55	100	163
UC-4	174	95	228	414
UC-3	28	37	62	92
COM-24	287	191	407	697
U-CREEK-8	279	192	406	677
PRE-2	291	173	397	707
EP-87	45	37	50	66
PRE-1	37	46	79	119
COM-28	48	51	100	154
UC-1	119	100	203	339

Subwatershed	10-Year Pre-Settlement Flow	Future Land Use Conditions		
		2-Year Flow	10-Year Flow	100-Year Flow
UC-2	24	32	53	79
COM-27	442	328	662	1128
U-CREEK-9	430	315	660	1099
PRW-5	82	56	120	205
EX-POND	0	0	0	0
PRW-4	122	106	234	408
COM-50	122	74	163	285
EP-78	33	26	47	52
PRW-3	151	103	228	399
PRW-2	86	59	128	221
COM-29	236	162	356	620
PRW-1	121	83	182	317
COM-30	353	242	526	911
COM-31	377	264	560	956
STR-77	348	242	528	914

The results of the modeling show that in every subwatershed, peak discharge increases in the proposed conditions. The data were then applied to the stormwater quantity management projects throughout the Watershed. These projects are modeled as proposed stormwater detention facilities in the Best Management Practice Recommendation section later in this report. These criteria also shall be the guidelines for stormwater management of future developments in this study area.

WATER QUANTITY GOALS

A. Stormwater runoff produced in each subwatershed over the 10-year event and up to the 100-year event will be released at the runoff rate of the pre-settlement conditions for the 10-year event.

B. Stormwater ponds if so designated in this plan will be designed to provide water quality benefits in the smaller storm events.

Additional water quantity benefits will be achieved with the implementation of the Water Quality Recommendations presented in Chapter IX of this report.

7) WATER QUALITY BEST MANAGEMENT PRACTICES (BMP) ALTERNATIVES

Urban and rural areas produce a wide array of pollutants, some of which are unique to urban area runoff and some of which are also produced by rural land uses. Rural land use is considered to be a mix of residential and agricultural lands with some commercial and light industrial, while urban land use consists of higher density residential, commercial, and industrial lands. Pollutants produced in common with land uses include sediment, nutrients, pesticides and bacteria and other pathogens. Pollutants generated primarily in urban areas include a wide range of heavy metals such as lead, copper, zinc, cadmium, and chromium, and a large number of toxic organic chemicals. A matrix of available BMPs is presented in Table 4, Appendix A. These BMPs can be used separately or in combination to achieve the desired results. Table 5, Appendix A, is a comparative assessment of the effectiveness of BMPs.

The BMPs given most attention in this study were source control reductions like construction erosion, grass lined swales, and vegetative filterstrips; structural controls such as wet-detention ponds, streambank stabilization, and constructed wetlands; and public education. Some of the other alternatives do have some merit, but in some cases appeared to be less cost-effective than those mentioned above. For instance, water quality inlets, sand filter inlets, and underground storage are high cost alternatives and are usually used for high priority areas such as large commercial parking lots. Likewise, some alternatives such as infiltration trenches and basins would not be practical for the mostly rural Ulao Watershed, due to their high cost.

The delivery to surface waters of urban pollutants from established urban areas varies greatly depending on the type of urban land use, the storm water conveyance system, and urban housekeeping practices. In general the Ulao Watershed is planned to be more rural in nature and pollutant pathways to the Ulao Creek will be less connected than in an urban watershed. Future land use will dictate a mostly grass swale and ditch system rather than curb and gutter and storm sewer. The pollutants include sediment, phosphorus, indicative of pollutants also produced in the agricultural areas, and lead, which represents heavy metals produced primarily in urban areas.

Generally freeways, industrial areas, and commercial areas are the greatest generators of urban pollutants on a per-acre basis. High density residential lands are also significant contributors of some pollutants. Medium density residential areas are of much less importance for sediment and lead on a per acre basis, but continue to be significant as sources of pesticides, bacteria, and household or automotive maintenance products dumped into the storm sewer system. Low density residential areas are generally important only if housekeeping practices, including use of pesticides and fertilizers, are poor.

Source areas vary in the types and amounts of pollutants available for transport by rainfall and runoff and vary in the extent to which pollutant-producing surfaces are hydrologically "connected" to the downstream system. These two factors are at the core of what makes urban land uses significant as pollution sources. For example, automobile traffic density, a prime determinant in the production of lead, asbestos, cadmium, and street dirt is highest for street surfaces in commercial areas and freeways. Commercial areas and urban freeways are also highly "connected" to storm sewers and have little or no pollutant buffering. Lawn areas, important contributors of nutrients, pesticides, and sediment, are more prevalent in residential areas. Rooftops are important sources of zinc and asbestos, vary in the proportion of land they cover in each urban land use, and vary in the degree to which they are "connected" to the storm sewer system. Generally, "connectedness" is higher in commercial areas than in residential areas.

It is important to identify those land uses that are most important in contributing to the total pollutant load. Land uses gain significance based on a combination of factors, including the unit area rate of pollutant production for the land use and the total mass loading from a particular land use. In most sub-watersheds throughout the Milwaukee River South Priority Watershed, commercial and industrial areas produce the most significant portion of the lead loading. These land uses also have significantly higher unit area lead loads than the other land uses.

When considering sources of sediment, medium and high density residential areas take on greater significance across the watershed, competing more closely with commercial and industrial areas as important sources of the urban sediment loading.

Enforcement of construction erosion control ordinances is recognized as an effective means to control this source. Compliance with construction erosion provisions in the Town code is generally high. Items that would improve compliance include consistent statewide requirements and workshops for developers, builders, and contractors.

The Ulao Creek Watershed is mostly agricultural and is planned for become mostly 3-acre residential. The developed areas along the I-43 corridor will probably utilize curb and gutter and pipes for drainage control. This type of system offers fewer water quality benefits than a system consisting of grassed-lined swales; however, there are water quality alternatives that can be used for both rural area and the commercial areas.

The following section discusses stormwater quality BMPs that the Town of Grafton might consider using throughout the Ulao Creek Watershed.

Stormwater Quality BMPs

There are many options available for controlling pollutants in stormwater to protect the water resources of the watershed. The methods available for controlling stormwater pollution are often referred to generically as BMPs. While there are many BMPs available the appropriateness, effectiveness, and cost of each method will vary with each particular situation.

It is important to be aware of all the water quality options that are available and choose those that are most effective for each situation. Some of the issues that will affect the selection of the necessary BMPs are:

- Developed or undeveloped condition
- Urban or rural cross section
- Availability and cost of land
- Amount of water needing to be treated
- Level of treatment required
- Target pollutants
- Topography and soils of the site

Source Control Reduction Practices

These practices are meant to curb the generation of urban pollutants as close to the source as possible. Ideally, pollutant generation is stopped. At a minimum, pollutants that are generated are controlled prior to entering the Ulao Creek.

Source area controls are generally non-structural in commercial and residential areas, relying instead on changes in products people use and in the way people live. Reducing the amount of automobile traffic in an area would be one example of a source control, since automobiles are the source of many urban pollutants. Current programs removing lead from gasoline and asbestos from automobile brake linings are also examples of source controls. In other cases, such as for industrial materials storage areas, control of runoff may require a structure.

Source area controls that prevent the generation of pollutants, such as the removal of lead from gasoline and asbestos from brake linings, are ultimately the most effective. However this type of control cannot be readily initiated at the local level. Regional and often national action is required. Citizen action that leads to this type of control is an important component of a long range urban management strategy.

Source area controls that rely on better housekeeping practices, such as pet waste control programs and judicious use of lawn and garden products, can be initiated locally. These types of controls are an inexpensive and vital component of any urban stormwater management program. Information and education efforts are critical in supporting this approach since this type of urban action is only as good as the collective effort made by the general public responsible for carrying it out. Several source control alternatives recommended in this watershed are:

- Manage the timing, amount, and type of fertilizer and pesticide applications.

- Properly dispose automobile waste fluids, such as radiator water and engine oil, to keep them out of the storm sewer system and of residential driveways.

- Upgrading of failing septic systems.

- Reduce the area extent of future parking lots.

- Base zoning of land use, in part, on site suitability for stormwater management practices needed to meet water quality, habitat, and flood related objectives.

- Strictly limit construction site erosion.

- Keep use of street de-icing compounds to a minimum.

- Construct grass lined swales in new residential and industrial developments and along new roadways with the following design criteria:
  - Minimum grade 0.8 percent, 5 percent maximum
  - 3:1 maximum side slopes
  - Minimum depth to groundwater of three feet
  - Maximum flow velocity of 6 feet per second
  - Prevent compaction during construction

- Provide areas for vegetative filter strips in commercial developments prior to runoff into grassed swales.

Wet Detention Ponds

Wet detention ponds are effective at controlling particulate pollutants and can be designed to control peak flow discharges. Consequently, they can be employed to serve many needs including pollution control, flood control, and control of stormwater flows that may cause flooding.

Wet detention ponds in existing and planned urban areas should be designed to control 90 percent of the incoming suspended sediment load. Pollution reduction will be achieved by trapping the five micron particle size. Ponds will provide approximately 70 percent control of the annual lead load from tributary lands. Where retrofitted, ponds should be located to control runoff primarily from the critical land uses.

Table 7-1
Selected Preliminary Design Criteria for Wet Detention Basins

	DESIGN CRITERIA
1	Percent of drainage required as pond surface for 90% control of solids: Freeways 2.8% Industrial 2.0% Commercial 1.7% Institutional 1.7 % Residential 0.8% Open Space 0.6%
2	Permanent pond minimum 5 ft. deep when constructed.
3	Minimum 10 ft. shelf around pond perimeter.
4	Minimum 4:1 side slope to edge of pond.
5	Pond shape must be minimum 3:1 length to width ratio.
6	Maintain minimum pond depth of 3 ft.
7	Minimum 25 ft. vegetated buffer strip.
8	Protect outlet channel from erosion.
9	Minimum depth to groundwater 3 ft. *
10	Minimum drainage area: 2 acres

* As measured from bottom of practice to seasonally high groundwater.

Streambank Stabilization

Streambank stabilization practices commonly include livestock exclusion, shoreline buffers, livestock and machinery crossings, grading, seeding and planting, and riprap placement. Traditional riprap and gabion alternatives should be used where flows dictate method of stabilization, while more innovative bioengineered methods should be used in lower flow tributaries. Creation of low and high flow channels in eroded sections while properly armoring or vegetating the bank is imperative to stabilization success. Eroding streambanks on the Ulao Creek and tributary streams cause significant sediment loading to downstream waters. Increased sediment loading causes a compounding effect on erosion. As the stream bed load or sediment load increases the erosive force of the stream increases causing more erosion. Grading and stabilization may not be enough in areas where farming close to the stream or livestock access continually degrades the bank. In these situations, shoreline buffers and fencing may be required to limit activities along the top of the bank. Typical buffer zones are 20 - 30 feet from the top of bank. Fencing not only prevents trampling of vegetation and bank erosion but also limits nutrient loading from manure.

Constructed Wetlands

Constructed wetlands include both created wetlands in uplands and restoration of previously drained or destroyed wetlands. Creating wetlands generally more expensive than restoring wetlands. Typical costs for projects are $15,000 per acre for creations and $2,000 to $5,000 per acre for restorations. Creation projects include stormwater wetlands created in uplands to handle flows from new developments and wildlife habitat creations like shallow marsh creations for waterfowl nesting. Restoration projects usually involve constructing of berms to hold water in a shallow basin with hydric soils, or simply breaking drain tiles or filling ditches and allowing a field to return to a wetland. Seedings and plantings also can be performed to augment wetland plant colonization.

Table 5 compares four different stormwater wetland designs. These designs can be created in uplands, located in drained wetlands (usually farm fields with hydric soils), or in a combination of both. A shallow marsh system has a forebay, marsh area, and micro-pool at the outlet. The pond/wetland system combines the benefits of an alternating pond (anaerobic) and wetland (aerobic) conditions for pollutant reduction. The extended detention wetland system is the same as the shallow marsh system except that higher slopes surrounding the system allow it to "bounce" and hold more water in high flow events. The pocket wetland system is a much smaller scale of the shallow marsh system without a forebay and also includes more variable water depths. Typical shallow marsh systems are designed for an 18" water depth.

Education

The successful implementation of the Stormwater Management Plan will require individuals and groups involved in the Plan to have an understanding of the objectives of the management plan. Informing the public of the water quantity and quality issues in this Plan should be part of a continuing Town of Grafton educational program.

In order to obtain the necessary political and economic support for successful Plan implementation, education is vital to inform Town residents about basic water quality concepts, the policies and recommendations in the Plan, the progress of water quality improvements, and the residents' role in improving water quality.

Initial education efforts should focus on explaining the causes of water quality degradation and the manner in which the Plan addresses these problems. Resident expectations for the quality of a given waterbody will be important in maintaining public support for the Plan. This initial information can be presented to the public during the public hearing process, Town newsletters, and press releases to local papers. The Town should attempt to develop newsletters annually to remind residents what they can do to improve water quality. The WDNR and University of Wisconsin-Extension also have produced very good hand-out materials that can be used for education.

Periodic updates on water quality trends in the Town of Grafton, the progress of Plan implementation, and information on specific improvement projects should also be provided to the public. Again, Town newsletters and press releases to local papers are effective information dissemination methods.

Special efforts should be made to coordinate educational and environmental awareness programs with the school districts. These programs should focus on K through 12 science curriculum as well as adult community education. These groups are constantly in need of speakers and would probably welcome requests by the Town or the Partnership to provide information on water quality. Slide shows and/or videos concerning water quality should be provided to local area schools for inclusion in science curriculum.

In addition, and especially in the more developed portions of the Watershed, training should be provided to residents on the proper methods of containing, neutralizing, and disposing of spills of oil, gasoline, pesticides, and other hazardous material. The crucial factor to emphasize is the prevention of spilled materials from the storm sewer system. Oil absorbent materials should be available for use in spill containment and clean-up. Proper use of these materials can be provided by the manufacturer.

An Outdoor Educational Center can be a cornerstone to increasing knowledge in the community and can institute a beneficial level of pride in the Town. A center could be designated in an existing resource location like the U.S. Fish and Wildlife property west of County Trunk Highway C and east of Ulao Parkway, or in a newly designated area of the Ulao Swamp. The center could begin with the creation of a gravel parking area and new stages undertaken as resources are available. New stages could include a trail or boardwalk system, an observation platform, and a pavilion. This feasibility could be similar to the Riveredge Nature Center but would focus on the Ulao Swamp.

The development community will need a good understanding of the reasons for the development of the policies impacting their activities. Specifically, developers and their consultants must understand the impact of development on water quality, the economic and social value of maintaining high water quality, and the demonstrated effectiveness of nutrient detention basins in treating runoff water. Much of the necessary information can be disseminated to the developers in an information packet during the preliminary plat stage.

8) BEST MANAGEMENT PRACTICE RECOMMENDATIONS

WATER QUALITY

Best Management Practices (BMP) recommended for water quality in the Ulao Creek Watershed can be divided into those for existing developed land use conditions and those for future land use including new developments. Existing development accounts for only 17 percent of the Watershed, while 66 percent of the Watershed is open and agricultural land which will become available for new developments.

EXISTING LAND USE BMP RECOMMENDATIONS

One very important BMP often overlooked is preservation of existing resources that provide natural attenuation of pollutants. The two most valuable natural resources in the Watershed, besides the Creek itself, are the Watershed's wetlands and woodlands. The most efficient way to protect these resources is for the Town Board to adopt the primary environmental corridor, secondary environmental corridor, wetlands outside the corridors, and woodlands outside the corridors (shown in Map 19, Appendix B) as conservancy lands. The second step in the process is to rezone areas conservancy not already zoned conservancy.

Management of the Watershed's wetlands should consist of purple loosestrife, buckthorn and reed canary grass control (when possible), shelter wood harvesting of wooded wetlands, and tree stand improvement in wooded wetlands in the form of release. Shelter woods harvests remove a portion of even-age trees, and allow low shade intolerant saplings and seedlings to regenerate. After regeneration is established the remaining, even-aged trees are harvested. Release involves eliminating competition around preferred trees, such as cutting of buckthorn or box elder from around maples, oaks, and ashes and their saplings. Herbiciding reed canary grass around saplings also qualifies as release.

Upland woods should be managed using selective harvesting and release improvements. Selective harvesting is a process by which trees with certain attributes, usually saw log trees or specified firewood lumber are chosen for harvesting and then the same practice is performed on 10 - 15 year cycles. Usually these are saw log trees or specified firewood lumber. More detailed information can be found in the 1990 Forest Practice Guidelines for Wisconsin prepared by the WDNR Bureau of Forestry and the Wisconsin Paper Council.

Areas that have already developed are most suited for practices such as management of household wastes, stream bank stabilization, wetland restoration, and education. Proper maintenance of existing grass swales, culverts, and ditches should be a high priority for the Town of Grafton. Vegetated filter strips also can be used in existing developments. An example of this would be the conversion of a downslope portion of an oversized parking lot into a vegetated filter strip. Adjacent lawn areas also can be transformed into vegetated filter strips.

FUTURE LAND USE BMP RECOMMENDATIONS

New developments have the best opportunity for practices such as construction erosion ordinance enforcement, grass-lined swales, porous pavement, wet-detention ponds, streambank stabilization, constructed wetlands, and education. These practices should be required for new developments in the watershed. Each development should be analyzed by the Town Engineer as development occurs to determine the specific type of practice or practices required. See Map 19, Appendix B, for location of specific areas as they relate to the recommended type of best management practice. Water quality BMPs are one of the Items listed on the stormwater management planning checklist for new developments, Appendix G.

WATER QUANTITY

PROPOSED STRUCTURAL BMP RECOMMENDATIONS

The recommendations for controlling the water quantity in the Ulao Creek will involve the implementation of Best Management Practices. Some of the proposed water quantity best management practices will include preserving and enhancing wetlands, construction of wet detention ponds, and protection of existing detention areas as development occurs. The goal of proposed recommendations within a subwatershed is to control the rate at which stormwater is passed through the drainage system while eliminating the potential of flooding existing structures and roads within the subwatershed.

Proposed structural water quantity best management practices are presented on Maps 16, 17 and 18. These structural BMPs are designed to meet the flood reduction goal of storing the 100-year future land use rain event and releasing it at the 10-year resettlement land use rain event discharge rate. The implementation of the recommended structural BMPs water quantity BMPs will result in the reduction of the future 100-year rain event discharge (914 cfs) to 329 cfs. The modeled 10-year resettlement rain event discharge rate is 348 cfs. Each pond location was analyzed to determine what storage volume is required to meet the recommended criteria. Storage volumes are generally reflections of the difference between stormwater inflow and outflow. The exact size and orientation of a pond capable of detaining a required storage volume can be of many different designs. It is the responsibility of the future developments to provide the required storage volume on the site.

The structural water quantity BMPs recommended are separated by subwatershed with improvement projects listed following flow data.

WATERSHED USN - ULAO SWAMP NORTH

This watershed has a total of nine subwatersheds, all draining to North Ulao swamp. The total area is 1,170.2 acres. Existing land use conditions are: 14 percent Residential, 1 percent Commercial/Industrial, 24 percent Open, 38 percent Agricultural, and 20 percent Wetland. Future planned land use increases to 47 percent Residential and 17 percent Commercial/Industrial or 575 acres to be developed.

Stormwater management projects and recommendations will be implemented to achieve runoff peak control objectives.

<u>USN Project 1:</u> **POND PP12**

Proposed project to provide storage such that 100-year high water level (HWL) does not exceed 746.5 and peak discharge limited to 30 cfs. Pond PP12 will be 0.1 acres at NWL and 4.5 acres at a HWL of 746.3. The discharge shall be limited to 29 cfs and the pond will provide 9.9 acre-feet of storage. A 34 X 52" squash CMP will be replaced with a 24" RCP.

<u>USN Project 2:</u> **POND PPP1**

The analysis indicates that the 100-year rainfall will result in complete flooding of the area presently occupied by Pond EP-5. Note that Project No. 1 will be part of the management of runoff at this location.

It appears that the location of Pond EP-5 will be far too close to existing homes. Therefore any additional work to provide storage at this location will need to take place upstream of EP-5 along the existing stream (as shown on Map 16).

The project will provide storage enough to keep the high water levels to 726 and discharge from Culvert No. 5 limited to 123 cfs. The project will require grading of a pond upstream of Culvert No. 5 that will provide 27 acre-feet of storage. Pond PPP1 will be 3.75 acres at normal water level (NWL) and 6.1 acres at a HWL of 730.0. The discharge from this pond will be held to 29 cfs.

<u>USN Project 3:</u> **POND PPP2**

Hydrologic and hydraulic analysis indicates that under fully developed conditions, the 100-year rainfall will cause EP-18 to reach unacceptably high levels behind culvert No. 18. In order to prevent this situation, the project will require grading to obtain storage so that after implementation, EP-18 HWL will not exceed 714.5 and the peak discharge from the culvert will be reduced from 29 cfs to 5 cfs.

Pond PPP2 will be constructed to provide the necessary storage upstream of EP-18. This pond will be 1.2 acres at NWL and 2.2 acres at a HWL of 727.24. Discharge from this pond shall be restricted to 5.0 cfs and will provide 8.8 acre-feet of storage. During preparation of this report, a wetland restoration was performed on the Wisconsin Electric Power Company property. This pond provides some storage of smaller rain events, but does not provide the storage and release rate necessary for a 100-year storm under future land use conditions.

<u>USN Project 4:</u> **POND PPP3**

Behind Culvert No. 1 and Culvert No. 2, storage must be provided so that high water levels are limited and existing dwellings will not flood. The project will involve grading of a pond upstream of these two culverts.

Pond PPP3 will be 2.3 acres at NWL and 5.1 acres at a HWL of 747.85. Discharge from this pond shall be restricted to 11.0 cfs and will provide 14.2 acre-feet of storage.

<u>Other Recommendations</u>

Pond PP-13	Replace 36" CMP with 12" RCP to provide storage in existing wetland to an elevation of 758.55
Pond PP-14	Replace 24" RCP with 12" RCP to provide storage
Pond EP-1	Replace 68" x 48" box culvert with 24" x 36" Concrete Box and provide storage to an elevation of 723.35.

<u>Overall Recommendations for USN:</u>

In addition to the four projects outlined above, there are some existing depressions act as storage areas. The storage available at these locations is taken for granted at the present time and it is recommended that the area covered by the high water level in these locations be designated as ponding areas and filling and development of these depressions be prevented.

On Map 16, these storage areas are identified as existing 100-year ponding areas. Note that any storage lost in these areas (e.g., due to development) must be made up by the construction of equivalent storage facilities at the cost of the party causing the loss of the existing storage. Stripping of topsoil from these areas will allow increased groundwater recharge.

Along the east side of the North Ulao Swamp, within the subwatershed USN (1), there will be no stormwater management projects for water quantity control. It has been confirmed that any additional runoff from this area in the future will not appreciably affect the high water levels in the North Ulao Swamp.

Furthermore, the topography of USN (1) will project existing developed areas against the danger of flooding due to additional runoff caused by future development.

TABLE 8-1

POND	TYPE	Area @ NWL Flow	Area @ 100 Yr. HWL	Discharge (CFS)	Storm Storage (Ac - Ft.)	Low Flow Elevation	100 Yr. High Water Level
PP-1a	Existing Wetland	0.10	6.04	11.0	11.39	759.0	762.71
PP-13	Existing Wetland	2.5	3.55	8.0	3.72	758.0	759.23
PP-14	Modified	0.91	3.74	3.0	5.42	770.0	772.33
PP-12	Modified	0.10	4.52	29.0	9.93	742.0	746.3
PPP-1	New	3.76	6.11	29.0	27.09	724.0	729.5
EP-5	Existing	0.23	0.76	109.0	2.72	720.0	725.5
EP-7	Existing	0.8	7.52	32.0	15.77	742.0	745.8
PPP-2	New	1.20	2.17	5.0	8.83	722.0	727.2
EP-18	Existing	0.01	0.05	5.0	0.03	711.8	712.7
PPP-3	New	2.27	5.10	11.0	14.19	744.0	747.9
EP-2	Existing	0.40	1.02	65.0	2.08	724.0	726.9
EP-1	Existing	0.01	1.07	45.0	2.34	719.0	723.3
Swamp N	Existing	0.05	116.60	34.0	179.06	698.0	701.0

WATERSHED USS - ULAO SWAMP SOUTH

This watershed is comprised of six subwatersheds, all draining to the South Ulao Swamp. The total area is 1458.9 acres. Existing land use conditions are classified as 15 percent Residential, 10 percent Commercial/Industrial, 11 percent Open, 39 percent Agricultural, and 23 percent Wetland. Future planned land use increases Residential area to 57 percent and Commercial/Industrial to 16 percent. Approximately 638 acres are planned to be developed.

USS Project 1: POND PPP 20

The proposed project involves the construction of a pond to detain the proposed flows from subwatershed USS6 before the flow enters the headwaters of the Ulao Creek. The proposed pond will be 2.5 acres at NWL and 3.2 acres at a HWL of 708.9. The discharge shall be limited to 19 cfs and provide 8.25 acre-feet of storage during the 100-year event. During preparation of this report, an agricultural sedimentation basin was installed on the Helm's property within the watershed. This pond provides some storage of smaller rain events, but does not provide the storage necessary for a 100-year storm under future land use conditions.

Overall Recommendations For USS

The outlet of the Ulao Swamp South is an 18' by 10' bridge under the Union Pacific Railroad. We do not recommend making modifications to this structure because the backwater effect will create a rise in the high water level to 697.50. This backwater will affect the stability of the railroad embankment over the long term.

The existing natural areas that currently act as storage basins are identified on the individual stormwater management map and future 100-year high water levels are delineated.

It is recommended that these natural areas be preserved as storage basins and identified as undevelopable areas. Should storage provided by the basins be eliminated by future development, the developer should be made to compensate for the lost storage by constructing ponds to achieve equivalent storm detention.

Table 8-2

POND	TYPE	Area @ Low Flow	Area @ HWL	Discharge (CFS)	Storm Storage (Ac - Ft.)	Low Flow	High Flow
EP-36	Existing Wetland	5.23	14.23	43	31.33	698.0	701.22
EP-34	Existing Wetland	13.89	26.28	32	48.4	698.0	700.4
PPP-20	New	2.50	3.22	19	8.24	706.0	708.88
Swamp S	Existing Wetland	20.1	135.2	210	228.29	694.0	696.94

WATERSHED I-43 - INTERSTATE HIGHWAY 43

This watershed has a total of 13 subwatersheds draining to a tributary of the Ulao Creek from the northwest. The total area is 1,052.1 acres. Existing land use is composed of 13 percent residential, 6 percent commercial/industrial, 27 percent open (about 60 percent of which is I-43 roadway, 45 percent agricultural, and 6 percent wetlands. Planned land use conditions increase residential area to 60 percent and 22 percent commercial/industrial and represents 713 acres of land under development.

The predominant feature of this watershed is Interstate 43 and Port Washington Road, and in particular, the interchange of these two highways, which play an important role in the hydraulics of the Watershed.

Numerous existing culverts across I-43, Port Washington Road, and the interchange create a number of runoff detention areas that help attenuate peak discharges at the present time and will continue to do so in the future.

<u>I-43 Project 1:</u> **POND PP-29**

The drainage area tributary to this detention area is currently served by two culverts, No. 29 and No. 31. The proposed project will require some grading to connect the two detention areas into one and a single 36" x 48" box culvert acting as the control. One large pond will regulate the discharge from this area at a more controlled rate.

<u>I-43 Project 2:</u> **POND PP-51**

The proposed project will provide storage such that 100-year HWL does not exceed 738 and overtop the road. This work will involve grading the 738 contour to an area of 2.3 acres and replacing the existing culvert with a 48" RCP.

<u>I-43 Project 3:</u> **POND PPP-21**

This proposed project will provide the most measurable reduction in peak flows entering the Ulao Creek at the junction of the I-43 tributary. The project involves the construction of a large detention pond located at the far downstream end of the Ulao Creek tributaries from the I-43 watershed. This pond will be 4.0 acres at NWL and 6.5 acres at a HWL level of 696.3. The discharge shall be limited to 30 cfs and provide 21.8 acre-feet of storage. The design should include low flow groundwater discharge to the Ulao Creek in dry conditions.

The location of this pond is critical to the hydrology of the I-43 watershed. The orientation of the pond allows for collection and attenuation of the three major drainage ways contributing flow to Ulao Creek.

Other Recommendations:

Pond PP-27	Minor grading of the 758 contour to an area of 2.2 acres to provide additional storage
Pond EP-20	Replace 54" RCP with 12" RCP to control flow and provide storage in the existing wetland to an elevation of 746.25

Overall Recommendations for I-43

Existing low areas behind culverts (EP-38, 39, 50, 55, 56) should be designated as stormwater detention ponds. The areas occupied by high water levels should be considered undevelopable and be reserved for future ponding.

Those areas designated as detention areas may require minor grading and removal of some vegetation where necessary. In general, this will only be the case in situations where frequent inundation is likely to damage existing vegetation.

Although some detention areas within the interchange were included in the analysis, they need not be designated as ponds since they are not developable and will remain functional independent of the future condition of the watershed.

The required ponding areas are shown on the stormwater management map.

Table 8-3

POND	TYPE	Area @ NWL Flow	Area @ 100 Yr. HWL	Discharge (CFS)	Storm Storage (Ac - Ft.)	Low Flow Elevation	100 Yr. High Water Level
PP-27	Modified	0.05	2.41	219	9.57	754.0	761.78
EP-20	Existing Wetland	1.37	22.95	6	76.00	740.0	746.25
PP-29	Modified	0.82	6.02	127	19.94	744.0	749.83
EP-55	Existing	0.04	1.20	50	2.77	756.0	760.46
PP-51	Modified	0.05	2.30	123	8.74	730.5	737.96
EP-50	Existing	0.01	1.77	57	6.17	724.0	730.93
EP-39	Existing	0.01	0.30	90	0.72	726.0	730.63
EP-38	Existing	0.05	2.75	225	11.15	714.0	721.96
EP-56	Existing	5.01	6.20	44	8.18	700.0	701.46
PPP-21	New	4.0	6.5	30	22.73	692.0	696.33

WATERSHED FRE - FALLS ROAD EAST

This watershed has a total of five subwatersheds all draining to a tributary to the Ulao Creek. The total area of the watershed is 423 acres. Existing land use consists of 11 percent residential, less than one percent commercial/industrial, five percent open, 77 percent agricultural, and three percent wetlands. Planned land use conditions propose 100 percent residential or development and redevelopment of 376 acres.

FRE Project 1: **POND PPP4, Pond 1**

The proposed pond will collect runoff from subwatershed FRE (5), downstream of the existing wetland area. The pond will reduce peak 100-year future runoff of 50 cfs to the calculated 10-year pre-settlement peak discharge of 18 cfs.

Additionally, the pond will keep the pre-settlement high water level in the Pond 1 to 714. This will be accomplished by excavation of adjacent upland areas to provide more storage. Pond PPP4 will constitute 5.35 acres at NWL and 10.5 acres at a HWL of 712.63. The discharge shall be limited to five cfs while providing 20.2 acre-feet of storage.

The proposed pond and the existing basin should both be designated as storage areas and should not be allowed to be considered developable.

FRE Project 2: **PP - 58, 91, 59**

This project is located at the intersection of CTH C and Falls Road. Future development will require additional ponding in an area not capable of providing additional storage due to the low elevation of the intersection. Downstream conditions will allow for lowering the culverts at the intersection and providing storage behind Culvert No. 59.

The first part of the project involves replacing the 36" culvert at No. 58 with a 48" x60" concrete box culvert and lowering the invert to 689.0. This new culvert will direct flow into the proposed pond downstream and restrict flow during the 100-year storm to an elevation of 694.20.

The second part of the project involves minor grading upstream of Culvert No. 91 by enlarging the 694 contour to 3.1 acres to provide additional storage without overtopping the intersection during the 100-year storm event.

The third part of this project is constructing a pond directly upstream of Culvert No. 59. This pond will be 3.7 acres at NWL and 7.0 acres at a HWL of 689.4. The discharge of the pond will be controlled with a 48" x 72" concrete box culvert and will be lowered to an invert elevation of 685.0.

Overall Recommendations for FRE

This watershed is unique because all five subwatersheds converge on the same point, the intersection. This intersection , however, cannot provide the necessary storage due to the topography of the surrounding area. The recommendations as part of FRE project 2 will control the stormwater runoff during the 100-year event to a level that does not flood the intersection or surrounding structures. The recommendations will not reduce the 100-year peak discharge rate to the 10-year pre-settlement rate. Additional flow will be passed through the system because the portion of the Ulao Creek and floodplain downstream of watershed FRE is capable of attenuating the additional flows during a storm event.

It is recommended that this area (as defined by this future high water level) be designated as a ponding area and be considered not developable.

If the storage provided by EP-59 is lost due to future development, those developing the site should be responsible for providing an equivalent storm storage basin serving subwatersheds FRE (2) , FRE (3), and FRE (4).

Table 8-4

POND	TYPE	Area @ NWL Flow	Area @ 100 Yr. HWL	Discharge (CFS)	Storm Storage (Ac - Ft.)	Low Flow Elevation	100 Yr. High Water Level
Pond 1	Existing Wetland	8.42	13.12	30	17.56	712.0	713.63
PPP-4	New	5.35	10.58	3	20.15	710.0	712.53
PP-58	Modified	0.25	1.48	145	4.50	689.0	694.20
PP-91	Modified	0.05	3.07	66	9.67	688.0	694.20
PP-59	Modified	3.70	7.04	101	23.69	685.0	689.41

WATERSHED FRW - FALLS ROAD WEST

This watershed has a total of four subwatersheds draining into the Ulao Creek at two locations. The total area is 152.7 acres. Currently the watershed is 19 percent residential, 8 percent commercial/industrial, 20 percent open, 37 percent agricultural, and 2 percent wetlands. Planned land use dictates increases to 38 percent residential and 51 percent commercial/industrial. This represents 95 acres of development.

The watershed has four existing detention areas at the upstream side of culverts under I-43 and the railroad. These storage areas provide runoff peak reduction functions and will continue to do so under future conditions.

No structural stormwater management measures are recommended in the watershed because even with fully developed conditions, the total discharge to Ulao Creek is calculated at 70 cfs, five percent of the creek flow rate at this location.

Minor grading to enlarge the 710 contour to an area of 2.4 acres at Pond EP-64 will be required to ensure that high water levels for pond do not exceed 713.56.

Controlling runoff from watershed FRW does not offer real benefits that can be measured by a decrease of flow rate in the Creek.

The existing four detention areas should be designated as ponding locations and any filling or otherwise altering these ponding areas should be prohibited. The calculated high water elevations should indicate the minimum extent of the land specifically dedicated to runoff detention.

Table 8-5

POND	TYPE	Area @ NWL Flow	Area @ 100 Yr. HWL	Discharge (CFS)	Storm Storage (Ac - Ft.)	Low Flow Elevation	100 Yr. High Water Level
EP-63	Existing	0.68	1.06	31	2.40	698.0	700.69
PP-64	Modified	0.68	2.66	18	14.99	706.0	713.56
EP-83	Existing	0.23	1.40	106	3.88	700.0	704.
EP-84	Existing	0.05	2.0	103	4.10	702.0	706.0

WATERSHED UC - ULAO CREEK

This watershed has a total of nine subwatersheds directly draining to the Ulao Creek. These subwatersheds are located at both sides of the Creek bed. Total area is 997 acres. Existing conditions are composed of nine percent residential, three percent commercial/industrial, five percent open, 66 percent agricultural, and nine percent wetlands. Planned land use predicts 747 acres to develop increasing the residential area to 53 percent and commercial//industrial to four percent.

All future runoff in the UC Watershed should be subject to the stormwater management criteria and each subwatershed peak future runoff should be limited to the 10-year pre-settlement rates.

The objective of the intensive management effort in this watershed is to prevent flashy runoff flow into the creek from the immediate vicinity of the waterway. As noted earlier, while most other watersheds that feed Ulao Creek are dotted with existing or future ponding areas, the UC Watershed consists of moderate slopes that drain into the Creek without any natural or artificial detention areas or low wetland spots.

UC Project 1: **PPP-11**

This stormwater detention pond will be constructed in line with the stream that drains subwatershed UC-(8). With increasing development in this watershed, it is important to control flows from this stream into the Ulao Creek.

The objective of the pond is to reduce the peak runoff discharge of 260 cfs to 110 cfs. Since the pond is proposed within the stream, Chapter 30 and NR 103 alternatives analysis will be required when construction occurs.

The pond will be 1.0 acres at NWL and 4.9 acres at a HWL of 696.8. The pond will provide 13.8 acre-feet of storage while limiting the discharge to 22 cfs.

UC Project 2: **PPP-10**

Project 2 consists of a detention pond to reduce peak future runoff discharge rates to Ulao Creek from subwatershed UC(9).

The pond should be constructed such that runoff from all currently undeveloped areas are routed through the proposed pond. The 100-year future discharge of 206 cfs will be reduced to 86 cfs.

The pond will be 0.25 acre at NWL and 3.78 acres at a HWL of 704.2. The pond will provide 16.3 acre-feet of storage while limiting the discharge to 7 cfs.

UC Project 3: **PPP-12**

The project consists of a detention pond serving the northern half of subwatershed UC6. The overall runoff discharge from UC6 under future conditions is calculated as 898 cfs. The 10-year pre-settlement discharge rate was estimated as 369 cfs.

All runoff control in UC6 will be located on the east bank of Ulao Creek and therefore the detention ponds will compensate for those portions of UC6 where no runoff controls are recommended.

The pond will be 1.0 acre at NWL and 5.1 acres at a HWL of 696.9. The pond will provide 15.0 acre-feet of storage while limiting the discharge to 33 cfs.

UC Project 4: **PPP-13**

The project consists of a detention pond serving the southern half of the subwatershed UC 6. This pond also will compensate for portions of UC6 west of the creek where no runoff controls are recommended.

The pond will be 1.0 acre at NWL and 8.2 acres at a HWL of 698.6. The pond will provide 30.4 acre-feet of storage while limiting discharge to 45 cfs.

UC Project 5: **PPP-35**

Project 5 consists of a detention pond to reduce peak future runoff discharge rates to Ulao Creek from subwatershed UC4. The overall runoff discharge from UC4 under future conditions is calculated as 414 cfs. The 10-year pre-settlement discharge rate was estimated at 174 cfs. This pond will provide storage of stormwater before water enters the Ulao Creek and flows under the railroad tracks.

The pond will be a 1.0 acre at NWL and 4.1 acres at a HWL of 679.6. The pond will provide 11.6 acre-feet of storage while limiting discharge to 156 cfs.

UC Project 6: **PP-90**

The project consists of minor grading enlarging the 670 contour to an area of 2.9 acres to increase the amount of storage capacity at the location of Culvert No. 90. The outlet to this detention area will remain the same.

Overall Recommendations

The existing natural areas that currently act as storage basins are identified on the stormwater management map. The future 100-year high water levels are delineated.

It is recommended that these areas be preserved as storage basins and identified as undevelopable areas. Should storage provided by the basins be eliminated by future development, the developer should be made to compensate for the lost storage by constructing ponds to achieve equivalent storm detention.

Table 8-6

POND	TYPE	Area @ NWL Flow	Area @ 100 Yr. HWL	Discharge (CFS)	Storm Storage (Ac - Ft.)	Low Flow Elevation	100 Yr. High Water Level
PPP-10	New	0.25	3.78	7	16.34	696.0	704.11
PPP-11	New	1.0	4.9	22	13.81	692.0	696.68
PPP-12	Existing	1.0	5.1	33	15.01	692.0	696.92
PPP-13	Existing	1.0	8.2	45	30.41	692.0	698.61
PPP-35	New	0.05	4.10	146	11.56	674.0	679.22
PP-90	Modified	0.01	2.15	50	4.82	664.0	668.46

WATERSHED LF - LAKEFIELD ROAD

This watershed has a total of six subwatersheds draining into Ulao Creek at two locations. The total area is 239.1 acres. Currently the watershed is 24 percent residential, one percent commercial/industrial, 14 percent open, 52 percent agricultural, and one percent wetland. Planned land use conditions are 94 percent residential, development is occuring about 170 acres of residential area.

Stormwater management projects and recommendations will be implemented to achieve runoff peak control objectives.

LF Project 1: PPP-30

The project will involve the construction of a detention pond to serve drainage from subwatershed 6 and 2. The pond will reduce the flow to the outlet of the entire watershed and will help to reduce flooding of downstream residences. Pond PPP-30 will be 1.2 acres at NWL and 3.7 acres at a HWL of 689.30. The discharge will be limited to 25 cfs and the pond will provide 12.9 acre-feet of storage.

LF Project 2: PPP-33

Subwatersheds 3 and 5 currently drain to the two detention areas that are separated by a hill along Port Washington Road. The project involves the grading of this area to create one pond that will control the discharge of both of the areas with a 24" RCP. One combined pond will provide the detention necessary to control flooding of downstream areas. The pond will be 3.0 acres at NWL and 4.2 acres at a HWL of 695.3. The pond will provide 15.2 acre-feet of storage while limiting discharge to 23 cfs.

LF Project 3: PP-81

This project will alleviate the flooding with future land use conditions at the existing culvert location. Grading will be done to increase the area of detention behind Culvert No. 81 while avoiding the opportunity for water to reach a level to overtop the road. The outlet will remain the same with the pond providing 3.5 acre-feet of storage and limiting discharge to the 10-year pre-settlement rate of 68 cfs.

Other Recommendations

Pond EP-69 — Minor grading enlarging the 727 contour to an area of 0.7 acres to provide 1.15 acre-feet of storage with existing outlet structure

Overall Recommendations for LF

It is recommended that existing and proposed areas be preserved as storage basins and identified as undevelopable areas. Should storage provided by the basins be eliminated by future development, the developer should be made to compensate for the lost storage by constructing ponds to achieve equivalent storm detention.

Table 8-7

POND	TYPE	Area @ NWL Flow	Area @ 100 Yr. HWL	Discharge (CFS)	Storm Storage (Ac - Ft.)	Low Flow Elevation	100 Yr. High Water Level
PPP-69	Modified	0.05	0.70	22	1.14	724.0	727.04
PPP-30	New	1.20	3.67	25	12.91	684.0	689.30
PPP-33	New	3.0	4.15	23	15.12	691.0	695.23
PP-81	Modified	0.05	2.58	64	3.46	673.5	676.16

WATERSHED PRE - PIONEER ROAD EAST

This watershed has a total of two subwatersheds draining to the Ulao Creek at one location. The total area of this watershed is 341.6 acres. Existing land use conditions are 13 percent residential, one percent commercial/industrial, seven percent open, 70 percent agricultural, and one percent wetlands. Planned land use conditions call for 89 percent residential and 6 percent commercial/industrial, or 277 total acres of development.

The majority of the watershed drains to a detention area east of the railroad tracks. This area is currently a navigable waterway with regulations attached to development. Furthermore the area will serve as a major detention area in the future due to the limitations for development and existing flow patterns.

PRE Project 1: POND PPP-40

The project will consist of constructing a detention pond to handle the northern half of subwatershed PRE-2. The pond will limit the flows to six cfs during the 100-year storm event and provide 19.4 acre-feet of storage. The pond will be 1.0 acres at NWL and 5.2 acres at HWL of 701.8.

Overall Recommendations for PRE

The remaining area of subwatershed PRE-2 drains to the existing detention area behind Culvert No. 87. The storage available at this location is taken for granted at the present time and it is recommended that the area covered by the high water level in this location be designated as a ponding area so that filling or development of this depression is prevented. Should storage provided by this basin be eliminated by future development, the developer should be made to compensate for the lost storage by constructing ponds to achieve equivalent storm detention.

Table 8-8

POND	TYPE	Area @ NWL Flow	Area @ 100 Yr. HWL	Discharge (CFS)	Storm Storage (Ac - Ft.)	Low Flow Elevation	100 Yr. High Water Level
PPP-40	New	0.50	5.20	6	19.44	695.0	701.29
EP-87	Existing	1.13	13.47	57	38.03	672.0	677.20

WATERSHED PRW - PIONEER ROAD WEST

This watershed is a total of five subwatersheds draining south and ultimately enters the Ulao Creek after passing through a wetland near the end of the project, Structure No. 77. The total area of the watershed is 509.6 acres. Existing land use consists of 8 percent residential, 81 percent agricultural, and 7 percent wetlands. Planned land use proposes 99 percent residential, to develope 464 acres.

Stormwater management projects and recommendations will be implemented to achieve runoff peak control objectives.

PRW Project 1: PP-78

The project involves grading the area behind Culvert No. 78 to provide additional storage during the 100-year event. The existing 36" CMP will be replaced with a 24" RCP to control the discharge to 30 cfs. The extended detention created by enlarging the 708 contour to 6.1 acres at this location will provide 14.9 acre-feet of storage.

PRW Project 2: PPP-50

Stormwater from subwatershed PRW 4 discharged through pond PP-78 is channeled into subwatershed PRW 3. A large drainage way runs through PRW 3 and conveys the generated stormwater south to the wetland. The drainage patterns of subwatershed PRW2 also channelize the stormwater to a point of connection with the channel from PRW 3. At this location, the two channels join and continue towards Ulao Creek.

The proposed project involves the construction of a detention pond located at the junction of the two major drainage ways from PRW 2 and PRW 3. This pond will attenuate the flows of all areas tributary to the wetland adjacent to Ulao Creek. The pond will be 4.6 acres at NWL and 15.7 acres at a HWL of 676.2. The discharge will be limited to 47 cfs and will provide 42.0 acre-feet of storage for the future development in subwatersheds 2 and 3.

The adjoining wetland can control the quantity aspect of the stormwater generated in subwatershed PRW1. A water quality basin is recommended upland of the wetland as development occurs.

Overall Recommendations for PRW

Existing and proposed areas should be preserved as storage basins and identified as undevelopable areas. Should storage provided by the basins be eliminated by future development, the developer should be made to compensate for the lost storage by constructing ponds to achieve equivalent storm detention.

Table 8-9

POND	TYPE	Area @ NWL Flow	Area @ 100 Yr. HWL	Discharge (CFS)	Storm Storage (Ac - Ft.)	Low Flow Elevation	100 Yr. High Water Level
Ex Pond	Existing	1.90	8.74	0	12.77	738.0	740.40
PP-78	Modified	0.05	6.09	30	14.86	703.0	708.57
PPP-50	New	4.6	15.7	47	41.91	672.0	676.13

SUMMARY OF WATER QUANTITY BMP RECOMMENDATIONS

The challenge in the water quantity section of this study requires providing enough storm storage for a rapidly urbanizing watershed while trying to maintain a natural and rural landscape. The north and south area of the Ulao Swamp currently acts as a detention basin providing storage during large storm events. The problem areas in this study however are those tributary to the Ulao Swamp and Ulao Creek. Water quantity mechanisms designed in accordance with the design goals presented earlier in this section will help control stormwater runoff during large storm events and prevent existing roads and structures from flooding.

The results of the water quantity recommendations can be seen in Table 8-10. This table is a comparison of the 10-year pre-settlement flows versus the peak discharge rates of the subwatersheds and proposed ponds during a 100-year storm with recommendations in place. In the majority of subwatersheds, the peak discharge rates of the watershed or a pond in the watershed match the goal of reducing flow to a 10-year pre-settlement value. In some areas, attaining this goal for a subwatershed is not feasible due to the constraints of topography and existing roads and structures. In the areas where the reduction goal has not been met, the downstream drainage systems have been evaluated and determined adequate to handle additional flow.

Pond locations are only suggested locations, based on topography and existing sub-basin constraints not property boundaries. The specific location of ponds shown on Maps 16, 17, and 18 are not required for effective implementation. The flow reductions in Table 8-10 are what is required for implementation to meet the plan goals.

Table 8-10

Hydraulic Model Nodes	10-Year Pre-Settlement Flow (cfs)	Hydraulic Model Nodes	100- Year developed flow with Water Quality Recommendations In Place
USN-7	112	USN-7	353
Pond-1	7	PP-1a	11
EP-13	5	PP-13	8

Hydraulic Model Nodes	10-Year Pre-Settlement Flow (cfs)	Hydraulic Model Nodes	100- Year developed flow with Water Quality Recommendations In Place
USN-8	68	USN-8	93
EP-14	5	PP-14	3
USN-9	142	USN-9	326
COM-1	145	COM-1	329
EP-12	25	PP-12	29
USN-6	215	USN-6	517
		PPP-1	29
		USN-6a	170
COM-2	228	COM-2	198
EP-5	123	EP-5	109
USN-3	74	USN-3	243
COM-3	160	COM-3	338
EP-6	80	EP-6	114
USN-4	90	USN-4	251
EP-7	30	EP-7	32
		PPP-2	5
EP-18	13	EP-18	5
		USN-5a	269
		PPP-3	11
		USN-5b	119
		Node 24	127
		EP-2	65
USN-5	135	USN-5	103
EP-1	27	EP-1	45
USN-2	32	USN-2	102
USN-1	420	USN-1	1162
COM-4	501	COM-4	1394
SWMP-N	29	SWMP-N	34
USS-4	212	USS-4	523
EP-35	21	EP-36	43
USS-3	191	USS-3	470
COM-6	198	COM-6	494
EP-34	15	EP-34	32
USS-1	797	USS-1	2331
USS-2	225	USS-2	562
COM-5	1011	COM-5	2896
USS-6	105	USS-6	252
EP-44	80	PPP-20	25

Hydraulic Model Nodes	10-Year Pre-Settlement Flow (cfs)	Hydraulic Model Nodes	100- Year developed flow with Water Quality Recommendations In Place
USS-5	209	USS-5	499
COM-7	1275	COM-7	3409
SWMP-S	92	SWMP-S	210
I-43-12	175	I-43-12	579
EP-27	120	PP-27	219
I-43-11	156	I-43-11	426
COM-9	332	COM-9	598
EP-20	53	EP-20	6
I-43-10	219	I-43-10	638
EP-29	70	PP-29	127
I-43-9	58	I-43-9	142
EP-55	34	EP-55	50
I-43-8	107	I-43-8	300
EP-51	43	PP-51	123
COM-10	74	COM-10	349
EP-53	37	EP-53	
I-43-7	87	I-43-7	218
EP-50	54	EP-50	57
I-43-6	21	I-43-6	68
I-43-1	108	I-43-1	330
COM-11	299	COM-11	650
I-43-3	173	I-43-3	461
EP-38	122	EP-38	225
I-43-2	47	I-43-2	150
I-43-5	33	I-43-5	102
EP-39	32	EP-39	90
I-43-4	44	I-43-4	154
COM-13	77	COM-13	244
EP-56	11	EP-56	44
I-43-13	51	I-43-13	175
COM-40	81	COM-40	330
		PPP-21	30
UC-TRB	79	UC-TRB	30
COM-12	199	COM-12	247
UCRK-1	199	UCRK-1	245
WASH-1	146	WASH-1	113
COM-14	345	COM-14	377
UCRK-2	341	UCRK-2	376

Hydraulic Model Nodes	10-Year Pre-Settlement Flow (cfs)	Hydraulic Model Nodes	100- Year developed flow with Water Quality Recommendations In Place
WASH-2	213	WASH-2	169
COM-15	554	COM-15	613
U-CREEK-4	553	U-CREEK-4	619
FRE-5	178	FRE-5	411
POND-10	18	POND-10	30
		PPP-4	3
FRE-4	117	FRE-4	270
COM-19	125	COM-19	270
EP-58	26	EP-58	145
FRE-2	91	FRE-2	208
FRE-3	115	FRE-3	266
		PP-90	66
COM–18	206	COM–18	382
EP-59	17	PP-59	101
FRE-1	67	FRE-1	159
COM-17	84	COM-17	188
FRW-4	112	FRW-4	360
EP-64	8	PP-64	18
FRW-1	24	FRW-1	79
COM-20	29	COM-20	90
EP-63	11	EP-63	31
UC-9	111	UC-9	206
		PPP-10	7
UC-8	86	UC-8	259
		PPP-11	22
		UC-7	307
COM-16	388	COM-16	1097
U-CREEK	377	U-CREEK-5	1079
FRW-3	78	FRW-3	224
EP-84	44	EP-84	103
FRW-2	19	FRW-2	62
COM-21	53	COM-21	143
EP-83	18	EP-83	34
COM-22	390	COM-22	1101
UCRK-6	368	UCRK-6	1058
UC-5	41	UC-5	133
UC-6	369		
		UC-6a	74

Hydraulic Model Nodes	10-Year Pre-Settlement Flow (cfs)	Hydraulic Model Nodes	100- Year developed flow with Water Quality Recommendations In Place
		UC-6c	328
		PPP-12	33
		UC-6b	615
		PPP-13	45
COM-23	748	COM-23	181
UCRK-7	721	UCRK-7	166
LF-5	82	LF-5	210
LF-3	55	LF-3	136
EP-70	31		
EP-71	23		
COM-26	317		
		PPP-33	23
LF-1	43	LF-1	110
LF-6	25	LF-6	62
		PP-69	22
LF-2	89	LF-2	241
		PPP-30	25
COM-25	150	COM-25	136
EP-81	68	EP-81	64
UC-4	174	UC-4	414
		PPP-35	146
COM-24	287	COM-24	230
U-CREEK-8	279	U-CREEK-8	230
PRE-2	291	PRE-2a	277
		PPP-40	6
		PRE-2b	638
		Node 26	642
EP-87	45	EP-87	57
PRE-1	37	PRE-1	119
COM-28	48	COM-28	156
UC-3	28	UC-3	92
UC-2	24	UC-2	79
		Node 27	171
		Node 28	171
		EP-90	50
UC-1	119	UC-1	339
LF-4	26	LF-4	64
		COM-27	626

Hydraulic Model Nodes	10-Year Pre-Settlement Flow (cfs)	Hydraulic Model Nodes	100- Year developed flow with Water Quality Recommendations In Place
U-CREEK-9	430	U-CREEK-9	624
PRW-5	82	PRW-5	205
POND-2	0	POND-2	0
PRW-4	122	PRW-4	285
COM-50	122	COM-50	285
EP-78	33	EP-78	30
PRW-3	151	PRW-3	399
PRW-2	86	PRW-2	221
COM-29	236	COM-29	620
		PPP-50	47
PRW-1	121	PRW-1	317
COM-30	353	COM-30	338
COM-31	377	COM-31	356
STR-77	348	STR-77	329

During the 100-year storm event under a future Town of Grafton land use condition, water will be detained at existing and proposed ponding locations and will be discharged at the 10-year presettlement storm event rate. This will reduce the future flooding problems that will occur if all stormwater management practices are not put in place.

ULAO CREEK CORRIDOR

The Ulao Creek corridor is geographically in the center of the long narrow watershed and composes most of the natural resources of the watershed. The SEWRPC Natural Areas Management Plan recommends, as does this plan, the protection of part, parts, or the entire Ulao Swamp. Protection may be accomplished through a combination of methods including: stewardship grants, park dedication, conservation easements, creation of nature preserve, WDNR wildlife area designation, and the purchasing of development rights.

The following is a list of recommendations for the Ulao Creek corridor. The number for each project is not a rank in order of priority, but a reference to the location on Map 20, Appendix B. A priority ranking list follows the description of the projects.

CC1. **Stream rehabilitation** at Ulao Creek and Port Washington Road immediately south of the two billboards on the east side of Port Road. The creek is about 10 feet from the road pavement and badly eroded. The project should include the regrading, stabilization, and re-planting of the eroded bank and the upstream and downstream meanders.

Removal of sediment in this reach also is recommended. The project length is about 300 feet.

CC2. **Stream rehabilitation** at Ulao Creek and the "family farm property" immediately west of I-43. The creek is about five feet from a new private fence and badly eroded. The project should include the regrading, stabilization, and re-planting of the eroded bank and the two upstream and one downstream meanders. Removal and clean out of sediment and upstream debris, exacerbating the problem in this reach also would be required. The project length is about 200 feet.

CC3. **Overflow pond** adjacent to the Ulao Creek on the Wisconsin Sump and Pump property, between I-43 and the Ulao Creek immediately south of Lakefield Road. The creation of an overflow pond in this area would allow for increased storage of flood waters prior to crossing under I-43. The pond should be designed to allow inflow and outflow at set elevations for given storm events using a staged inlet and outlet. The pond should also be designed to incorporate fish habitat structures like fish cribs. The surface area of the pond would be about 0.75 acre.

CC4. **Stream rehabilitation, clean out, and buffer easement** on the property immediately north of Lakefield Road and east of the Creek. This area gives horses direct access and is suffering from bank instability due to trampling. The project should begin from upstream where a culvert has been recently removed, to downstream to the bridge at Lakefield Road. The 30 foot wide and 400 foot long buffer easement, 15 feet each side of the creek, should then be fenced and replanted with floodplain forest species like silver maple, green ash, and swamp white oak. The project should plant 40 trees.

CC5. **Plantings and streambank rehabilitation** in the SE1/4 of the NW1/4 of Section 30, T10N, R22E along the Ulao Creek (near Foxglove Estates). This area is immediately upstream of the large forested wetland north of Lakefield Road. The northern limits of this project include three meanders that need to be stabilized with hard armor. The southern limit, which extends to the existing forested wetland, should be planted with floodplain forest species like silver maple, green ash, and swamp white oak. These plantings will provide two major benefits of long term bank stabilization and provide shade for the creek, as well as add wildlife habitat to the Creek corridor. The project should plant 50 trees.

CC6. **Two habitat ponds,** 0.25 and 0.5 acres in size, should be constructed to provide both fish and wildlife habitat in an area where few over-flow or backwater ponds exist adjacent to the Creek. Both locations are on the west side of the Creek east of Foxglove Estates and located in areas of dense reed canary grass. The off-line ponds should be designed using a two tiered pond bottom. The deep tier should be considered for fish habitat on the Creek side of the pond and a shallow tier, on the other side, should be utilized as a planting shelf to be inundated in flood events. The ponds also should have the same inlet and outlet controls discussed in recommendation CC3. The surface area of the two ponds totals about 0.75 acres.

CC7. **Plantings** should occur along both sides of the bank of Ulao Creek from 1,200 feet to 1,800 feet downstream of where the Ulao Creek crosses the Railroad south of CTH Q (Karin Manley farm). A mixed planting of 2" diameter at breast height (dbh) green ash, silver maple, and swamp white oaks should provide stream shading and increase wildlife habitat in the creek corridor. Approximately 120 trees would be required, 60 per side in two staggered rows spaced 20 feet apart.

An alternative approach would be to use trees from the Ozaukee County Land Conservation Department tree program. If the trees from Ozaukee County were used and planting was done with volunteers the cost would be reduced significantly.

CC8. A **clean out** of the 28 inch X 36 inch stone box culvert that drains the Mr. Z's and Tillman properties west of the railroad and south of CTH Q should occur. Vegetation that has overgrown in the channel should be removed and taken off site, so as not to be washed back into the channel from the bank. Two workers should be able to cut and remove the debris in one day.

CC9. **Overflow pond** adjacent to the Ulao Creek on the Tews property south of CTH Q. The creation of an overflow pond in this area would allow for increased storage of flood waters and could be designed to serve the storm water needs of the undeveloped land to the northeast when it develops. The pond should be designed to allow inflow and outflow at set elevations for given storm events by use of a staged inlet and outlet. The pond also should be designed to incorporate water fowl nesting structures. The surface area of the pond would be about 1.0 acre. Water quantity project PP-11 satisfies this projects requirements, but may not be built if lands do not develop.

CC10. **Plantings** along both sides of the bank of Ulao Creek from 1,300 feet to 1,800 feet upstream of CTH Q (Helms farm). A mixed planting of 2" d.b.h. green ash, silver maple, tamaracks, and swamp white oaks should provide stream shading and increase wildlife habitat in the Creek corridor. Approximately 100 trees would be required, 50 per side in two staggered rows spaced 20 feet apart. An alternate approach would be to use trees from the Ozaukee County Land Conservation Department tree program and volunteers to plant them.

CC11. **Cut back and clean out** the willows, which have overgrown the creek (ditch) and are limiting flows. Vegetation that has overgrown in the channel should be removed and taken off site, so as not to be washed back into the channel from the bank. Two workers should be able to cut and remove the debris in one day. This segment extends 100 feet west and 200 feet north in a 90 degree bend of the Creek and is located as noted on Map 20. This project also includes clean out of the 90 degree bend on the Hoppe Property.

CC12. A **wetland restoration** directly east of the CC11 clean out area is recommended about one acre in size. The site would require only some minor grading for incorporation of some overflow retention from the Creek, plantings, and reseeding.

CC13. **Two habitat ponds,** 0.25 and 0.5 acre in size, should be constructed to provide both fish and wildlife habitat in another area where there are few over flow or backwater ponds adjacent to the creek (Kaul property). Both locations are on the east side of the creek and located in areas of reed canary grass surrounded by lake sedge. The off-line ponds should be designed to be oblong allowing for overflow lengthwise from the Creek. The design also should use a two tiered pond bottom. A deep tier for fish habitat on the creek side of the pond should be constructed and a shallow tier, on the other side, for a planting shelf to be inundated in flood events. The ponds also should have the same inlet and outlet controls discussed in recommendations CC3 and CC6. The surface area of the two ponds totals about 0.75 acres.

CC14. **Wetland restoration** of a part of the Ulao Swamp should be accomplished by respreading the dredge piles, while leaving the ditch in place. This will require coordination with the landowner, the Tillman Corp. The ditch is about 20-30 feet wide by 1,800 feet long or about one acre in area. Grading should be done in fall after freeze up and would consist of spreading existing dredge on the bank and a placement wetland dormant seed. In spring, white cedars and tamaracks should be planted at a spacing of 180 trees in two staggered rows 20 feet apart.

Additionally, other wildlife enhancement projects are encouraged to be undertaken by private landowners and wildlife organizations. Projects may include planting crops for wildlife food and cover, waterfowl nesting boxes, bat houses, buckthorn control in woods. For example, wood duck nesting boxes could be constructed and located in good cover with one-half mile of open marsh land and should be protected from prevailing winds.

GROUNDWATER

Northern Environmental's groundwater study, Appendix C, explains in greater detail the issues presented below.

Groundwater/surface-water interactions can be used to reduce stormwater runoff and support dry-weather baseflow. The techniques and modifications needed to implement these possibilities complement traditional stormwater management options. It is recommended that the Town of Grafton and the Ulao Creek Partnership follow a phased approach to increase dry-weather baseflow and decrease stormwater runoff volume.

Primary attention should be given to options that minimize dry-weather loss of stream flow to groundwater. Specific management options include attenuating the effect of gravel mining and agricultural drainage at the extreme north end of the Ulao Swamp, decreasing dry-weather infiltration under eastern portions of the Ulao Swamp, and assuring that newly constructed stream channel modifications, wetlands, and ponds are designed to prevent surface-water backflow and infiltrations during dry weather.

In addition to preventing dry-weather loss of surface flow, attention should immediately be given to alternatives that detain flood water or transfer it out of the Watershed. Detained stormwater will be released slowly to the creek. Options to detain stormwater include storage in granular deposits paralleling Ulao Creek, modifying agricultural drainage tile and ditch systems to promote temporary storage in low areas, and infiltrating water in uplands west of Ulao Creek. Water can be transferred from the Watershed by maximizing stormwater infiltration under areas east of Ulao Creek and the Ulao Swamp, and encouraging infiltration in the Ulao Creek floodplain between Ulao Road and Falls Road.

After management options that decrease dry-weather water losses from the Creek and detain stormwater for slow release are implemented, the quantity and quality of water in Ulao Creek should be re-evaluated. If insufficient water is available during dry periods to reach management objectives, artesian groundwater could be used to supplement Ulao Creek's flow. Most supplemental water is available in the lowlands north of Ulao Road. Wells, interceptor trenches, and/or discharging ponds/wetlands could be developed to promote groundwater discharge.

PUBLIC EDUCATION PROGRAM

An educational and informational program is very important for the implementation of the plan recommendations. Specific groups of people, termed target audiences, will implement the recommendations. These target audiences are the same as those described in the Milwaukee River South Priority Watershed Plan.

Rural landowners and operators need to identify and enter into agreements to implement streambank stabilization practices and manage nutrient and pesticide applications. The Town of Grafton must understand the plan and its recommendations as well as, the implementation structure, funding options, and plan benefits. Urban, rural and industrial residents must understand their role as pollution sources and how to reduce this role through methods such as best housekeeping practices. Business and industry have to take part in reducing pollutants from product production activities and from development of new facilities. Lastly, community youth must be educated on the process of pollutant loading and reduction methods to lead the Watershed into the future.

The Town of Grafton, the Ulao Creek Partnership, and the Ozaukee County Land Conservation Department should focus first on watershed project participation by entering into project specific cost share agreements with the WDNR and rural landowners and through community backing of ordinances and public works programs. Secondly, individuals in the community must be made aware of education of urban/suburban housekeeping practices, rural nutrient loading, and pesticide BMPs. Thirdly, the Town of Grafton should utilize other existing state, and federal conservation programs in addition to the nonpoint program for funding resources. Lastly, the Town of Grafton, Ozaukee County Land Conservation Department, and Ulao Creek Partnership should increase community awareness of existing and future plan implementation to gain Watershed support. The list below represents specific educational projects, not ranked by priority, that can be undertaken by the Town of Grafton, Ozaukee County Land Conservation Department, and Ulao Creek Partnership to further water quality education in the watershed.

1. Personal meetings with rural land owners
2. Watershed newsletters and UW-Extension Stormwater Informational Handouts
3. Town meetings
4. Rural, industrial, and youth water quality workshops
5. Demonstration projects
6. Watershed tours
7. BMP fact sheet distribution at the town hall
8. Articles in local newspapers; and agricultural, industrial, and business publications
9. Television and radio news, interviews and public service announcements
10. Speakers for business and industrial conferences and shows
11. Water quality testing for high school students
12. Exhibits at local events, the County Fair, and trade shows
13. Youth group projects for organizations like church groups, and the Boy Scouts
14. Outdoor education center creation

9) STORM WATER MANAGEMENT PLAN IMPLEMENTATION

TIME SCHEDULE and COST ESTIMATES

Timing of the implementation is dependent on the type of recommendation, its location in an existing or future development, and how important it is to satisfy the water quantity and quality goals. Table 9-1 outlines recommended, prioritized structural stormwater quantity projects for the Town of Grafton. Some of these projects may be funded by the WDNR through the Nonpoint Source Pollution Program if they are in subwatersheds with critical land use areas and have water quality design elements incorporated.

Water Quality

Water quality BMPs have been assigned based on urban or rural practices. Based on planned land use conditions, with all corridors, wetlands and woodlands zoned conservancy, approximately 1035 acres of commercial, business, and industrial lands will make up the area. Currently about 258 acres are developed, leaving 777 acres planned for development. This totals, including I-43 areas,19 percent critical land use in the watershed. Based on an average cost of $2000/acre for implementing water quality BMPs from Map 19. The amount of $1,554,000.00 in expenditures for urban BMPs (commercial, business, and industrial) is planned to meet the recommended percent pollution reduction goals. Planned land use conditions, with recommended conservancy zoning, predicts 3975 acres of rural residential land use, 813 acres of which is currently developed. In the future 3162 acres of residential land are planned to be developed. Of the 3162 acres, 1988 acres is residential lots and 1174 acres is one-acre residential lots. The average cost per acre for three-acre rural BMP implementation has been determined to be $500.00. This results in the need to expend $994,000.00 on three-acre rural BMPs and $1,174,000.00 for one-acre residential BMPs. All of the $3,772.000 needed for water quality BMPs will be funded through developer agreements with the Town of Grafton.

The preservation of existing natural resources is the most significant component of the water quantity recommendations. All natural resources provide essentially free water quality benefits. Once lost, some kind of structural mechanism is required to have the same benefits, always at a cost to the developer or property owner. Currently, 1284 acres of natural resources exist in the watershed. The planned land use condition has 787 acres designated as conservancy. These 787 acres consist of the primary environmental corridor and some wetlands. Our plan recommends designation of 1284 acres as conservancy. This conservancy designation would include all wetlands (768 acres), primary and secondary environmental corridors outside wetlands (315 acres), and significant identified woodlands (221 acres). The implementation schedule should begin immediately because this designation process may be lengthy. The specific amount of area to be rezone shall be determined by the Town of Grafton through its zoning process.

Water Quantity

Costs for the pond projects have been standardized on a per acre basis of $80,000/acre. This includes design, construction, inspection, and contingencies but does not include land costs. This cost estimate is similar to those from other stormwater management plans in Ozaukee County. Cost for culvert replacement and grading activities also have been standardized to $20,000/culvert for most projects. The cost to preserve all lands inundated during the 100-year storm event through conservancy zoning has not been determined. Some of these areas already have preservation mechanisms in place, such as the 100-year flood plain, zoned primary environmental corridor to be sewered, and wetlands. Table 9-1 shows prioritized Town structural BMP projects. Table 9-2 shows developer-driven structural water quantity BMP recommendations for the watershed.

TABLE 9-1
PRIORITIZED TOWN STRUCTURAL BMP RECOMMENDATION COSTS

POND	TYPE	Town Cost *	WDNR Cost**
PP-51	Modified	$19,500	$10,500
PP-12	Modified	$30,000	
PP-81	Modified	$30,000	
PP-64	Modified	$20,000	
PP-14	Modified	$20,000	
PPP-2	Modified	$86,800	
TOTAL		$206,300	$10,500

* Funding from future sub-basin special drainage fee assessments.

** WDNR cost based on non-point source cost share funding based on existing critical land use in sub-basin and is dependant on funding availability.

TABLE 9-2
DEVELOPER DRIVEN STRUCTURAL BMP RECOMMENDATION COSTS

POND	TYPE	Developer Cost
PP-1a	Modified	$20,000
PPP-21	New	$520,000
PPP-1	New	$488,800
PP-13	Modified	$20,000
PP-29	Modified	$75,000
PPP-3	New	$408,000

POND	TYPE	Developer Cost
Pond 1	Modified	$20,000
PP-27	Modified	$20,000
PPP-4	New	$846,400
PP-58	Modified	$20,000
PPP-20	New	$257,600
PP-91	Modified	$30,000
PP-59	Modified	$40,000
PPP-10	New	$302,400
PPP-11	New	$392,000
PPP-12	New	$408,000
PPP-13	New	$656,000
PPP-69	Modified	$20,000
PPP-30	New	$293,600
PPP-33	New	$332,000
PPP-35	New	$328,000
PP-90	Modified	$20,000
PPP-40	New	$416,000
PP-78	Modified	$30,000
PPP-50	New	$1,256,000
TOTAL		$7,219,800

Ulao Creek Corridor

Table 9-3 outlines the costs for the Ulao Creek corridor BMP recommendations. The table is ranked by project priority. Some of these projects have funding alternatives such as the WDNR Nonpoint Source plan, Environmental Quality Incentive Program (EQIP) and Wildlife Habitat Incentive Program (WHIP) programs and others should be privately funded or required as part of development agreements. Total cost for the implementation of Ulao Creek corridor BMPs is $420,500, much of which is eligible for WDNR cost sharing under the Nonpoint Program. However, the availability of funding and ranking of Nonpoint Projects by the WDNR varies on an annual basis. These projects should be undertaken by the Town of Grafton, Ozaukee County, and private organizations like the Ulao Creek Partnership and Ducks Unlimited.

TABLE 9-3
ULAO CREEK CORRIDOR BMPs COSTS

RANK	PROJECT	ESTIMATED COSTS
3	CC1 - Stream Rehabilitation at Ulao Creek & Port Washington Rd.	$15,000
4	CC2 - Stream Rehabilitation at Ulao Creek & family farm	$10,000
10	CC3 - Overflow Pond	$60,000
5	CC4 - Stream rehabilitation, clean out & buffer easement north of Lakefield Road	$16,000
6	CC5 - Plantings & streambank rehabilitation near Foxglove Estates	$32,500
9	CC6 - Two habitat ponds east of Foxglove Estates	$60,000
7	CC7 - Plantings along both sides south of CTH Q (Karin Manley farm)	$18,000
1	CC8 - Clean out culvert draining Mr. Z's & Tillman properties	$500
11	CC9 - Overflow pond on Tews property	$80,000
8	CC10 - Plantings upstream of CTH Q (Helms farm)	$15,000
2	CC11 - Cut back and clean out willows	$500
13	CC12 - Wetland restoration east of CC11	$18,000
12	CC13 - Two habitat ponds (Kaul property)	$60,000
14	CC14 - Wetland restoration of part of Ulao Swamp	$35,000
	TOTAL	$420,500

FINANCING ALTERNATIVES

The financing alternatives used to finance stormwater management programs available for implementation in the Ulao Creek watershed are numerous; however, they vary in degree of ease of implementation, administrative requirements, and property owner acceptance. Furthermore, they also can be used in combination with each other. We are recommending, for the time being, the Town continue its current method of subidivsion exaction financing for stormwater management.

The financing alternatives, along with the stormwater management functions that can be addressed by each alternative, are listed in Table 9-4. Following Table 9-4 is a description of these alternatives used to finance stormwater management programs alternatives.

Advantages and disadvantages associated with each alternative also are discussed as well as an indication of the activity (e.g., administration services, operation/maintenance, renewal/replacement, capital improvements, and water quality monitoring) for which the funding sources are best suited.

Table 9-4
ALTERNATIVE FINANCING METHODS FOR STORMWATER MANAGEMENT ACTIVITIES

	Functional Program Elements			
Financing Alternative	Administration Planning & Engineering	Capital Improvement Program	Operation and Maintenance	Regulatory Enforcement
Stormwater Utility	*	*	*	*
General Fund	*	*	*	*
Preservation Cooperative	*	*		
Special Taxing District	*	*	*	
State WDNR Grants	*	*		*
Homeowners Association		*	*	*
Drainage District	*	*	*	*
Bonds		*		
Pay-As-You-Go Sinking Fund	0	*		*
Subdivision Exactions		*		
Fee-In-Lieu-Of		*		
Developer Incentives		*		
Betterment Charge		*		
Penalties/Fines	*	*		*
Fees/Permits	*			

* Indicates the alternative can fund the stormwater management activity.

Stormwater Utility

Funds from a stormwater utility are used for maintaining and operating a stormwater management system as well as for renovating or upgrading the system. Such items as pond dredging, sediment control, and educational efforts also can be funded.

Until recently, these items typically have been financed through real estate taxes; however, there are some inherent problems with this method. Financing stormwater improvements by the general tax role does not take into account the amount of runoff from the property being taxed and it does not recover costs from new taxable properties which often generate large amounts of runoff.

Stormwater utility charges are established to reflect the relative amounts of stormwater runoff generated. Runoff from a typical residential lot is determined and established as a Residential Equivalent Units (REU). A comprehensive engineering study then determines the estimated runoff from all existing properties and future developments in the drainage area. The runoff estimate for each property is divided by the runoff from one residential lot to determine each property's REU.

REUs for the entire watershed are tabulated and then divided into the annual stormwater management operation and maintenance expenses to arrive at the cost for one REU. Based on its total REUs, the cost for each property is computed and billed along with other user fees.

The Milwaukee River South Priority Watershed funding will run out in three years. Also, there has been discussion about changing the grant program to a loan program. NR 216 is reaching smaller communities and thus requiring those communities to comply with water quality standards that will cost money above and beyond what is funded at this time.

A stormwater utility provides a sound funding source as grant programs decrease and stormwater regulating increases.

General Fund

In most communities, funds for stormwater management are provided from the general fund. This source can be best considered a "bank" into which revenues are placed and from which most programs are funded. The major income source for the general fund is property taxes. This income is based upon the assessed valuation of property within the Town of Grafton. This revenue source can be used for funding of administration, renewal/replacement, construction, maintenance, and water quality monitoring.

Preservation Cooperative

The preservation cooperative system was specifically created for conditions of the Ulao Creek watershed. A key element of the water quantity recommendations is preserving areas around existing culverts that have been determined to provide important storage behind them under current conditions and as modeled under future development conditions. Secondly, ponds were proposed to eliminate flooding of existing structures that would occur under developed conditions if no action was taken.

Under these two circumstances, land has been utilized for ponding on one property to benefit not only that property, but additional properties up stream. This creates an unfair situation for the property owner where the pond is located. This property owner forfeits some developable land to benefit other property owners upstream. With the preservation cooperative system, this inequality is eliminated.

The preservation cooperation system strives for equity. Under this system, the property owner or owners whose property is impacted by the placement of a pond or by an area behind a culvert reserved for storage is compensated for their land by all contributing property owners as they receive monies to develop their property.

To initiate this system, a watershed wide study would be undertaken to set up the mechanism for property owner compensation. The following items must be inventoried: size of ponds and ponding areas, size and property owners of contributing areas, and current and projected land values based on current zoning and the future land use map. With this information, costs would be allocated to individual property owners for their share of the stormwater facility benefitting them based on an engineering economic analysis.

This system is called a cooperative because property owners are responsible for the majority of its administration. All money would be transferred between property owners and the Town would not have to be significantly involved with any transaction.

The preservation cooperative functions as follows:

- The cost of each facility defined in this plan consists of two main components; land acquisition and structural implementation costs.

- Owners of land lost to stormwater management should be compensated for the lost development potential. This should be a direct payment to the affected owner by the other property owners in the benefit area of the ponding facility. The payment is required only at the time of development.

- If the property where the facility is located develops first, the pond area should be dedicated as such with the expectation that future upstream development will compensate the owner.

- The structural measures that may be needed at a given site (e.g., grading, outlet construction, culvert replacement, etc.) need to be implemented when 50 percent of the available land is developed. At this time, the entire developable area will become liable for the cost of the structural implementation. This includes the property on which the ponding will take place and those properties that have not been developed at that time.

Complications are inherent in paying for the proposed stormwater improvements to the Ulao Creek watershed because of their regional approach, unknown and varied timing of construction and its inherent multi-jurisdictional nature. The preservation cooperative system attempts to simplify financing of two types of stormwater practices recommended in this plan.

This financing method is not recommended for ponds not created through backing up culverts proposed to control runoff from future developments or to protect downstream structures from flooding under higher flows from future development. For these types of ponds, the other financing methods discussed in this section can be used.

Special Taxing/Assessment Districts

Income from a special taxing district or special assessment district is generally dedicated to that district. That is, the area that is designated as "special," for whatever reason, would pay an additional tax or have an increased assessment. The funds from the additional tax or assessment are returned to that area. For example, if stormwater management facilities are constructed to benefit the Ulao Creek Watershed, that watershed could be designated a special taxing district and an additional tax levy could be assigned to the residents of the Ulao Creek Watershed.

WDNR Grants

Grants are provided by the WDNR to help local communities implement nonpoint source pollution control programs. Two types of grants are available:

1. Local Assistance Grants
2. Nonpoint Source Grant

Local Assistance Grants are intended to prohibit the administrative costs for the implementation of the priority watershed plans from becoming a burden for local communities. The state will pay up to 100 percent of the cost of additional staff, professional services, training, travel expense, and additional office space.

Nonpoint Source Grants provide technical and financial help to implement nonpoint source pollution control practices. Nonpoint Source Grants require between 30 percent to 50 percent of the cost of the project to be paid by the local community. Part or all of the local share may be an "in-kind" match. Table 9-5 identifies practices that are eligible for cost sharing and Table 9-6 is a summary of state assistance for nonpoint source pollution control. The amount of grant funds available changes annually and a project funding is based on its ranking against all other projects in the priority watershed.

Home Owners Association

The home owners association concept is similar to the special assessment district in that a relatively small area would receive an additional levy. This method is generally available only for residential parcels. In the case where no special district could be established, or where a private entity is responsible for the maintenance of a stormwater facility, a home owners association fee is reasonable. Assessments are specific depending on the needs and desires of each association. Capital improvements, operation and maintenance, and water quality monitoring for the residential development can be funded by this method.

Drainage District

Drainage districts were originally started by farmers for the purpose of draining/tiling farm land. Based on discussions with Steve Narveson of the Ozaukee County Environmental Health Department, Ozaukee County at one time had drainage districts. These districts have since been dissolved; nevertheless, a drainage district could be resurrected in the Ulao Creek Watershed. Drainage districts are regulated under Wisconsin Statute, Chapter 88. The advantages of creating a drainage district include borrowing money, levying assessments, and creating a formal organization with powers well beyond that of the Ulao Creek Partnership.

Disadvantages to the drainage district method are the legal requirements, administration requirements, and liability issues. If this alternative is desirable, it is recommended that members of currently operating drainage district boards be interviewed as to their successes and pitfalls. Also, Wisconsin Statute Chapter 88 should be read and understood fully.

Bonds

General obligation, revenue, or special assessment bonds are normally used by governments to pay for large capital improvement programs. Repayment of the bond is normally through the general fund; however, special assessment district income, as well as utility revenues, can be used to pay the debt service. Bonds would allow large-scale capital improvement programs to be initiated when the facilities are needed rather than waiting until the funds are accumulated.

Pay-As-You-Go Sinking Fund

As an adjunct to revenue bond financing, this type of stormwater funding is most common. Essentially, a separate account is formed to receive revenues from numerous sources such as property taxes or stormwater utility income. The fund accumulates revenues until sufficient money is available for an identified project, then the total project amount is removed from the fund, the fund "sinks" in size, and the growth stage starts over. This method is generally associated with capital improvement programs where it is not advantageous to incur long-term debt.

Subdivision Exactions

As a condition for approval of development, the Town of Grafton can require the developer of a subdivision or large parcel to construct stormwater management facilities and dedicate them to the Town upon completion. In addition, developers can be required to donate drainage easements or other types of partial rights to the Town for stormwater management purposes. Thus, the developer would be responsible for funding the capital program while the Town would be responsible for funding the operation and maintenance. This is the basic method the Town employs today.

Fee-In-Lieu-Of

An alternative to requiring developers to construct stormwater management facilities is to require them to pay an initial front-end charge for the capital improvements needed to service their development. The charge would be representative of the development's contribution to the regional facility in the watershed. A fee-in-lieu-of is a technique to generate the funding needed for capital improvements in a watershed. The term is derived from the case in which a developer is required to construct infrastructure including stormwater systems. Since construction of small-scale systems is not always advisable, particularly because of the problems associated with the acceptance of the operation and maintenance costs, the better choice is a fee paid to the Town of Grafton to construct a larger, regional system. The fee covers the developer's share of the regional facility.

There are two general areas where a fee-in-lieu-of is appropriate. First, a fee-in-lieu-of is appropriate where there is a large marginal cost of constructing additional facilities with the development. A developer may pay for a portion of the construction of a large regional detention facility in-lieu-of the construction of a detention facility for an individual development.

A fee-in-lieu-of is also appropriate where the introduction of a sizable development causes the need for a new type of stormwater management system. For example, existing stormwater conditions may be adequately controlled within a watershed with the use of drainage ditches and swales. However, with the introduction of new development, a detention/retention facility may be required. In this case, the developer could elect to pay a fee-in-lieu-of for the construction of the facility.

The collection of fee-in-lieu-of monies promotes the implementation of regional systems rather than the small-scale individual systems. The larger stormwater facilities are easier to maintain and can handle larger-scale problems. Developers may be required to wait until sufficient funding is available for the regional system and until the facility can be constructed unless they commit to building an interim system that can be either removed or incorporated into the regional system.

In developed portions of the Town of Grafton that may have significant existing needs, few new developments are needed to contribute to the construction of larger regional facilities.

Nevertheless, the fee-in-lieu-of process can reasonably be associated with a stormwater utility in newer portions of communities.

Developer Incentives

Incentives could be offered to induce developers to use proper stormwater management planning techniques. Such incentives, for example, could include waiving maximum allowable residential densities if land is dedicated to the Town of Grafton for stormwater management purposes. This method still requires the construction of the stormwater facility by the Town; however, the land costs for the stormwater management facility would be reduced. The two significant concerns regarding the implementation of this method are: 1) to review the compatibility of developer's plans with respect to the goals and objectives of the land use element of the Town of Grafton's future planned land use map and 2) to assess the magnitude of nonpoint source pollution problems due to higher intensity level of development.

Betterment Charges

When a stormwater management facility is constructed to deal with a problem near a community, the property within the community will tend to increase in value. For example, if a drainage system is installed along a street where no stormwater management system had previously existed, then the control of flooding increases the value of property next to the street. The capital cost for such improvements could, therefore, be apportioned to the property owner. This apportionment of charges provides that the benefactors of the stormwater management system improvements would fund the program. The increase in property values resulting from such improvements is hard to estimate and this value may be less than the construction cost, thus limiting recovery.

Penalties and Fines

Similar to permit fees, penalties and fines are limited in scope. Such income can be placed in the general fund, however, it may be more reasonable to use the fines to correct the violation or any subsequent ones. This type of income could be used to subsidize a comprehensive stormwater management program but would not support the entire program.

Fees/Licenses/Permits

Funding from this source is generally limited to the cost of permit review and the inspection of construction. Other revenue sources must be utilized to finance other aspects of the stormwater management program such as administration, operation and maintenance, and capital improvements.

TABLE 9-5
NONPOINT SOURCE COST-SHARING GRANTS
WISCONSIN PRIORITY WATERSHEDS PROGRAM

Water Quality Practice	State Cost-Share Rate
Wet Detention Basins	70%*
Infiltration Basins/Trenches	70%*
Porous Pavement	70%*
Land Purchases and Storm Sewer Rerouting for Detention or Infiltration Structures	50%*
Increased Street Sweeping	50% for 5 years*
Stream Bank and Shoreline Stabilization	70%
Planting of Critical Eroding Areas	70%**
Drop Spillways and Channel/Grade Stabilization Structures	70%
Shoreline Buffers	70%**
Wetland Restoration	70%**

* For critical land uses in existing urban development as of the date of watershed plan adoption.

** The State or municipality may purchase an easement in conjunction with these practices.

Table 9-6
State Assistance for Urban Nonpoint Source Pollution Control

ACTIVITY	STATE SUPPORT	RATE	EXPLANATION
Construction Erosion Control	Local Assistance	Up to 100%*	To develop an ordinance based on the state model. To administer the ordinance for five years.
	Technical Assistance		For information on the model ordinance, state handbook, and workshops, contact UW-Extension Water quality Education.
Stormwater Pollution Control	Cost-sharing	50-70%	For wet detention basins, infiltration basins or trenches, and porous pavement to serve critical areas in existing development.** In new development, cost of facilities to be borne by developer.
	Local assistance	Up to 100%	For planning, design, inspection, and landowner contacts needed to develop cost-shared facilities. Also to develop a stormwater quality plan and ordinance consistent with state guidelines and to administer the ordinance for five years.
	Technical assistance		Model ordinance and handbook being developed. For workshop information, contact UWEX Water Quality Education.
Stream Bank Stabilization	Cost-sharing	70%	For regrading, revegetation, and riprap to stabilize severely eroding stream banks and shorelines.
	Local assistance	Up to 100%	For design, inspection, and landowner contacts..
	Technical assistance		Design standards and specifications available from county Land Conservation Departments.
Housekeeping Programs	Cost-sharing	50%	For equipment to upgrade street sweeping for five years in critical areas.**
	Local assistance	Up to 100%	For public information programs and for additional labor to upgrade street sweeping for five years in critical areas.**
	Technical assistance		Public information program assistance available from county and district UWEX offices.

* Local assistance grants cover up to 100 percent of the cost of professional service contracts and additional staff costs, including salary and fringe benefits, training, travel, vehicle leases, and office space. Up to 70 percent of equipment and supply costs may also be covered. For more information on state financial assistance, call your District DNR Nonpoint Source Coordinator.

** Critical areas are identified for each municipality in the watershed plan. In most cases, critical areas include commercial, industrial, and high-density residential areas (6 units/acre or more).

10) SUMMARY OF RECOMMENDATIONS

ULAO CREEK: VILLAGE OF GRAFTON STORM WATER MANAGEMENT PLAN

The Village of Grafton Northeast Drainage Study encompasses a 560 acre area in the east side of the Village – a rapidly urbanizing watershed. The watershed is separated into 11 subwatersheds draining to the Ulao Creek through two main channels. The proposed recommendations for this study are similar to the Ulao Creek study. Water quantity recommendations include the construction of detention facilities in each subwatershed to control the 100-year developed flow to a 10-year pre-settlement discharge rate. Water quality recommendations include the design of proposed detention basin to reduce the 10-year developed flow to a two-year existing discharge rate for a site. Other water quality practices associated with pond design are also recommended in this plan.

The second area of recommendations involve the two main channels. The plan stresses the need to preserve and enhance these channels as development occurs. Possible recommendations include designating the channels and channel banks as drainage easements, relocating the channels to provide for future development, and re-vegetating the buffer zones for water quality benefits. If implemented, the result of the recommendations for the Northeast Drainage Study will decrease the discharge rates of the future developed areas while preserving and enhancing the channel and existing wetland through the use of proper water quality techniques.

ULAO CREEK: TOWN OF GRAFTON STORM WATER MANAGEMENT PLAN

The Town of Grafton Ulao Creek Stormwater Management Plan encompasses 6,294 acres planned to be a mostly rural residential area with some commercial and industrial lands. Water quality recommendations include preserving existing natural resources through conservancy designation, construction of structural BMPs for commercial, industrial, and 1-acre residential lands, and nonstructural BMPs for 3-acre residential lands. Water quantity recommendations consist of preserving existing lands flooded during 100-year storm events, construction of 13 new detention facilities, and retrofitting 18 existing ponded areas to control the 100-year developed flow to be released at the 10-year pre-settlement flow. Recommendations for preserving and enhancing groundwater resources and the Ulao Creek corridor include locating stormwater facilities to maximize groundwater recharge and a detailed list of projects for the Creek corridor. Also, numerous educational opportunities are presented: Town meetings, watershed newsletters and tours, water quality workshops, demonstration projects, and creation of an outdoor education center. Once implemented, the recommended BMPs will reduce flood flows in the Ulao Creek, enhance and protect the Watershed's natural resources, and educate the community on water quality and stormwater management.

ULAO CREEK: CITY OF MEQUON STORM WATER MANAGEMENT PLAN

Camp, Dresser, McKee, Inc. has not yet completed a draft report and therefore a summary of Mequon's recommendations are not available at this time. The plan is proposed to be available in late May 1998.

11) WATERSHED WIDE IMPLEMENTATION

The fact that a watershed encompasses multiple municipalities is common. Communication is the key to implementing recommendations throughout a watershed. A Ulao Creek Watershed stormwater implementation committee should be formed with one representative from each municipality. The committee should hold short semi-annual meetings to discuss the progress of implementing plan recommendations, including design and construction of structural measures and nonstructural measures and allocation of monies from each of the municipalities capital improvement budgets. The time commitment from each municipality amounts to only half a day per year. Yet, this is a very important element for the management of the entire watershed. The members of this committee should be the respective municipal engineer or director of public works, a representative from the Wisconsin Department of Natural Resources, the Ozaukee Land Conservation Department, and the Ulao Creek Partnership.

APPENDIX A

Table 1: Ulao Creek Town of Grafton Watershed Hydraulic Structures

Structure Number	Subcatchment Location	Type	Size
1	USN (5)	Oval CMP*	68" X 48"
2	USN (5)	Oval CMP	68" X 48"
3	USN (2)	Round CMP	32"
4	USN (2)	Round CMP	48"
5	USN (6)	Oval CMP	68" X 48"
6	USN (3)	Round CMP	48"
7	USN (4)	Oval CMP	68" X 48"
8	USN (4)	Round CMP	18"
9	USN (4)	Round CMP	18"
10	USN (9)	Round CMP	16"
11	USN (9)	Round CMP	16"
12	USN (9)	Squash CMP	34" X 52"
13	USN (6)	Round CMP	36"
13A	USN (7)	Round CMP	18"
14	USN (8)	Round RCP*	24"
15	I-43 (11)	Round RCP	30"
16	USN (1)	Round RCP	24"
17	USN (1)	Round CMP	26"
18	USN (4)	Round CMP	24"
19	USN (4)	Lannon Box	34" X 34"
20	I-43 (11)	Round RCP	54"
21	I-43 (10)	Concrete Box	48" X 72"
22	I-43 (11)	Concrete Box	52" X 122"
23	USN (1)	Round CMP	2 - 24"
24	USN (1)	Round CMP	16"
25	USS (2)	Round CMP	18"
26	USS (2)	Round CMP	12"
27	I-43 (12)	Concrete Box	42" X 60"
28	I-43 (12)	Round RCP	30"
29	I-43 (10)	Round RCP	30"
30	I-43 (10)	Round RCP	30"
31	I-43 (10)	Round RCP	42"
32	I-43 (10)	Round RCP	42"

Structure Number	Subcatchment Location	Type	Size
33	I-43 (1)	Concrete Box	52" X 122"
34	USS (3)	Round CMP	42"
35	USS (3)	Round CMP	18"
36	USS (4)	Round CMP	42"
37	UC (9)	Round CMP	24"
38	I-43 (3)	Concrete Box	48" X 60"
39	I-43 (5)	Concrete Box	24" X 48"
40	I-43 (1)	Round CMP	18"
41	UC (11)	Round CMP	18"
42	UC (11)	Round CMP	12"
43	UC (11)	Round CMP	12"
44	UC (11)	Concrete Box	60" X 72"
45	UC (10)	Concrete Box	48" X 21'
46	I-43 (1)	Concrete Box	54" X 18'
47	I-43 (8)	Round RCP	36"
48	I-43 (6)	Round RCP	36"
49	I-43 (6)	Round CMP	48"
50	I-43 (7)	Concrete Box	72" X 42"
51	I-43 (8)	Concrete Box	24" X 36"
52	I-43 (8)	Concrete Box	24" X 36"
53	I-43 (8)	Round RCP	48"
54	I-43 (10)	Round RCP	18"
55	I-43 (9)	Round RCP	36"
56	I-43 (2)	2-Round RCP	48"
57	FRE (5)	Round CMP	15"
58	FRE (4)	Round CMP	36"
59	FRE (2)	Round CMP	36"
60	UC (7)	Round CMP	42"
61	UC (7)	Bridge	18' X 5'
62	FRW (1)	Round RCP	27"
63	FRW (1)	Round CMP	18"
64	FRW (4)	Round CMP	18"
65	FRW (3)	Round CMP	27"
66	PRW (4)	Round CMP	15"

Structure Number	Subcatchment Location	Type	Size
67	FRW (4)	Concrete Box	24" X 36"
68	FRW (3)	Round RCP	18"
69	LF (6)	Concrete Box	24" X 24"
70	LF (5)	Concrete Box	36" X 48"
71	LF (3)	Concrete Box	36" X 36"
72	LF (4)	Round RCP	18"
73	LF (4)	Concrete Box	18" X 24"
74	LF (4)	Concrete Box	36" X 24"
75	PRW (1)	Concrete Box	36" X 60"
76	UC (1)	Bridge	30' X 8'
77	PRW (1)	Bridge	42' X 7'
78	PRW (4)	Round CMP	36"
79	LF (3)	Concrete Box	66" X 48"
80	LF (4)	Concrete Box	24" X 24"
81	LF (2)	2-Round CMP	36"
82	UC (6)	Bridge	32' X 8'
83	FRW (2)	Round RCP	24"
84	FRW (3)	2-Round RCP	48"
85	UC (4)	Bridge	40' X 40'
86	UC (3)	Bridge	32' X 7'
87	PRE (2)	Round RCP	36"
88	PRE (1)	Round CMP	36"
89	PRE (1)	2-Round RCP	48"
90	UC (2)	Round RCP	36"
91	FRE (3)	Round RCP	30"

CMP= Corregated Metal Pipe
RCP= Reinforced Concrete Pipe

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Table 2: Existing Conditions: Land Use

	Acres								
SubWatershed	Total	Residential	Commercial	Industrial	Open	Agricultural	Wetland	Woods	Surface Water
Ulao Swamp North									
USN (1)	529.6	46.5	11.3		140.5	102.3	207.0	14.0	7.3
USN (2)	19.1		5.8		6.0	6.0	1.3		
USN (3)	47.3	8.4			34.8	2.7	1.4		
USN (4)	77.8	32.4			7.3	35.2	2.9		
USN (5)	109.5	4.1				105.4			
USN (6)	165.2	33.9			23.0	94.3	8.0	6.0	
USN (7)	67.3	2.9			5.0	51.7	5.7	2.0	
USN (8)	49.3	12.6			25.9		7.3	3.5	
USN (9)	105.1	20.8			25.5	40.4	4.8	13.6	
Ulao Swamp South									
USS (1)	625.7	51.9		121.3	23.5	193.2	214.9	16.00	4.9
USS (2)	162.7	83.6			31.1	27.0	33.5	7.5	
USS (3)	165.0	49.7			45.0	56.0	14.3		
USS (4)	183.7	27.6			44.0	87.7	14.9	9.5	
USS (5)	191.4	1.2	10.3		5.3	150.6	24		
I-43 Corridor									
I43 (1)	149.8	20.1			56.0	61.0	9.2	3.5	
I43 (2)	28.1	1.2			1.5	20.6	4.8		
I43 (3)	141	6.1			35	83.5	4.4	12	
I43 (4)	29.7				4.3	25.4			
I43 (5)	19.8					18.1		1.7	
I43 (6)	12.3	2.2			5.6	4.5			
I43 (7)	63.2	26.5	2.0		2.9	20.9	1.8	9.1	
I43 (8)	80.5	15	16		45.3		2.1	2.1	
I43 (9)	35	15.2			5.7	14.1			
I43 (10)	153.4	27.7	8.7		13	88.5	1.0	14.5	
I43 (11)	140	16			76.1	26.7	21.2		
I43 (12)	142.7	2	8.9	28	48.2	42	6.8	6.8	
I43 (13)	137.1	10.3			10	100	14.6	2.2	
Ulao Creek									
UC (1)	119.1	21.2	11.6		15.5	60.5	6.9	3.4	
UC (2)	14.6				4.4	6.8	2.2	1.2	
UC (3)	17		1.6		7.3		4	4.1	
UC (4)	150.3	15.3				117.8		17.2	
UC (5)	24.6				20.9	3.7			
UC (6)	410.1	28.1			6.2	292.7	51.3	31.8	
UC (7)	79.6	6				48.6	25		
UC (8)	78.9	7	12			51.8	8.1		
UC (9)	102.3	16				73	3.1	10.2	
Falls Road East									
FRE (1)	47.1	12				28.9	0.7	5.5	
FRE (2)	67.1	7.3				58.1		1.7	
FRE (3)	86.7	8.6				72.1		6	
FRE (4)	88.1	9.5				74.2	4.4		
FRE (5)	134	10.1	2.1		21.5	91	9.3		
Falls Road West									
FRW (1)	14.6		7.9		5.9				0.8
FRW (2)	11.4				4.5	6.9			
FRW (3)	52.1	4	1.1		4.8	36.4	0.8	5	
FRW (4)	74.6	25	2.6		14.7	13.1	2.5	16.7	
Pioneer Road East									
PRE (1)	22.3				19.1	3	0.2		
PRE (2)	319.3	45.9	4.7		5.2	236.7	3.5	23.3	
Pioneer Road West									
PRW (1)	104.5	15.6				67.9	21		
PRW (2)	81.1					75.6	1.1	4.4	
PRW (3)	161.7	10.2				137.9	2.4	10.8	0.4
PRW (4)	162.3	15.9				132.6	13.8		
Lakefield Road									
LF (1)	28.5	11.8	2.6		4.4	8.2	1.5		
LF (2)	82.8	18.1			28.8	26.9	0.5	8.5	
LF (3)	32.7	3				29.7			
LF (4)	15.4	15.4							
LF (5)	64.9	4.5				50.7	0.2	9.5	
LF (6)	14.8	4.9				9.9			
Totals	6293.8	813.3	109.2	149.3	883.7	3272.5	768.4	283.3	13.4
Watershed %	100%	13%	2%	2%	14%	52%	12%	4%	1%

Table 3 – Fish Distribution Data for Ulao Creek

Data Source: WDNR Water Resource Appraisal and Standards review for the Milwaukee River South Branch Watershed - Lakefield Subwatershed

Date	Location	Species	Number	Class A
09/10/75	0.6 miles upstream from Milwaukee River	Black bullhead	47	S
		White sucker	22	T
		Spotfir shiner	12	T
		Northern pike	10	S
		Green sunfish	10	S
		Bluntnose minnow	9	T
		Yellow bullhead	7	S
		Pumpkinseed	6	S
		Common carp	3	VT
		Black crappie	1	S
		Green sunfish	1	S
05/16/84	1.7 miles upstream from Milwaukee River	Black bullhead	10	S
		Green sunfish	3	S
		Central mudminnow	2	VT
		White sucker	1	T
07/24/84	@ Bonniwell Rd.	Northern pike	12	S
		Golden shiner	3	T
		Common shiner	185	T
		White sucker	7	T
		Black bullhead	24	S
		Green sunfish	30	S
		Pumpkinseed	6	S
		White crappie	1	S
		Green Sunfish X Pumpkinseed	1	S
		Bluegill X Green sunfish	1	S
		Hornyhead chub	8	T
		Common Carp	2	VT
		Central mudminnow	48	VT
05/24/85	@ CTH C Bridge	Green sunfish	3	S
		Black bullhead	10	S
		White sucker	1	T
		Central mudminnow	7	VT
10/07/87	@ Falls Road	White sucker	18	T
		Creek chub	11	T
		Central mudminnow	>200	VT
		Black bullhead	2	S
		Brook stickleback	2	T
		Sunfish (unsp)	3	S
		Northern pike	4	S
		Bluegill	4	S
		Common shiner	14	T
		Largemouth bass	2	S
		Green sunfish	9	S

Date	Location	Species	Number	Class A
08/28/90	Downstream of CTH T and downstream of horse pasture	Creek chub	8	T
		Central mudminnow	791	VT
		Golden shiner	1	T
		White sucker	5	T
		Common shiner	8	T
		Black bullhead	54	S
		Green sunfish	11	S
		Northern pike	5	S
		Brook stickle back	2	VT
		Largemouth bass	1	S
09/12/90	West of I-43 & w/in cattle pasture	Central mudminnow	17	VT
09/12/90	South of CTH "T" and Horse Pasture	Central mudminnow	791	VT
		Black bullhead	54	S
		Green sunfish	11	S
		Creek chub	8	T
		Common shiner	8	T
		Northern pike	5	S
		White sucker	5	T
		Brook stickleback	2	VT
		Largemouth bass	1	S
09/20/90	Upstream of CTH T w/in horse pasture	Common shiner	1	T
		Northern pike	2	S
		Brook stickleback	21	VT
		green sunfish	77	S
		Central mudminnow	413	VT
		Black bullhead	2	S
10/02/90	Downstream of cattle pasture & west of I-43	Central mudminnow	101	VT
		Northern pike	3	S
		Common shiner	3	T
		Green sunfish	17	S
08/20/91	Downstream of CTH T and horse pasture	White sucker	250	T
		Creek chub	144	T
		Brook stickleback	6	VT
		Central mudminnow	13	VT
08/20/91	Upstream of CTH T upstream of horse pasture	Smallmouth bass	9	S
		White sucker	1	T
		Central mudminnow	597	VT
08/20/91	North of CTH T and within horse active pasture reach	Central mudminnow	597	VT
		Largemouth bass	9	S
		White sucker	1	T
08/22/91	Downstream of CTH T and horse pasture	Common carp	1	VT
		Creek chub	5	T
		Central mudminnow	300	VT
		Golden shiner	21	T
		White sucker	1	T
		Common shiner	24	T

Date	Location	Species	Number	Class A
08/23/91	Upstream of CTH T w/in horse pasture	Central mudminnow	527	VT
		White sucker	180	T
		Largemouth bass	19	S
		Brook stickleback	15	VT
		Golden shiner	4	T
		Common shiner	14	T
		Black bullhead	4	S
		Central stoneroller	2	IT
		Common carp	3	VT
		Bluegill	1	S
		Creek chub	59	T
		Fathead minnow	31	VT
08/23/91	Downstream of cattle pasture & west of I-43	Northern pike	2	S
		Black bullhead	4	S
		Common carp	9	VT
		Central mudminnow	18	VT
		Largemouth bass	4	S
		White sucker	36	T
		Green sunfish	2	S
		Bluegill	2	S
		Brook stickleback	1	VT
		Sand shiner	7	T
		Common shiner	3	T
08/26/91	Upstream of CTH T upstream of horse pasture	Creek chub	199	T
		Northern pike	4	S
		Central mudminnow	932	VT
		Green sunfish	11	S
		Common carp	5	VT
		White sucker	46	T
		Largemouth bass	28	S
		Black bullhead	80	S
		Pumpkinseed	47	S
		Common shiner	24	T
		Golden shiner	6	T
06/08/94	0.7 miles upstream from Milwaukee River	Northern pike	21	S
		Central mudminnow	17	VT
		White sucker	5	T
		Bluegill	2	S
		Green sunfish	2	S
		Fathead minnow	2	VT
		Pumpkinseed	1	S
		Yellow bullhead	1	S
		Creek chub	1	T

Date	Location	Species	Number	Class A
06/08/94	1.9 miles upstream from Milwaukee River	Central mudminnow	92	VT
		Green sunfish	9	S
		Pumpkinseed	6	S
		Common shiner	5	T
		Northern pike	3	S
		Johnny darter	2	T
		Bluntnose minnow	2	T
		Brook stickleback	1	VT
		Yellow bullhead	1	S
		Black bullhead	1	S
08/28/96	Active horse pasture reach upstream of Lakefield Road	Central mudminnow	75	VT
		White sucker	15	T
		Largemouth bass	14	S
		Creek chub	4	T
		Green sunfish	3	S
08/28/96	Inactive horse pasture reach upstream of Lakefield Road	Central mudminnow	149	VT
		Largemouth bass	9	S
		White sucker	7	T
		Northern pike	2	S
		Creek chub	2	T
		Black bullhead	1	S
		Common shiner	1	T
08/28/96	Single pool immediately downstream of Falls Road Bridge	Central mudminnow	29	VT
		Bluegill	29	S
		Green sunfish	21	S
		Creek chub	12	T
		Pumpkinseed	7	S
		Common shiner	5	T
		Black bullhead	4	S
		Largemouth bass	1	S
08/28/96	Downstream of Falls Road bridge and excluding pool at Ulao 8	Central mudminnow	209	VT
		Brook stickleback	6	VT
		Largemouth bass	5	S
		Green sunfish	3	S
		Creek chub	1	T
		Bluegill	1	S
		White sucker	1	T
08/30/96	Pasture along I-43 - Post Best Management Practice (BMP) installation	Central mudminnow	60	VT
		Creek chub	28	T
		White sucker	18	T
		Largemouth bass	11	S
		Brook stickleback	14	VT
		Bluntnose minnow	7	T
		Common shiner	4	T

Table 4
Stormwater Quality BMPs Matrix Continued

BMP Control Practices	Usable in Existing Development	Newly Developed Areas - Slope -			Operate in clay soils	Cost	Maintenance Frequency	Comments
		mild	moderate	steep				
Structural Controls								
Water quality inlets	Yes	Yes	Yes	Yes	Yes	high	medium	
Sand filter inlets	Yes	Yes	Yes	Yes	Yes	high	medium	Treat small areas
Infiltration trenches	No	Yes	Yes	No	No	medium	medium	Need pretreatment
Infiltration basins	No	Yes	Yes	Yes	No	high	low	Need pretreatment
Wet detention ponds	Maybe	Yes	Yes	Yes	Yes	medium	low	Proven effective
Underground storage	Yes	Yes	Maybe	No	Yes	high	medium	Costly
Stream bank stabilization	Yes	Yes	Yes	Yes	Yes	medium	low	Bio engineering
Constructed Wetlands	Maybe	Yes	Yes	Yes	Yes	high	low	Large land areas

TABLE 5 Comparison of Four Stormwater Wetland Designs				
ATTRIBUTE	DESIGN No. 1 SHALLOW MARSH	DESIGN No. 2 POND/ WETLAND	DESIGN No. 3 EXTENDED DETENTION WETLAND	DESIGN No. 4 POCKET WETLAND
POLLUTANT REMOVAL CAPABILITY	moderate, reliable removal of sediments and nutrients	moderate to high, reliable removal of nutrients and sediment	moderate, less reliable removal of nutrients	moderate, can be subject to resuspension and groundwater displacement
LAND CONSUMPTION	high, shallow marsh storage consumes space	moderate, as vertical pool substitutes for marsh storage	moderate, as vertical ED substitutes for marsh storage	moderate, but can be shoehorned in site
WATER BALANCE	dry weather baseflow normally recommended to maintain water elevations. Groundwater not recommended as the primary source of water supply to wetland.			water supply provided by excavation to groundwater
WETLAND AREA WATERSHED AREA	minimum ratio of .02	minimum ration of .01	minimum ration of .01	minimum ration of .01
CONTRIBUTING WATERSHED AREA	DA of 25 acres or greater, with dry weather Q	DA of 25 acres or greater, with dry weather Q	minimum of ten acres required for ED	1 o 10 acres
DEEP WATER CELLS	forebay, channels micropool	pond micropool	forebay micropool	micropool, if possible
OUTLET CONFIGURATION	reversed slope pipe extending from riser, withdrawn approximately one foot below normal pool. Pipe and pond drain equipped with gate valve.			broad crested wier with half round trash rack, and pond drain.
SEDIMENT CLEANOUT CYCLE (approximate)	cleanout of forebay every 2-5 years	cleanout of pond every ten years	cleanout of forebay every 2 to 5 years.	cleanout of wetland every 5 to 10 years, onsite disposal and stockpile mulch
NATIVE PLANT DIVERSITY	high, if complex microtopography is present	high, with sufficient wetland complexity and area	moderate, fluctuating water levels impose physiological constraints	low to moderate, due to small surface area and poor control of water levels
WILDLIFE HABITAT POTENTIAL	high, with complexity and buffer	high, with buffer, attracts waterfowl	moderate, with buffer	low, due to small area and low diversity

Source: *Design of Stromwater Wetland Systems, Guidelines for Creating Diverse and Effective Stormwater Wetland Systems in the Mid-Atlantic Region*, Anacostia Restoration Team, Department of Environmental Programs Metropolitan Washington Council of Governments

TABLE 6 Comparative Assessment of the Effectiveness of Best Management Practices							
BMP OPTIONS*	COMPARATIVE COST	RELIABILITY FOR POLLUTANT REMOVAL	LONGEVITY*	APPLICABLE TO MOST DEVELOPMENTS	WILDLIFE HABITAT POTENTIAL	ENVIRONMENTAL CONCERNS	SPECIAL CONSIDERATIONS
STORM-WATER WETLANDS	Marginally higher than wet ponds	Moderate to High depending on design	20+ years expected	Applicable to most site if land is available	High	Stream warming; natural wetland alteration	Recommended with design improvements and with the use of micropools and wetlands
EXTENDED DETENTION PONDS	Lowest cost alternative in size range	Moderate, but not always reliable	20+ years, but frequent clogging and short detention common.	Widely applicable, but requires at least 10 acres of drainage area.	Moderate	Possible stream warming and habitat destruction	Recommended with design improvements and with the use of micropools and wetlands
WET PONDS	Moderate to high compared to conventional	Moderate to high	20+ years	Widely applicable, but requires drainage area of greater than 2 acres	Moderate to High	Possible stream warming, trophic shifts, habitat	Recommended, with careful site evaluation
MULTIPLE POND SYSTEMS	Most expensive pond option	Moderate to high; redundancy increases reliability	20+ years	Widely applicable.	Moderate to high	Selection of appropriate pond option minimizes overall environmental impact	Recommended
INFILTRATION TRENCHES	Cost-effective on smaller sites. Rehab costs can be considerable.	Presumed moderate	50% failure rate within five years	Highly restricted (soils, groundwater, slope, area, sediment input)	Low.	Slight risk of groundwater contamination.	Recommended with pretreatment and geotechnical evaluation.
INFILTRATION BASINS	Construction cost moderate, but rehab cost high.	Presumed moderate, if working	60 - 100% failure within five years	Highly restricted (see infiltration trench)	Low to moderate	Slight risk of groundwater contamination	Not widely recommended until longevity is improved.
POROUS PAVEMENT	Cost-effective compared to conventional asphalt when working properly	High (if working)	75% failure within five years	Extremely restricted (traffic, soils, ground water, slope, area, sediment input).	Low	Possible ground water impacts; uncontrolled runoff	Recommended in highly restricted applications with careful construction and effective maintenance.
SAND FILTERS	Comparatively high construction costs and frequent maintenance .	Moderate to high	20+ years	Applicable (for smaller developments)	Low	Minor	Recommended with local demonstration.
GRASSED SWALES	Low, compared to curb and gutter	Low to moderate, but unreliable	20+ years	Low density development and roads	Low	Minor	Recommended, with checkdams, as one element of a BMP system
FILTER STRIPS	Low	Unreliable in urban settings	Unknown, but may be limited	Restricted to low density areas	Moderate if forested	Minor	Recommended as one element of a BMP system.
WATER QUALITY INLETS	High, compared to trenches and sand filters	Presumed low	20+ years	Small, highly impervious catchments (< 2 acres)	Low	Resuspension of hydro-carbon loadings. Disposal of hydro carbon and toxic residuals	Not currently recommended as a primary BMP option.

Source: *Design of Stromwater Wetland Systems, Guidelines for Creating Diverse and Effective Stormwater Wetland Systems in the Mid-Atlantic Region*, Anacostia Restoration Team, Department of Environmental Programs Metropolitan Washington Council of Governments

TABLE 7 - WDNR Approved Unit Area Pollutant Loading Rates
(pounds/acre/year)

Land Use	Sediment	Phosphorus	Lead	Copper	Zinc
Residential	512	0.47	0.32	0.14	0.20
Commercial	1,056	1.07	2.70	0.40	2.10
Industrial	280	0.27	2.40	0.50	7.30
Open	124	0.09	0.10	0.10	0.10
Agriculture	450	0.86	0.10	0.10	0.10
Wetland	3	0.03	0.10	0.10	0.10
Woodland	3	0.03	0.10	0.10	0.10
Surface Water	185	0.13	0.10	0.10	0.10

TABLE 8: Water Quality Pollutant Loading: Existing Conditions - Sediment

SubWatershed	Acres									
	Total	Residential	Commercial	Industrial	Open	Agricultural	Wetland	Woods	Surface Water	SEDIMENT LBS./YR.
USN (1)	529.6	46.5	11.3		140.5	102.30	207.60	14.00	7.30	101,213.10
USN (2)	19.1		5.8		6.0	6.00	1.30			9,572.70
USN (3)	47.3	8.4			34.8	2.70	1.40			9,835.20
USN (4)	77.8	32.4			7.3	35.20	2.90			33,342.70
USN (5)	109.5	4.1				105.40				49,529.20
USN (6)	165.2	33.9			23.0	94.30	8.00	6.00		62,685.80
USN (7)	89.7	13.9			15.6	51.70	6.50	2.00		32,341.70
USN (8)	26.9	1.6			15.3		6.50	3.50		2,746.40
USN (9)	105.1	20.8			25.5	40.40	4.80	13.60		32,046.80
									Subtotal	333,313.60
USS (1)	625.7	51.9		121.3	23.5	193.20	214.90	16.00	4.90	151,990.00
USS (2)	162.7	63.6			31.1	27.00	33.50	7.50		48,692.60
USS (3)	165.0	49.7			45.0	56.00	14.30			56,269.30
USS (4)	183.7	27.6			44.0	87.70	14.90	9.50		59,125.40
USS (5)	191.4	1.2	10.3		5.3	150.60	24.00			79,990.40
USS (6)	80.9	8.1			1.0	69.60		2.20		35,597.80
									Subtotal	431,665.50
I43 (1)	149.8	20.1			56.0	61.00	9.20	3.50		44,723.30
I43 (2)	28.1	1.2			1.5	20.60	4.80			10,084.80
I43 (3)	141	6.1			35.0	83.50	4.40	12.00		45,087.40
I43 (4)	29.7				4.3	25.40				11,963.20
I43 (5)	19.8					18.10		1.70		8,150.10
I43 (6)	12.3	2.2			5.6	4.50				3,845.80
I43 (7)	63.2	26.5	2.0		2.9	20.90	1.80	9.10		25,477.30
I43 (8)	80.5	15	16.0		45.3		2.10	2.10		30,205.80
I43 (9)	35	15.2			5.7	14.10				14,834.20
I43 (10)	153.4	27.7	8.7		13.0	88.50	1.00	14.50		64,853.10
I43 (11)	140	16			76.1	26.70	21.20			29,707.00
I43 (12)	142.7	2	8.9	28.0	48.2	42.00	6.80	6.80		43,180.00
I43 (13)	56.2	2.2			9.0	30.40	14.60			15,966.20
									Subtotal	348,078.20
UC (1)	119.1	21.2	11.6		15.5	60.50	6.90	3.40		52,281.90
UC (2)	14.6				4.4	6.80	2.20	1.20		3,615.80
UC (3)	17		1.6		7.3		4.00	4.10		2,619.10
UC (4)	150.3	15.3				117.80		17.20		60,895.20
UC (5)	24.6				20.9	3.70				4,256.60

TABLE 8: Water Quality Pollutant Loading: Existing Conditions - Sediment

SubWatershed	Acres									
	Total	Residential	Commercial	Industrial	Open	Agricultural	Wetland	Woods	Surface Water	SEDIMENT LBS./YR.
UC (6)	410.1	28.1			6.2	292.70	51.30	31.80		147,120.30
UC (7)	79.6	6				48.60	25.00			25,017.00
UC (8)	78.9	7	12.0			51.80	8.10			39,590.30
UC (9)	102.3	16				73.00	3.10	10.20		41,081.90
									Subtotal	376,478.10
FRE (1)	47.1	12				28.90	0.70	5.50		19,167.60
FRE (2)	67.1	7.3				58.10		1.70		29,887.70
FRE (3)	86.7	8.6				72.10		6.00		36,866.20
FRE (4)	88.1	9.5				74.20	4.40			38,267.20
FRE (5)	134	10.1	2.1		21.5	91.00	9.30			51,032.70
									Subtotal	175,221.40
FRW (1)	14.6		7.9		5.9				0.80	9,222.00
FRW (2)	11.4				4.5	6.90				3,663.00
FRW (3)	52.1	4	1.1		4.8	36.40	0.80	5.00		20,202.20
FRW (4)	74.6	25	2.6		14.7	13.10	2.50	16.70		23,321.00
									Subtotal	56,408.20
PRE (1)	22.3				19.1	3.00	0.20			3,719.00
PRE (2)	319.3	45.9	4.7		5.2	236.70	3.50	23.30		135,704.20
									Subtotal	139,423.20
PRW (1)	104.5	15.6				67.90	21.00			38,605.20
PRW (2)	81.1					75.60	1.10	4.40		34,036.50
PRW (3)	161.7	10.2				137.90	2.40	10.80	0.40	67,391.00
PRW (4)	162.3	15.9				132.60	13.80			67,852.20
									Subtotal	207,884.90
LF (1)	28.5	11.8	2.6		4.4	8.20	1.50			13,027.30
LF (2)	82.8	18.1			28.8	26.90	0.50	8.50		24,970.40
LF (3)	32.7	3				29.70				14,901.00
LF (4)	15.4	15.4								7,884.80
LF (5)	64.9	4.5				50.70	0.20	9.50		25,148.10
LF (6)	14.8	4.9				9.90				6,963.80
									Subtotal	92,895.40
Totals	6293.8	813.3	109.2	149.3	883.7	3272.50	769.00	283.30	13.40	2,161,368.50

TABLE 9: Water Quality Pollutant Loading: Existing Conditions - Phosphorous

	Acres									
SubWatershed	Total	Residential	Commercial	Industrial	Open	Agricultural	Wetland	Woods	Surface Water	PHOSHORUS LBS./YR.
USN (1)	529.6	46.5	11.3		140.5	102.3	207.6	14.0	7.3	142.17
USN (2)	19.1		5.8		6.0	6.0	1.3			11.95
USN (3)	47.3	8.4			34.8	2.7	1.4			9.44
USN (4)	77.8	32.4			7.3	35.2	2.9			46.24
USN (5)	109.5	4.1				105.4				92.57
USN (6)	165.2	33.9			23.0	94.3	8.0	6.0		99.52
USN (7)	89.7	13.9			15.6	51.7	6.5	2.0		52.65
USN (8)	26.9	1.6			15.3		6.5	3.5		2.43
USN (9)	105.1	20.8			25.5	40.4	4.8	13.6		47.37
									Subtotal	504.34
USS (1)	625.7	51.9		121.3	23.5	193.2	214.9	16.0	4.9	232.98
USS (2)	162.7	63.6			31.1	27.0	33.5	7.5		57.14
USS (3)	165.0	49.7			45.0	56.0	14.3			76.00
USS (4)	183.7	27.6			44.0	87.7	14.9	9.5		93.09
USS (5)	191.4	1.2	10.3		5.3	150.6	24.0			142.30
USS (6)	80.9	8.1			1.0	69.6		2.2		63.82
									Subtotal	665.32
I43 (1)	149.8	20.1			56.0	61.0	9.2	3.5		67.33
I43 (2)	28.1	1.2			1.5	20.6	4.8			18.56
I43 (3)	141.0	6.1			35.0	83.5	4.4	12.0		78.32
I43 (4)	29.7				4.3	25.4				22.23
I43 (5)	19.8					18.1		1.7		15.62
I43 (6)	12.3	2.2			5.6	4.5				5.41
I43 (7)	63.2	26.5	2.0		2.9	20.9	1.8	9.1		33.16
I43 (8)	80.5	15.0	16.0		45.3		2.1	2.1		28.37
I43 (9)	35.0	15.2			5.7	14.1				19.78
I43 (10)	153.4	27.7	8.7		13.0	88.5	1.0	14.5		100.07
I43 (11)	140.0	16.0			76.1	26.7	21.2			37.97
I43 (12)	142.7	2.0	8.9	28.0	48.2	42.0	6.8	6.8		58.89
I43 (13)	56.2	2.2			9.0	30.4	14.6			28.43
									Subtotal	514.13
UC (1)	119.1	21.2	11.6		15.5	60.5	6.9	3.4		76.11
UC (2)	14.6				4.4	6.8	2.2	1.2		6.35
UC (3)	17.0		1.6		7.3		4.0	4.1		2.61
UC (4)	150.3	15.3				117.8		17.2		109.02

TABLE 9: Water Quality Pollutant Loading: Existing Conditions - Phosphorous

	Acres								
SubWatershed	**Total**	**Residential**	**Commercial**	**Industrial**	**Open**	**Agricultural**	**Wetland**	**Woods**	**Surface Water**	**PHOSHORUS LBS./YR.**
UC (5)	24.6				20.9	3.7				5.06
UC (6)	410.1	28.1			6.2	292.7	51.3	31.8		267.98
UC (7)	79.6	6.0				48.6	25.0			45.37
UC (8)	78.9	7.0	12.0			51.8	8.1			60.92
UC (9)	102.3	16.0				73.0	3.1	10.2		70.70
									Subtotal	644.11
FRE (1)	47.1	12.0				28.9	0.7	5.5		30.68
FRE (2)	67.1	7.3				58.1		1.7		53.45
FRE (3)	86.7	8.6				72.1		6.0		66.23
FRE (4)	88.1	9.5				74.2	4.4			68.41
FRE (5)	134.0	10.1	2.1		21.5	91.0	9.3			87.47
									Subtotal	306.23
FRW (1)	14.6		7.9		5.9				0.8	9.09
FRW (2)	11.4				4.5	6.9				6.34
FRW (3)	52.1	4.0	1.1		4.8	36.4	0.8	5.0		34.97
FRW (4)	74.6	25.0	2.6		14.7	13.1	2.5	16.7		27.70
									Subtotal	78.09
PRE (1)	22.3				19.1	3.0	0.2			4.31
PRE (2)	319.3	45.9	4.7		5.2	236.7	3.5	23.3		231.44
									Subtotal	235.74
PRW (1)	104.5	15.6				67.9	21.0			66.36
PRW (2)	81.1					75.6	1.1	4.4		65.18
PRW (3)	161.7	10.2				137.9	2.4	10.8	0.4	123.84
PRW (4)	162.3	15.9				132.6	13.8			121.92
									Subtotal	377.30
LF (1)	28.5	11.8	2.6		4.4	8.2	1.5			15.82
LF (2)	82.8	18.1			28.8	26.9	0.5	8.5		34.50
LF (3)	32.7	3.0				29.7				26.95
LF (4)	15.4	15.4								7.24
LF (5)	64.9	4.5				50.7	0.2	9.5		46.01
LF (6)	14.8	4.9				9.9				10.82
									Subtotal	141.34
Totals	6,293.8	813.3	109.2	149.3	883.7	3,272.5	769.0	283.3	13.4	3,466.60

TABLE 10: Water Quality Pollutant Loading: Existing Conditions - Lead

SubWatershed	Total	Residential	Commercial	Industrial	Open	Agricultural	Wetland	Woods	Surface Water	LEAD LBS./YR.
USN (1)	529.6	46.5	11.3		140.50	102.30	207.60	14.00	7.30	92.56
USN (2)	19.1		5.8		6.00	6.00	1.30			16.99
USN (3)	47.3	8.4			34.80	2.70	1.40			6.58
USN (4)	77.8	32.4			7.30	35.20	2.90			14.91
USN (5)	109.5	4.1				105.40				11.85
USN (6)	165.2	33.9			23.00	94.30	8.00	6.00		23.98
USN (7)	89.7	13.9			15.60	51.70	6.50	2.00		12.03
USN (8)	26.9	1.6			15.30		6.50	3.50		3.04
USN (9)	105.1	20.8			25.50	40.40	4.80	13.60		15.09
								Subtotal		197.02
USS (1)	625.7	51.9		121.30	23.50	193.20	214.90	16.00	4.90	352.98
USS (2)	162.7	63.6			31.10	27.00	33.50	7.50		30.26
USS (3)	165.0	49.7			45.00	56.00	14.30			27.43
USS (4)	183.7	27.6			44.00	87.70	14.90	9.50		24.44
USS (5)	191.4	1.2	10.3		5.30	150.60	24.00			46.18
USS (6)	80.9	8.1			1.00	69.60		2.20		9.87
								Subtotal		491.17
I43 (1)	149.8	20.1			56.00	61.00	9.20	3.50		81.00
I43 (2)	28.1	1.2			1.50	20.60	4.80			4.67
I43 (3)	141	6.1			35.00	83.50	4.40	12.00		15.44
I43 (4)	29.7				4.30	25.40				12.86
I43 (5)	19.8					18.10		1.70		1.98
I43 (6)	12.3	2.2			5.60	4.50				6.75
I43 (7)	63.2	26.5	2.0		2.90	20.90	1.80	9.10		19.96
I43 (8)	80.5	15	16		45.30		2.10	2.10		139.02
I43 (9)	35	15.2			5.70	14.10				6.84
I43 (10)	153.4	27.7	8.7		13.00	88.50	1.00	14.50		73.95
I43 (11)	140	16			76.10	26.70	21.20			47.96
I43 (12)	142.7	2	8.9	28.00	48.20	42.00	6.80	6.80		193.83
I43 (13)	56.2	2.2			9.00	30.40	14.60			6.10
								Subtotal		610.38
UC (1)	119.1	21.2	11.6		15.50	60.50	6.90	3.40		46.73
UC (2)	14.6				4.40	6.80	2.20	1.20		1.46
UC (3)	17		1.6		7.30		4.00	4.10		5.86
UC (4)	150.3	15.3				117.80		17.20		18.40
UC (5)	24.6				20.90	3.70				2.46

TABLE 10: Water Quality Pollutant Loading: Existing Conditions - Lead

SubWatershed	Total	Residential	Commercial	Industrial	Open	Agricultural	Wetland	Woods	Surface Water	LEAD LBS./YR.
UC (6)	410.1	28.1			6.20	292.70	51.30	31.80		47.19
UC (7)	79.6	6				48.60	25.00			9.28
UC (8)	78.9	7	12			51.80	8.10			40.63
UC (9)	102.3	16				73.00	3.10	10.20		13.75
									Subtotal	185.76
FRE (1)	47.1	12				28.90	0.70	5.50		7.35
FRE (2)	67.1	7.3				58.10		1.70		8.32
FRE (3)	86.7	8.6				72.10		6.00		10.56
FRE (4)	88.1	9.5				74.20	4.40			10.90
FRE (5)	134	10.1	2.1		21.50	91.00	9.30			21.08
									Subtotal	58.21
FRW (1)	14.6		7.9		5.90				0.80	22.00
FRW (2)	11.4				4.50	6.90				1.14
FRW (3)	52.1	4	1.1		4.80	36.40	0.80	5.00		8.95
FRW (4)	74.6	25	2.6		14.70	13.10	2.50	16.70		19.72
									Subtotal	51.81
PRE (1)	22.3				19.10	3.00	0.20			2.23
PRE (2)	319.3	45.9	4.7		5.20	236.70	3.50	23.30		54.25
									Subtotal	56.48
PRW (1)	104.5	15.6				67.90	21.00			13.88
PRW (2)	81.1					75.60	1.10	4.40		8.11
PRW (3)	161.7	10.2				137.90	2.40	10.80	0.40	18.41
PRW (4)	162.3	15.9				132.60	13.80			19.73
									Subtotal	60.13
LF (1)	28.5	11.8	2.6		4.40	8.20	1.50			12.21
LF (2)	82.8	18.1			28.80	26.90	0.50	8.50		12.26
LF (3)	32.7	3				29.70				3.93
LF (4)	15.4	15.4								4.93
LF (5)	64.9	4.5				50.70	0.20	9.50		7.48
LF (6)	14.8	4.9				9.90				2.56
									Subtotal	43.36
Totals	6293.8	813.3	109.2	149.30	883.70	3272.50	769.00	283.30	13.40	1,754.33

TABLE 11: Water Quality Pollutant Loading - Future Conditions: Sediment

SubWatershed	Total	Residential	Commercial	Industrial	Wetland&Woods	Surface Water	I-43(open)	Sediment lbs/yr
USN (1)	529.6	222.1		9.4	290.8	7.3		118570.1
USN (2)	19.1			17.8	1.3			4987.9
USN (3)	47.3			45.9	1.4			12856.2
USN (4)	77.8	49.6	4.7	23.5				36938.4
USN (5)	109.5	16.5	93.0					106656
USN (6)	165.2	63.1	97.4		4.7			135175.7
USN (7)	89.7	84.5			5.2			43279.6
USN (8)	26.9	17.9			4.0		5	9796.8
USN (9)	105.1	105.1						53811.2
						Subtotal		522071.9
USS (1)	625.7	172.7		214.7	233.4	4.9		150145.1
USS (2)	162.7	129.3			33.4			66301.8
USS (3)	165.0	134.4			30.6			68904.6
USS (4)	183.7	165.3			18.4			84688.8
USS (5)	191.4	161.4			30			82726.8
USS (6)	80.9	72.4			8.5			37094.3
						Subtotal		489861.4
I43 (1)	149.8	70.9		42.5	6.6		29.8	51915.8
I43 (2)	28.1		21.2		5.5		1.4	22577.3
I43 (3)	141	119.8	21.2					83724.8
I43 (4)	29.7		25.4				4.3	27355.6
I43 (5)	19.8	5.6	14.2					17862.4
I43 (6)	12.3		11.4				0.9	12150
I43 (7)	63.2	62.2					1	31970.4
I43 (8)	80.5	50					30.5	29382
I43 (9)	35	33.7					1.3	17415.6
I43 (10)	153.4	81.8	37.4				34.2	85616.8
I43 (11)	140	99.1			17.4		23.5	53705.4
I43 (12)	142.7	30.9	73.4				38.4	98092.8
I43 (13)	56.2	50.9			5.3			26076.7
						Subtotal		557845.6
UC (1)	119.1	94.1	7.9				17.1	58642
UC (2)	14.6			10.3			4.3	3417.2
UC (3)	17			10.4			6.6	3730.4
UC (4)	150.3	150.3						76953.6
UC (5)	24.6			12.3			12.3	4969.2
UC (6)	410.1	360.1			50			184521.2
UC (7)	79.6	54.6			25			28030.2
UC (8)	78.9	70.8			8.1			36273.9
UC (9)	102.3	102.3						52377.6
						Subtotal		448915.3

TABLE 11: Water Quality Pollutant Loading - Future Conditions: Sediment

SubWatershed	Total	Residential	Commercial	Industrial	Wetland&Woods	Surface Water	I-43(open)	Sediment lbs/yr
FRE (1)	47.1	47.1						24115.2
FRE (2)	67.1	67.1						34355.2
FRE (3)	86.7	86.7						44390.4
FRE (4)	88.1	88.1						45107.2
FRE (5)	134	134						68608
						Subtotal		216576
FRW (1)	14.6			10.2		0.8	3.6	3450.4
FRW (2)	11.4			8.2			3.2	2692.8
FRW (3)	52.1	37.9	9.4				4.8	29926.4
FRW (4)	74.6	20.2	49.4				5	63128.8
						Subtotal		99198.4
PRE (1)	22.3			15.3	0.6		6.4	5079.4
PRE (2)	319.3	305.1		14.2				160187.2
						Subtotal		165266.6
PRW (1)	104.5	104.5						53504
PRW (2)	81.1	81.1						41523.2
PRW (3)	161.7	161.3				0.4		82659.6
PRW (4)	162.3	155			7.3			79381.9
						Subtotal		257068.7
LF (1)	28.5	28.5						14592
LF (2)	82.8	68.5					14.3	36845.2
LF (3)	32.7	32.7						16742.4
LF (4)	15.4	15.4						7884.8
LF (5)	64.9	64.9						33228.8
LF (6)	14.8	14.8						7577.6
						Subtotal		116870.8
Totals	6293.8	4344.3	466	434.7	787.5	13.4	247.9	2873674.7

TABLE 12: Water Quality Pollutant Loading – Future Condition: Phosphorus

SubWatershed	Total	Residential	Commercial	Industrial	Wetland&Woods	Surface Water	I-43(open)	Phosphorus lbs/yr
USN (1)	529.6	222.1		9.4	290.8	7.3		116.598
USN (2)	19.1			17.8	1.3			4.845
USN (3)	47.3			45.9	1.4			12.435
USN (4)	77.8	49.6	4.7	23.5				34.686
USN (5)	109.5	16.5	93.0					107.265
USN (6)	165.2	63.1	97.4		4.7			134.016
USN (7)	89.7	84.5			5.2			39.871
USN (8)	26.9	17.9			4.0		5	8.983
USN (9)	105.1	105.1						49.397
						Subtotal		508.096
USS (1)	625.7	172.7		214.7	233.4	4.9		146.777
USS (2)	162.7	129.3			33.4			61.773
USS (3)	165.0	134.4			30.6			64.086
USS (4)	183.7	165.3			18.4			78.243
USS (5)	191.4	161.4			30			76.758
USS (6)	80.9	72.4			8.5			34.283
						Subtotal		461.92
I43 (1)	149.8	70.9		42.5	6.6		29.8	47.678
I43 (2)	28.1		21.2		5.5		1.4	22.975
I43 (3)	141	119.8	21.2					78.99
I43 (4)	29.7		25.4				4.3	27.565
I43 (5)	19.8	5.6	14.2					17.826
I43 (6)	12.3		11.4				0.9	12.279
I43 (7)	63.2	62.2					1	29.324
I43 (8)	80.5	50					30.5	26.245
I43 (9)	35	33.7					1.3	15.956
I43 (10)	153.4	81.8	37.4				34.2	81.542
I43 (11)	140	99.1			17.4		23.5	49.214
I43 (12)	142.7	30.9	73.4				38.4	96.517
I43 (13)	56.2	50.9			5.3			24.082
						Subtotal		530.193
UC (1)	119.1	94.1	7.9				17.1	54.219
UC (2)	14.6			10.3			4.3	3.168
UC (3)	17			10.4			6.6	3.402
UC (4)	150.3	150.3						70.641
UC (5)	24.6			12.3			12.3	4.428
UC (6)	410.1	360.1			50			170.747
UC (7)	79.6	54.6			25			26.412
UC (8)	78.9	70.8			8.1			33.519
UC (9)	102.3	102.3						48.081
						Subtotal		414.617

TABLE 12: Water Quality Pollutant Loading – Future Condition: Phosphorus

SubWatershed	Total	Residential	Commercial	Industrial	Wetland&Woods	Surface Water	I-43(open)	Phosphorus lbs/yr
FRE (1)	47.1	47.1						22.137
FRE (2)	67.1	67.1						31.537
FRE (3)	86.7	86.7						40.749
FRE (4)	88.1	88.1						41.407
FRE (5)	134	134						62.98
						Subtotal		198.81
FRW (1)	14.6			10.2		0.8	3.6	3.182
FRW (2)	11.4			8.2			3.2	2.502
FRW (3)	52.1	37.9	9.4				4.8	28.303
FRW (4)	74.6	20.2	49.4				5	62.802
						Subtotal		96.789
PRE (1)	22.3			15.3	0.6		6.4	4.725
PRE (2)	319.3	305.1		14.2				147.231
						Subtotal		151.956
PRW (1)	104.5	104.5						49.115
PRW (2)	81.1	81.1						38.117
PRW (3)	161.7	161.3				0.4		75.863
PRW (4)	162.3	155			7.3			73.069
						Subtotal		236.164
LF (1)	28.5	28.5						13.395
LF (2)	82.8	68.5					14.3	33.482
LF (3)	32.7	32.7						15.369
LF (4)	15.4	15.4						7.238
LF (5)	64.9	64.9						30.503
LF (6)	14.8	14.8						6.956
						Subtotal		106.943
Totals	6293.8	4344.3	466	434.7	787.5	13.4	247.9	2705.488

TABLE 13: Water Quality Pollutant Loading – Future Conditions: Lead

SubWatershed	Total	Residential	Commercial	Industrial	Wetland&Woods	Surface Water	I-43(open*)	Lead lbs/yr
USN (1)	529.6	222.1		9.4	290.8	7.3		123.442
USN (2)	19.1			17.8	1.3			42.85
USN (3)	47.3			45.9	1.4			110.3
USN (4)	77.8	49.6	4.7	23.5				84.962
USN (5)	109.5	16.5	93.0					256.38
USN (6)	165.2	63.1	97.4		4.7			283.642
USN (7)	89.7	84.5			5.2			27.56
USN (8)	26.9	17.9			4.0		5	18.128
USN (9)	105.1	105.1						33.632
						Subtotal		980.896
USS (1)	625.7	172.7		214.7	233.4	4.9		594.374
USS (2)	162.7	129.3			33.4			44.716
USS (3)	165.0	134.4			30.6			46.068
USS (4)	183.7	165.3			18.4			54.736
USS (5)	191.4	161.4			30			54.648
USS (6)	80.9	72.4			8.5			24.018
						Subtotal		818.56
I43 (1)	149.8	70.9		42.5	6.6		29.8	196.868
I43 (2)	28.1		21.2		5.5		1.4	61.15
I43 (3)	141	119.8	21.2					95.576
I43 (4)	29.7		25.4				4.3	78.9
I43 (5)	19.8	5.6	14.2					40.132
I43 (6)	12.3		11.4				0.9	32.94
I43 (7)	63.2	62.2					1	22.304
I43 (8)	80.5	50					30.5	89.2
I43 (9)	35	33.7					1.3	13.904
I43 (10)	153.4	81.8	37.4				34.2	209.236
I43 (11)	140	99.1			17.4		23.5	89.852
I43 (12)	142.7	30.9	73.4				38.4	300.228
I43 (13)	56.2	50.9			5.3			16.818
						Subtotal		1247.108
UC (1)	119.1	94.1	7.9				17.1	92.482
UC (2)	14.6			10.3			4.3	35.04
UC (3)	17			10.4			6.6	40.8
UC (4)	150.3	150.3						48.096
UC (5)	24.6			12.3			12.3	59.04
UC (6)	410.1	360.1			50			120.232
UC (7)	79.6	54.6			25			19.972
UC (8)	78.9	70.8			8.1			23.466
UC (9)	102.3	102.3						32.736
						Subtotal		471.864

TABLE 13: Water Quality Pollutant Loading – Future Conditions: Lead

SubWatershed	Total	Residential	Commercial	Industrial	Wetland&Woods	Surface Water	I-43(open*)	Lead lbs/yr
FRE (1)	47.1	47.1						15.072
FRE (2)	67.1	67.1						21.472
FRE (3)	86.7	86.7						27.744
FRE (4)	88.1	88.1						28.192
FRE (5)	134	134						42.88
						Subtotal		135.36
FRW (1)	14.6			10.2		0.8	3.6	33.2
FRW (2)	11.4			8.2			3.2	27.36
FRW (3)	52.1	37.9	9.4				4.8	49.028
FRW (4)	74.6	20.2	49.4				5	151.844
						Subtotal		261.432
PRE (1)	22.3			15.3	0.6		6.4	52.14
PRE (2)	319.3	305.1		14.2				131.712
						Subtotal		183.852
PRW (1)	104.5	104.5						33.44
PRW (2)	81.1	81.1						25.952
PRW (3)	161.7	161.3				0.4		51.656
PRW (4)	162.3	155			7.3			50.33
						Subtotal		161.378
LF (1)	28.5	28.5						9.12
LF (2)	82.8	68.5					14.3	56.24
LF (3)	32.7	32.7						10.464
LF (4)	15.4	15.4						4.928
LF (5)	64.9	64.9						20.768
LF (6)	14.8	14.8						4.736
						Subtotal		106.256
Totals	6293.8	4344.3	466	434.7	787.5	13.4	247.9	4366.706

*I-43 lead loading @ 2.4 lbs./acre/yr.

Table 14

ULAO CREEK FUTURE LAND USE

				FUTURE LAND USE CONDITIONS									
SUBWATERSHED	**AREA(Acres)**	A-1	A-2	R-1	R-2	R-3	B-1	M-1	C-1	SW	Freeway		Composite CN
Ulao Swamp North (1)	529.6			222.1				9.4	290.8	7.3			80
(2)	19.1							17.8	1.3				90
(3)	47.3							45.9	1.4				90
(4)	77.8				49.6		4.7	23.5					81
(5)	109.5				16.5		93.0						90
(6)	165.2				63.1		97.4		4.7				86
(7)	67.3				62.6				4.7				77
(8)	49.3				39.8				4.5		5.0		78
(9)	105.1				105.1								76
Ulao Swamp South (1)	625.7				172.7			214.7	233.4	4.9			84
(2)	212.6				170.1				42.5				78
(3)	165.0				134.4				30.6				77
(4)	183.7				165.3				18.4				77
(5)	191.4				161.4				30.0				77
(6)	80.9				72.4				8.5				77
Interstate-43 (1)	149.8				25.6	45.3		42.5	6.6		29.8		84
(2)	28.1						21.2		5.5		1.4		90
(3)	141.0			9.4		110.4	21.2						81
(4)	29.7						25.4				4.3		92
(5)	19.8					5.6	14.2						88
(6)	12.3						11.4				0.9		92
(7)	63.2					62.2					1.0		79
(8)	80.5				31.1	18.9					30.5		83
(9)	35.0				22.3	11.4					1.3		78
(10)	153.4				81.8		37.4				34.2		83
(11)	140.0				99.1				17.4		23.5		80
(12)	142.7				30.9		73.4				38.4		89
(13)	56.2				50.9				5.3				77
Washington Avenue (1)	424.65			63.7		118.75	165.5	37.8			38.9		85
Falls Road East (1)	47.1				47.1								76
(2)	67.1				67.1								76
(3)	86.7				86.7								76
(4)	88.1				88.1								76
(5)	134.0				134.0								76

FUTURE LAND USE CONDITIONS													
SUBWATERSHED	**AREA(Acres)**	A-1	A-2	R-1	R-2	R-3	B-1	M-1	C-1	SW	Freeway		Composite CN
Falls Road West (1)	14.6							10.2		0.8	3.6		91
(2)	11.4							8.2			3.2		91
(3)	52.1					37.9	9.4				4.8		83
(4)	74.6					20.2	49.4				5.0		88
Lakefield (1)	28.5					28.5							79
(2)	82.8					68.5					14.3		81
(3)	32.7					32.7							79
(4)	15.4					15.4							79
(5)	64.9					64.9							79
(6)	14.8					14.8							79
Ulao Creek (1)	119.1					94.1	7.9				17.1		82
(2)	14.6							10.3			4.3		91
(3)	17.0							10.4			6.6		91
(4)	150.3				150.3								76
(5)	24.6							12.3			12.3		91
(6)	410.1				360.1				50.0				77
(7)	79.6				54.6				25.0				79
(8)	78.9				70.8				8.1				77
(9)	102.3				102.3								76
Pioneer Road East (1)	22.3							15.3	0.6		6.4		90
(2)	319.3				305.1			14.2					77
Pioneer Road West (1)	104.5					104.5							79
(2)	81.1					81.1							79
(3)	161.7					161.3				0.4			79
(4)	113.2					108.1			5.1				79
(5)	49.1					46.9			2.2				79
Totals New	6719.25			295.2	3020.9	1251.45	631.5	472.5	796.6	13.4	286.8		81

A-1	Exclusive Agricultural	R-3	Residential
A-2	Agricultural/ Rural Residential	B-1	Business
R-1	Residential	M-1	Industrial
R-2	Residential	C-1	Conservancy Overlay

TABLE 15
WATER QUANTITY MODELING DATA

POND	TYPE	Area @ NWL Flow	Area @ 100 Yr. HWL	Discharge (CFS)	Storm Storage (Ac - Ft.)	Low Flow Elevation	100 Yr. High Water Level
PP-1a	Existing Wetland	0.10	5.76	4.0	9.96	759.0	762.4
PP-13	Existing Wetland	2.5	3.36	3.0	1.58	758.0	758.5
PP-14	Wetland & Storage Area	0.91	7.71	3.0	10.2	770.0	772.4
PP-12	Existing & Grading	0.10	4.52	29.0	9.93	742.0	746.3
PPP-1	New	3.76	6.11	29.0	27.09	724.0	729.5
EP-5	Existing	0.23	0.76	109.0	2.72	720.0	725.5
EP-7	Existing	0.8	7.52	32.0	15.77	742.0	745.8
PPP-2	New	1.20	2.17	5.0	8.83	722.0	727.2
EP-18	Existing	0.01	0.05	5.0	0.03	711.8	712.7
PPP-3	New	2.27	5.10	11.0	14.19	744.0	747.9
EP-2	Existing	0.40	1.02	65.0	2.08	724.0	726.9
EP-1	Existing	0.01	1.07	45.0	2.34	719.0	723.3
Swamp N	Existing	0.05	116.60	34.0	179.06	698.0	701.0
EP-36	Existing Wetland	5.23	14.23	43	31.33	698.0	701.22
EP-34	Existing Wetland	13.89	26.28	32	48.4	698.0	700.4
Swamp S	Existing Wetland	20.1	135.2	210	228.29	694.0	696.94
PPP-20	New	2.50	3.22	19	8.24	706.0	708.88
PP-27	Modified	0.05	2.41	219	9.57	754.0	761.78

POND	TYPE	Area @ NWL Flow	Area @ 100 Yr. HWL	Discharge (CFS)	Storm Storage (Ac - Ft.)	Low Flow Elevation	100 Yr. High Water Level
EP-20	Existing Wetland	1.37	22.95	6	76.00	740.0	746.25
EP-29	Existing	0.82	6.02	127	19.94	744.0	749.83
EP-55	Existing	0.04	1.20	50	2.77	756.0	760.46
PP-51	Modified	0.05	2.30	123	8.74	730.5	737.96
EP-50	Existing	0.01	1.77	57	6.17	724.0	730.93
EP-39	Existing	0.01	0.30	90	0.72	726.0	730.63
EP-38	Existing	0.05	2.75	225	11.15	714.0	721.96
EP-56	Existing	5.01	6.20	44	8.18	700.0	701.46
PPP-21	New	4.0	6.5	30	22.73	692.0	696.33
Pond 1	Existing Wetland	8.42	13.12	30	17.56	712.0	713.63
PPP-4	New	5.35	10.58	3	20.15	710.0	712.53
PP-58	Modified	0.25	1.48	145	4.50	689.0	694.20
PP-91	Modified	0.05	3.07	66	9.67	688.0	694.20
PP-59	Modified	3.70	7.04	101	23.69	685.0	689.41
PPP-10	New	0.25	3.78	7	16.34	696.0	704.11
PPP-11	New	1.0	4.9	22	13.81	692.0	696.68
EP-63	Existing	0.68	1.06	31	2.40	698.0	700.69
PP-64	Existing	0.68	2.66	18	14.99	706.0	713.56
EP-83	Existing	0.23	1.40	106	3.88	700.0	704.
EP-84	Existing	0.05	2.0	103	4.10	702.0	706.0
PPP-12	Existing	1.0	5.1	33	15.01	692.0	696.92
PPP-13	Existing	1.0	8.2	45	30.41	692.0	698.61
PPP-69	Modified	0.05	0.70	22	1.14	724.0	727.04
PPP-30	New	1.20	3.67	25	12.91	684.0	689.30
PPP-33	New	3.0	4.15	23	15.12	691.0	695.23

POND	TYPE	Area @ NWL Flow	Area @ 100 Yr. HWL	Discharge (CFS)	Storm Storage (Ac - Ft.)	Low Flow Elevation	100 Yr. High Water Level
PP-81	Modified	0.05	2.58	64	3.46	673.5	676.16
PPP-35	New	0.05	4.10	146	11.56	674.0	679.22
PP-90	Modified	0.01	2.15	50	4.82	664.0	668.46
PPP-40	New	0.50	5.20	6	19.44	695.0	701.29
EP-87	Existing	1.13	13.47	57	38.03	672.0	677.20
Ex Pond	Existing	1.90	8.74	0	12.77	738.0	740.40
PP-78	Modified	0.05	6.09	30	14.86	703.0	708.57
PPP-50	New	4.6	15.7	47	41.91	672.0	676.13

APPENDIX B

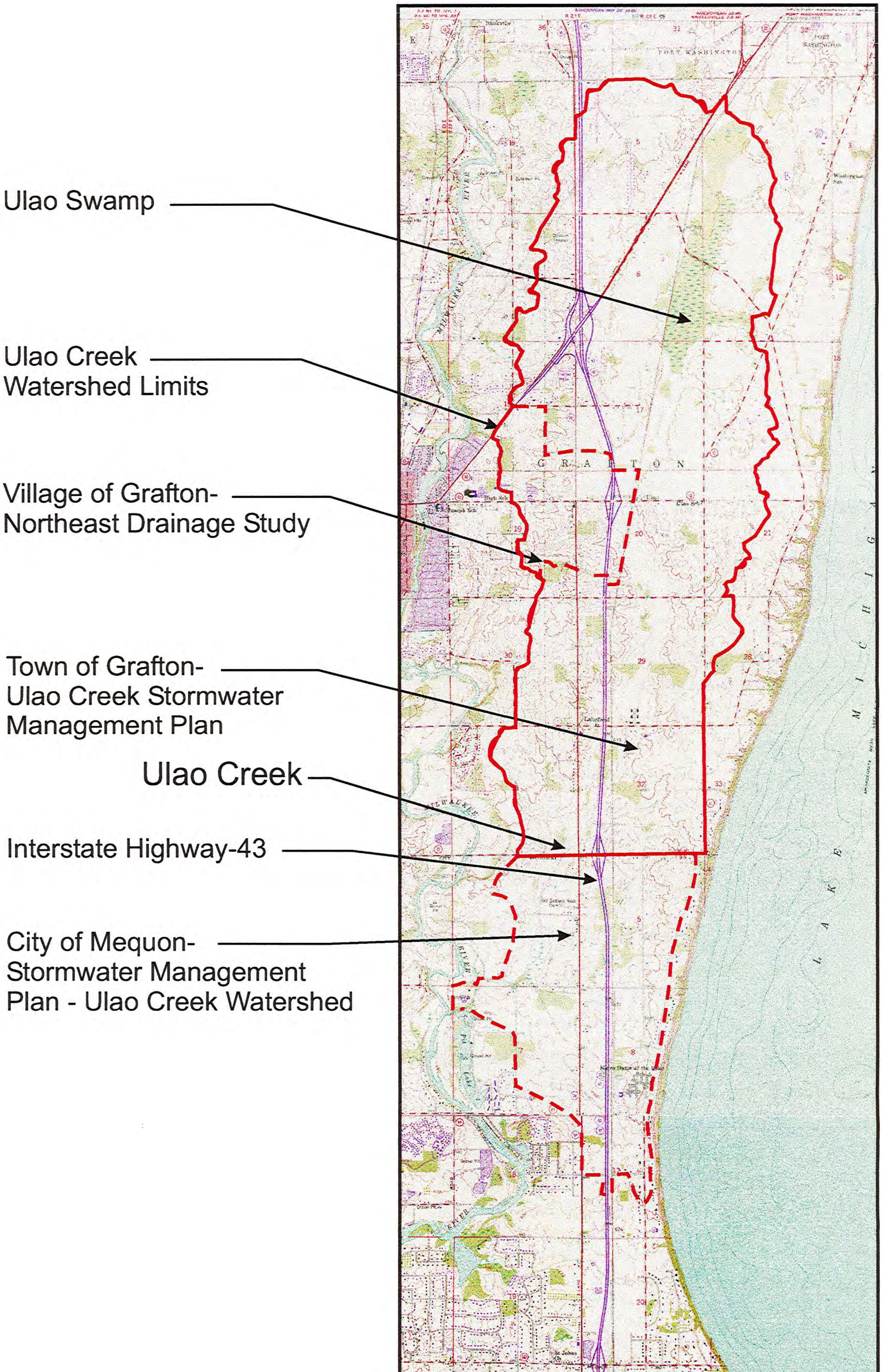

FIGURE 1 : ULAO CREEK WATERSHED

ULAO STORMWATER MANAGEMENT PLAN

TOWN OF GRAFTON

OZAUKEE COUNTY, WISCONSIN

Bonestroo Rosene Anderlik & Associates

Engineers & Architects

St. Paul, Minnesota
Mequon, Wisconsin

SURVEY	AJS
DRAWN	KAY
DESIGNED	BSL
APPROVED	ARS
DATE	9-22-97
FILE:	81624usg

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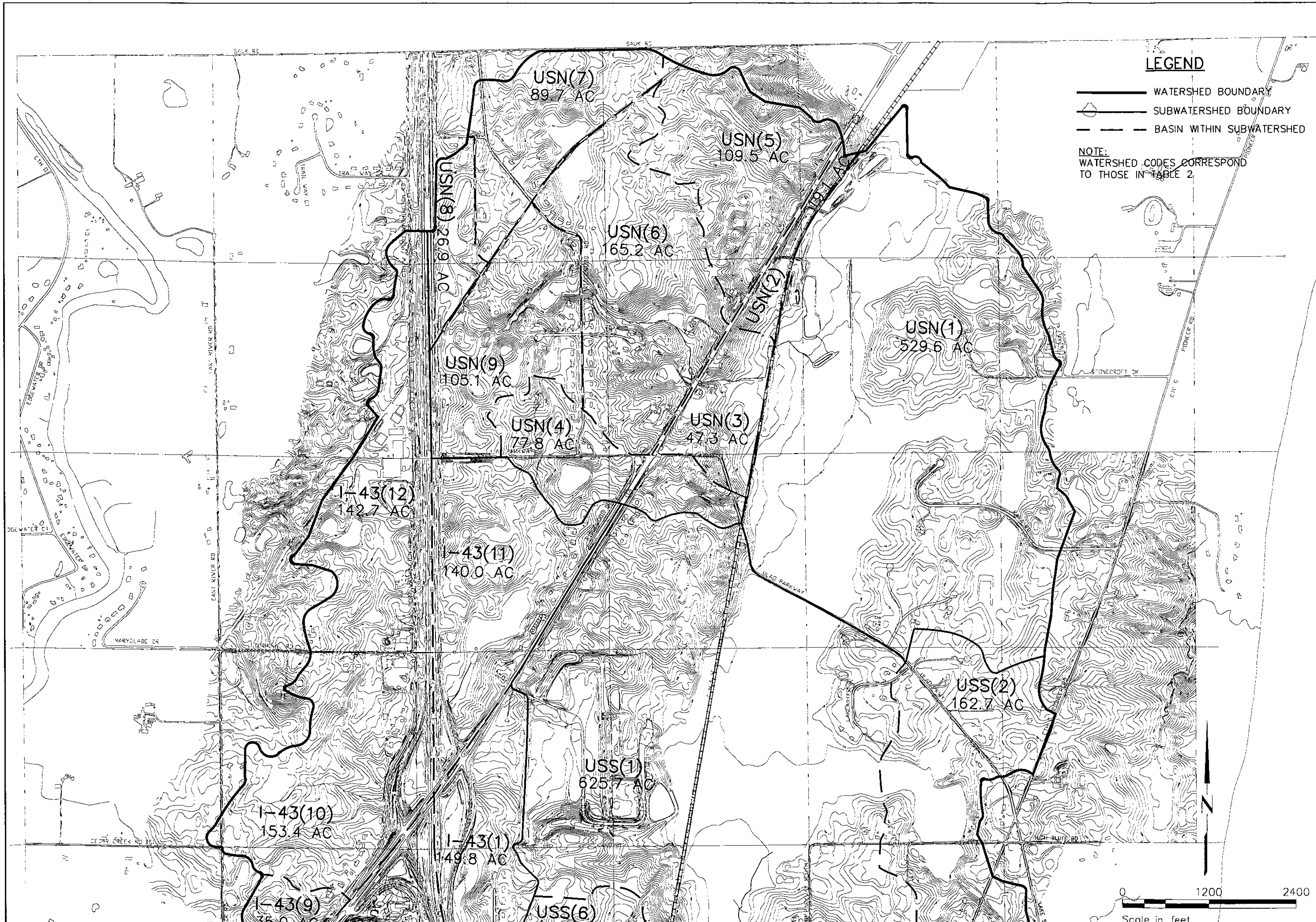


SURVEY	AJS
DRAWN	SRS
DESIGNED	BSL
APPROVED	ARS
DATE	10-13-97
FILE:	81624m02

Engineers & Architects

St. Paul, Minnesota
Mequon, Wisconsin

Bonestroo Rosene Anderlik & Associates

MAP 2 – WATERSHED BOUNDARY – NORTH

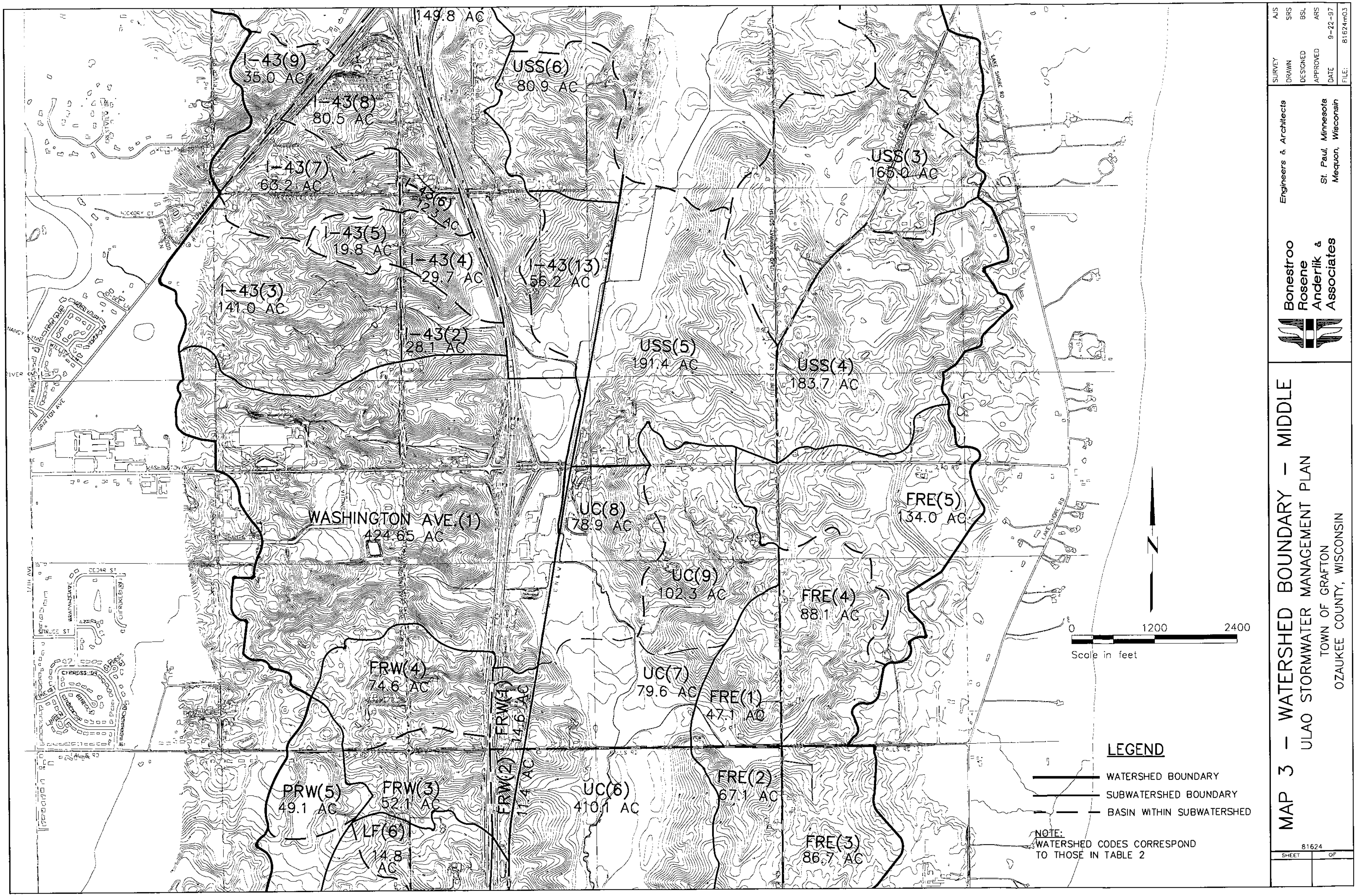
ULAO STORMWATER MANAGEMENT PLAN

TOWN OF GRAFTON

OZAUKEE COUNTY, WISCONSIN

81624

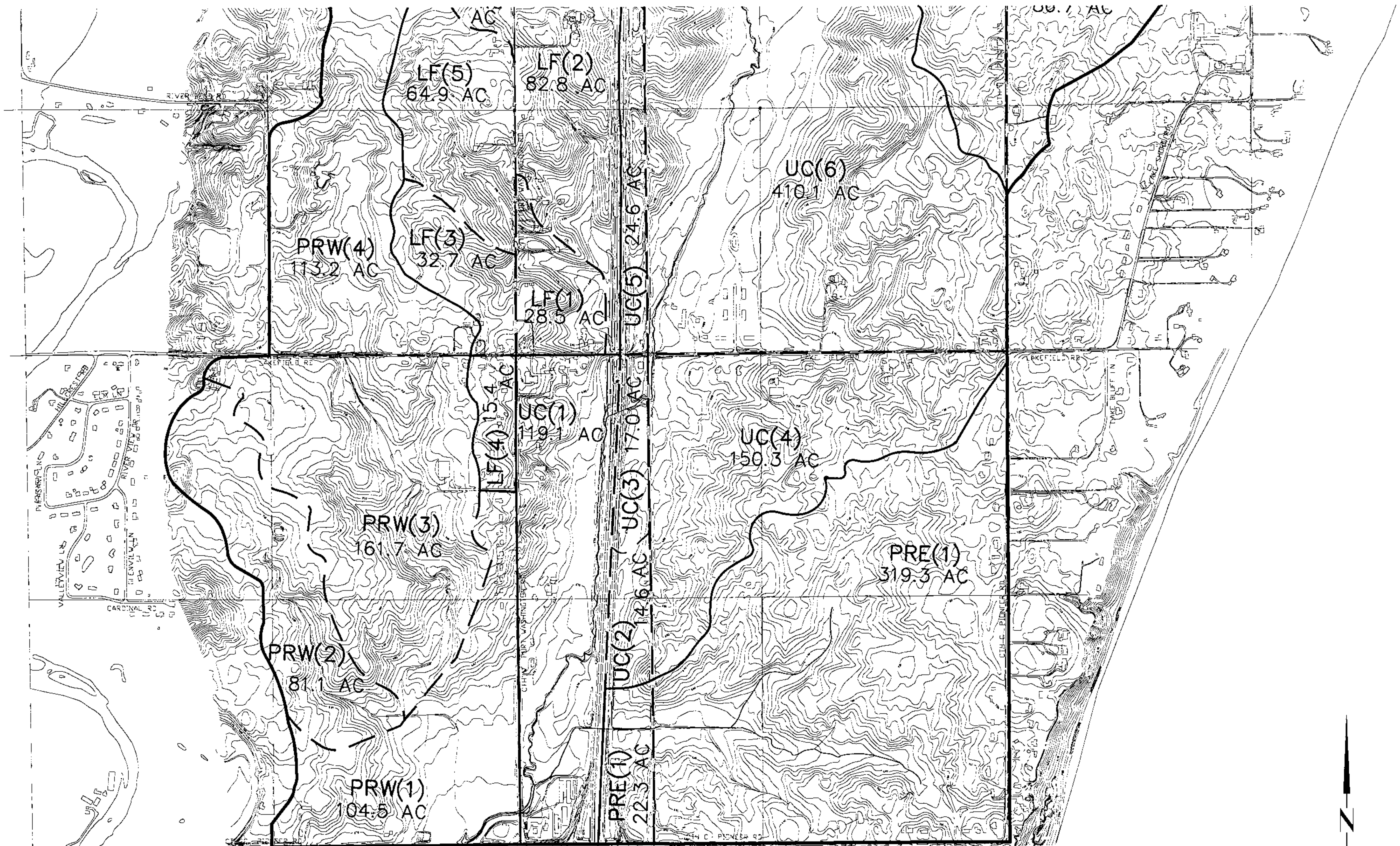
SHEET OF


149.8 AC
I-43(9)
35.0 AC
I-43(8)
80.5 AC
I-43(7)
63.2 AC
I-43(6)
7.2 AC
I-43(5)
19.8 AC
I-43(4)
29.7 AC
I-43(3)
141.0 AC
I-43(2)
28.1 AC
I-43(13)
56.2 AC
USS(6)
80.9 AC
USS(3)
165.0 AC
USS(5)
191.4 AC
USS(4)
183.7 AC
WASHINGTON AVE.(1)
424.65 AC
UC(8)
78.9 AC
UC(9)
102.3 AC
UC(7)
79.6 AC
UC(6)
410.1 AC
FRE(5)
134.0 AC
FRE(4)
88.1 AC
FRE(1)
47.1 AC
FRE(2)
67.1 AC
FRE(3)
86.7 AC
FRW(4)
74.6 AC
FRW(3)
52.1 AC
FRW(1)
14.6 AC
FRW(2)
11.4 AC
PRW(5)
49.1 AC
LF(6)
14.8 AC
HICKORY CT
WASHINGTON AVE
GRAFTON AVE
LAKE SHORE RD
CEDAR ST
SPRUCE ST
N
0
1200
2400
Scale in feet
LEGEND
WATERSHED BOUNDARY
SUBWATERSHED BOUNDARY
BASIN WITHIN SUBWATERSHED
NOTE:
WATERSHED CODES CORRESPOND
TO THOSE IN TABLE 2
MAP 3 - WATERSHED BOUNDARY - MIDDLE
ULAO STORMWATER MANAGEMENT PLAN
TOWN OF GRAFTON
OZAUKEE COUNTY, WISCONSIN
Bonestroo
Rosene
Anderlik &
Associates
Engineers & Architects
St. Paul, Minnesota
Mequon, Wisconsin
SURVEY AJS
DRAWN SRS
DESIGNED BSL
APPROVED ARS
DATE 9-22-97
FILE: 81624m03
81624
SHEET OF

LEGEND

- WATERSHED BOUNDARY (heavy solid line)
- SUBWATERSHED BOUNDARY (light solid line)
- BASIN WITHIN SUBWATERSHED (dashed line)

NOTE:
WATERSHED CODES CORRESPOND TO THOSE IN TABLE 2



0 1200 2400
Scale in feet

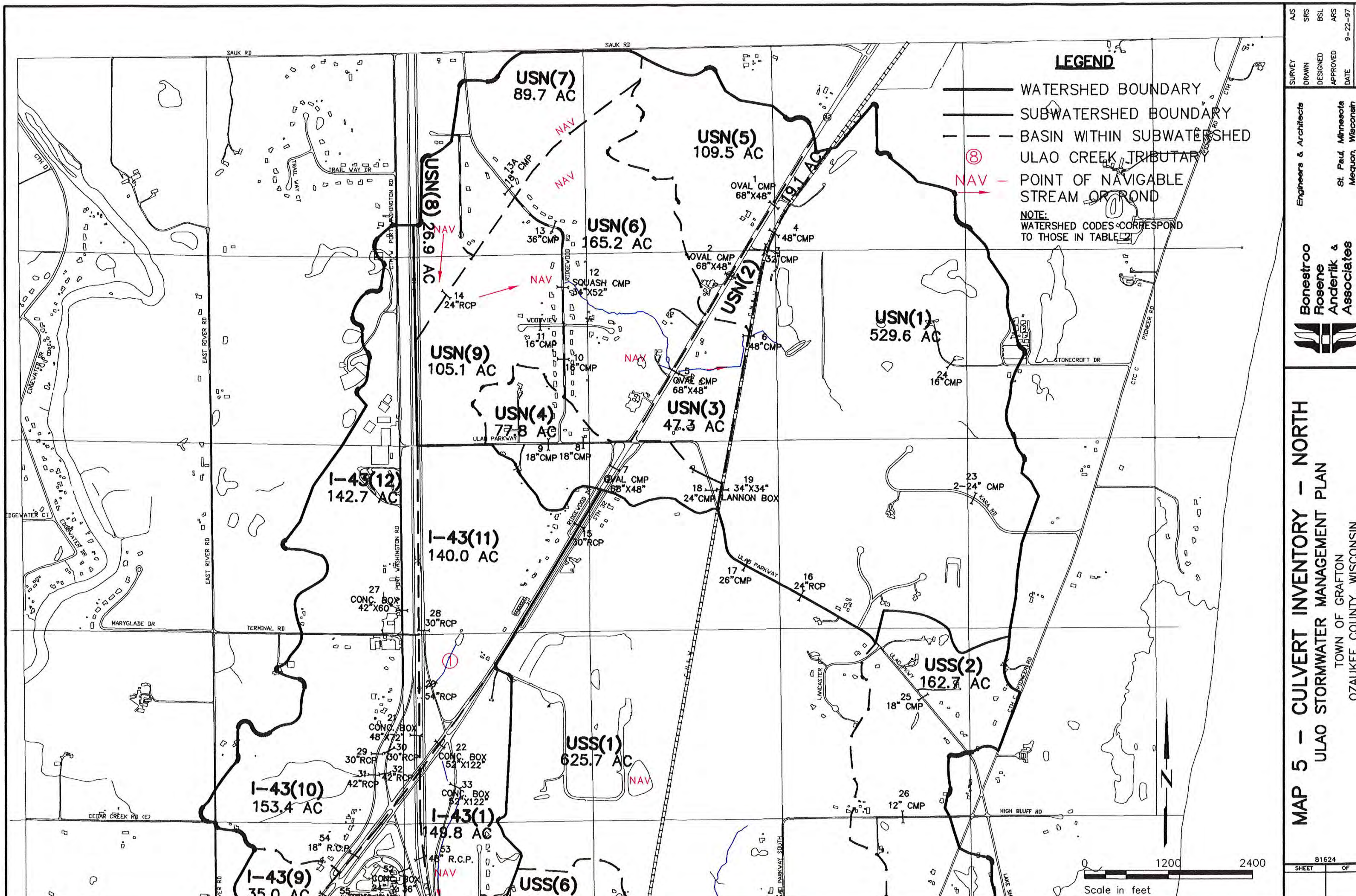
MAP 4 – WATERSHED BOUNDARY – SOUTH

ULAO STORMWATER MANAGEMENT PLAN
TOWN OF GRAFTON
OZAUKEE COUNTY, WISCONSIN

Bonestroo Rosene Anderlik & Associates
Engineers & Architects
St. Paul, Minnesota
Mequon, Wisconsin

SURVEY	AJS
DRAWN	SRS
DESIGNED	BSL
APPROVED	ARS
DATE	9-22-97
FILE:	81624m04

SHEET 81624 OF


LEGEND
WATERSHED BOUNDARY
SUBWATERSHED BOUNDARY
BASIN WITHIN SUBWATERSHED
⑧ ULAO CREEK TRIBUTARY
NAV – POINT OF NAVIGABLE STREAM OR POND
NOTE: WATERSHED CODES CORRESPOND TO THOSE IN TABLE 2
USN(7) 89.7 AC
USN(5) 109.5 AC
USN(8) 26.9 AC
USN(6) 165.2 AC
USN(2) 19.1 AC
USN(1) 529.6 AC
USN(9) 105.1 AC
USN(4) 77.8 AC
USN(3) 47.3 AC
I-43(12) 142.7 AC
I-43(11) 140.0 AC
USS(2) 162.7 AC
USS(1) 625.7 AC
I-43(10) 153.4 AC
I-43(1) 149.8 AC
I-43(9) 35.0 AC
USS(6)
1 OVAL CMP 68"X48"
2 OVAL CMP 68"X48"
3 32"CMP
4 48"CMP
5 OVAL CMP 68"X48"
6 48"CMP
7 OVAL CMP 68"X48"
8 18"CMP
9 18"CMP
10 18"CMP
11 16"CMP
12 SQUASH CMP 34"X52"
13 36"CMP
13A 18"CMP
14 24"RCP
15 30"RCP
16 24"RCP
17 26"CMP
18 24"CMP
19 34"X34" LANNON BOX
23 2–24" CMP
24 16"CMP
25 18" CMP
26 12" CMP
27 CONC. BOX 42"X60"
28 30"RCP
20 54"RCP
21 CONC. BOX 48"X72"
22 CONC. BOX 52"X122"
29 30"RCP
30 30"RCP
31 42"RCP
32 42"RCP
33 CONC. BOX 52"X122"
53 48" R.C.P.
54 18" R.C.P.
52 CONC. BOX 24"X36"
55
NAV
SAUK RD
TRAIL WAY DR
TRAIL WAY CT
PORT WASHINGTON RD
RIDGEWOOD RD
WOODVIEW
ULAO PARKWAY
STONECROFT DR
PIONEER RD
KARA RD
EAST RIVER RD
EDGEWATER DR
EDGEWATER CT
MARYGLADE DR
TERMINAL RD
CEDAR CREEK RD (E)
HIGH BLUFF RD
LANCASTER
PARKWAY SOUTH
LAKE SHORE
CTH C
CTH V
STH 32
C.N.W.
0 1200 2400
Scale in feet
N
MAP 5 – CULVERT INVENTORY – NORTH
ULAO STORMWATER MANAGEMENT PLAN
TOWN OF GRAFTON
OZAUKEE COUNTY, WISCONSIN
Bonestroo Rosene Anderlik & Associates
Engineers & Architects
St. Paul, Minnesota
Mequon, Wisconsin
SURVEY AJS
DRAWN SRS
DESIGNED BSL
APPROVED ARS
DATE 9-22-97
FILE: 81624m05
81624
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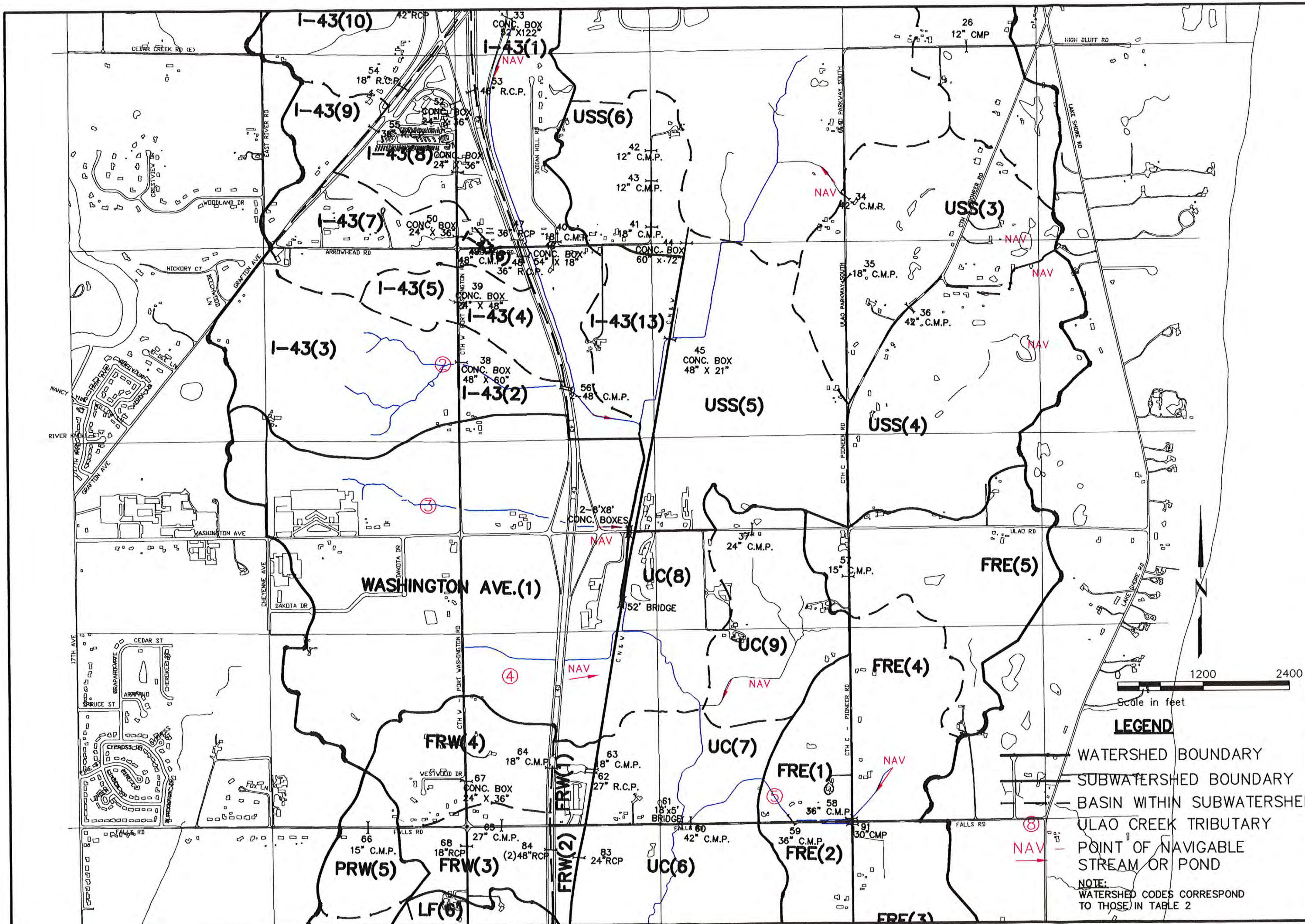

MAP - 6 CULVERT INVENTORY - MIDDLE

ULAO STORMWATER MANAGEMENT PLAN
TOWN OF GRAFTON
OZAUKEE COUNTY, WISCONSIN

Bonestroo Rosene Anderlik & Associates
Engineers & Architects
St. Paul, Minnesota
Mequon, Wisconsin

SURVEY	AJS
DRAWN	SRS
DESIGNED	BSL
APPROVED	ARS
DATE	9-22-97
FILE:	81624m06

81624
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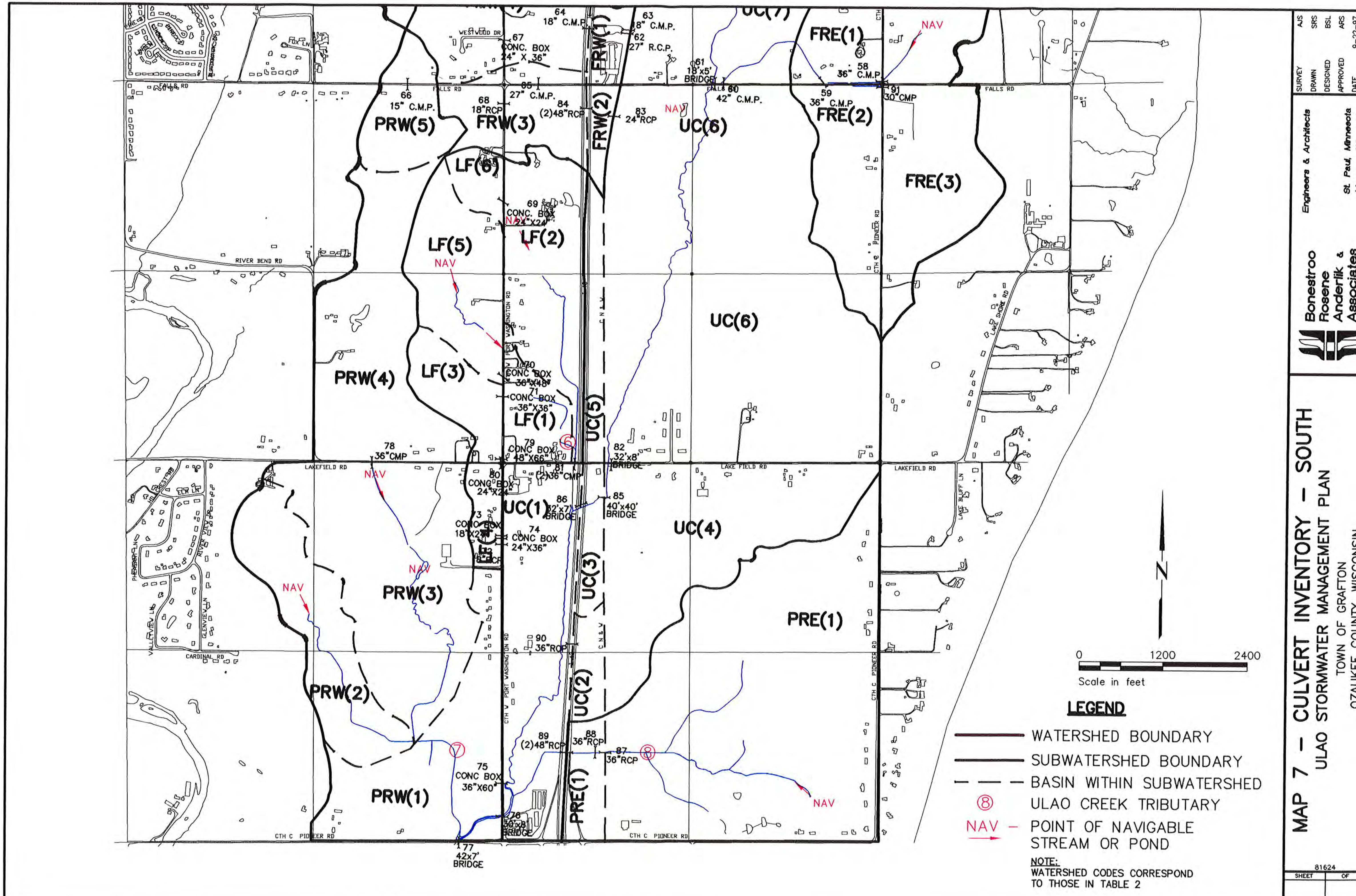
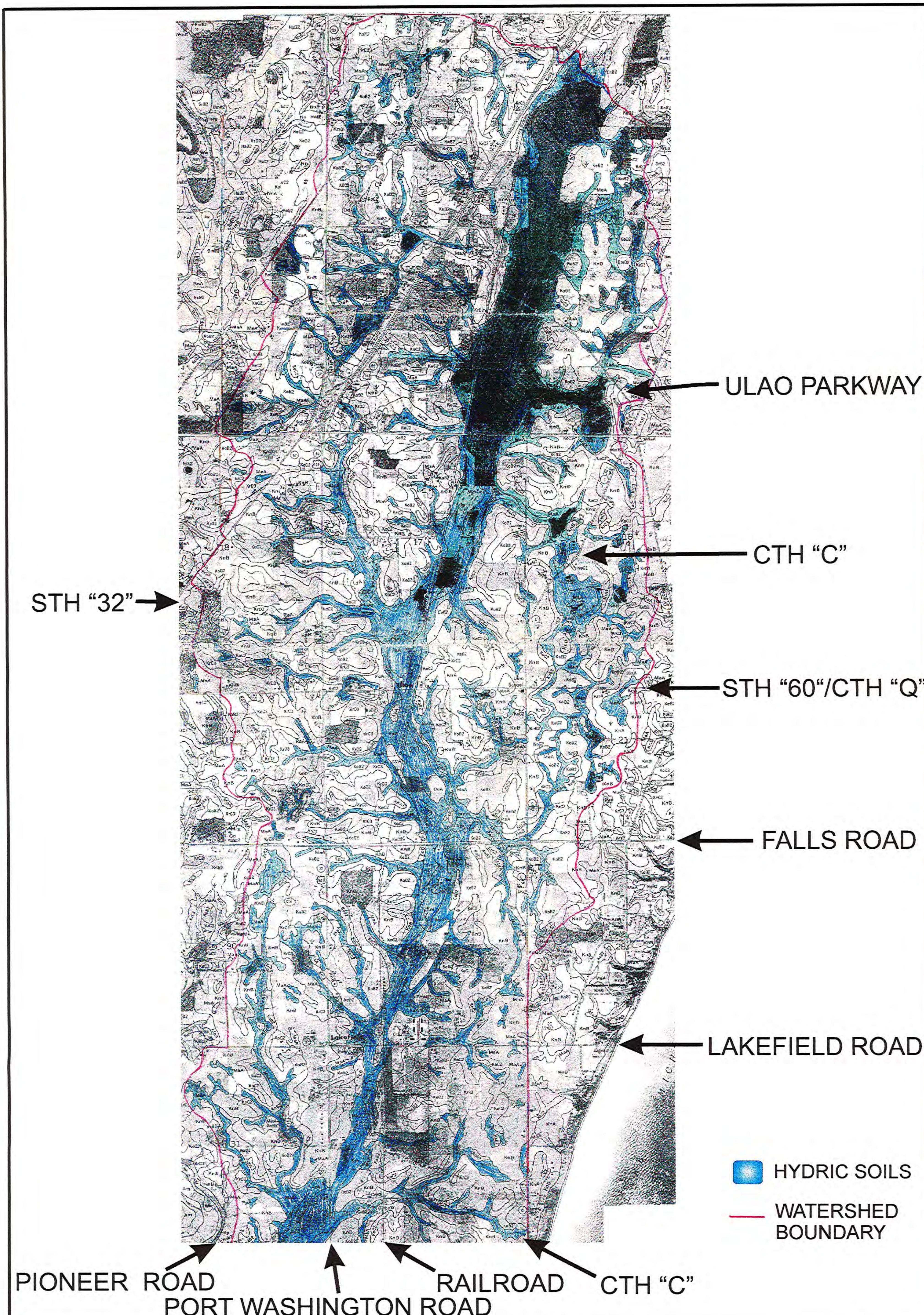

MAP 7 - CULVERT INVENTORY - SOUTH
ULAO STORMWATER MANAGEMENT PLAN
TOWN OF GRAFTON
OZAUKEE COUNTY, WISCONSIN
Bonestroo Rosene Anderlik & Associates
Engineers & Architects
St. Paul, Minnesota
Mequon, Wisconsin
SURVEY AJS
DRAWN SRS
DESIGNED BSL
APPROVED ARS
DATE 9-22-97
FILE: 81624m07
81624
SHEET
OF
LEGEND
WATERSHED BOUNDARY
SUBWATERSHED BOUNDARY
BASIN WITHIN SUBWATERSHED
⑧ ULAO CREEK TRIBUTARY
NAV – POINT OF NAVIGABLE STREAM OR POND
NOTE:
WATERSHED CODES CORRESPOND TO THOSE IN TABLE 2
0
1200
2400
Scale in feet
N
FALLS RD
RIVER BEND RD
LAKEFIELD RD
CARDINAL RD
CTH C PIONEER RD
CTH V PORT WASHINGTON RD
LAKE SHORE RD
LAKE BLUFF LN
WESTWOOD DR
FOX LN
C.N.& V.
PRW(1)
PRW(2)
PRW(3)
PRW(4)
PRW(5)
LF(1)
LF(2)
LF(3)
LF(5)
LF(6)
FRW(1)
FRW(2)
FRW(3)
UC(1)
UC(2)
UC(3)
UC(4)
UC(5)
UC(6)
UC(7)
FRE(1)
FRE(2)
FRE(3)
PRE(1)
58 36" C.M.P.
59 36" C.M.P.
60 42" C.M.P.
61 18"x5' BRIDGE
62 27" R.C.P.
63 18" C.M.P.
64 18" C.M.P.
65 27" C.M.P.
66 15" C.M.P.
67 CONC. BOX 24" X 36"
68 18"RCP
69 CONC. BOX 24"X24"
70 CONC BOX 36"X48"
71 CONC BOX 36"X36"
73 CONC BOX 18"X24"
74 CONC BOX 24"X36"
75 CONC BOX 36"X60"
76 30'x8' BRIDGE
77 42x7' BRIDGE
78 36"CMP
79 CONC BOX 48"X66"
80 CONC BOX 24"X24"
81 (2)36"CMP
82 32'x8' BRIDGE
83 24"RCP
84 (2)48"RCP
85 40'x40' BRIDGE
86 22'x7' BRIDGE
87 36"RCP
88 36"RCP
89 (2)48"RCP
90 36"RCP
91 30"CMP
NAV



MAP 8 - USDA HYDRIC SOILS

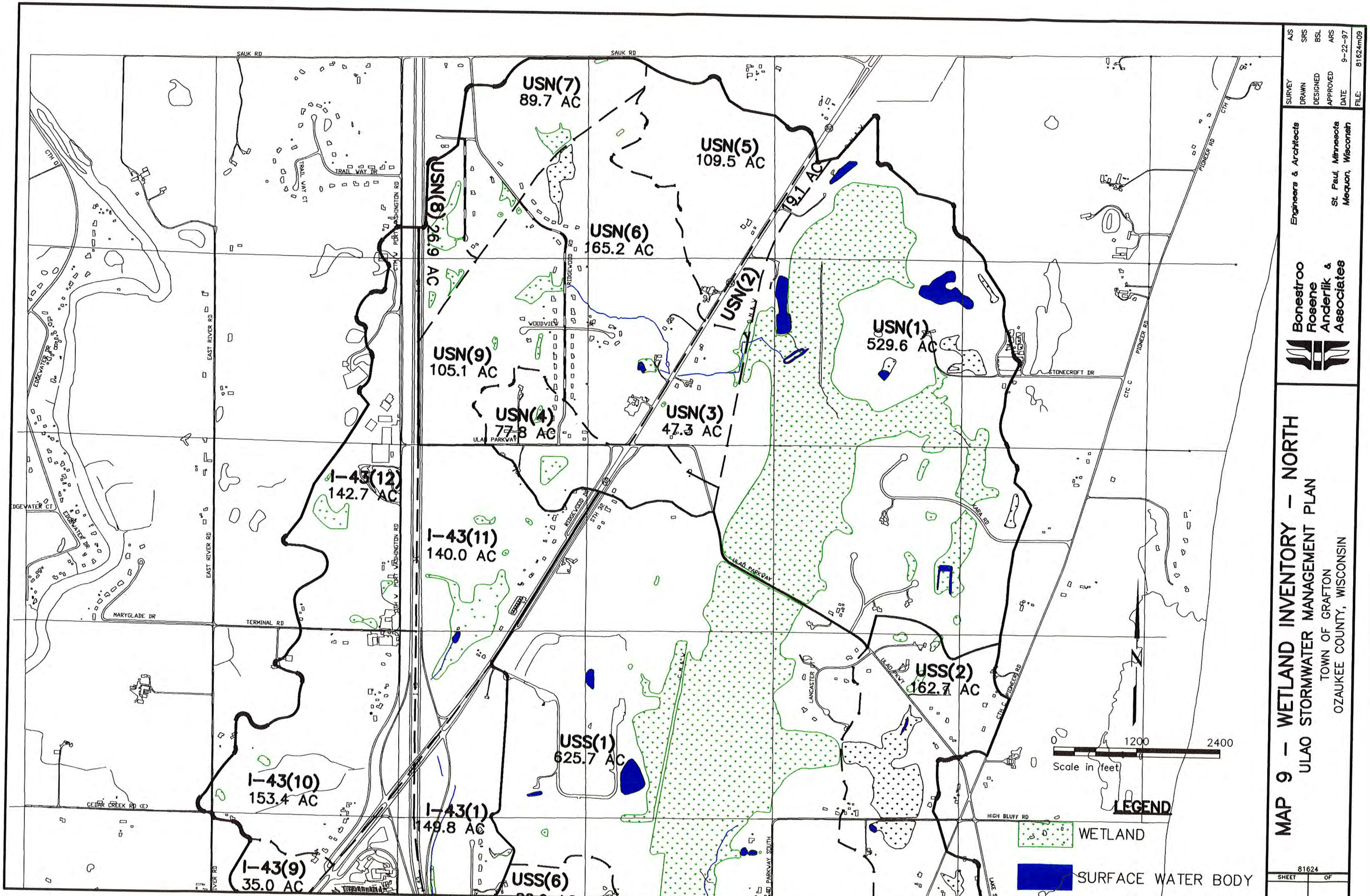
ULAO STORMWATER MANAGEMENT PLAN
TOWN OF GRAFTON
OZAUKEE COUNTY, WISCONSIN

Bonestroo Rosene Anderlik & Associates
Engineers & Architects

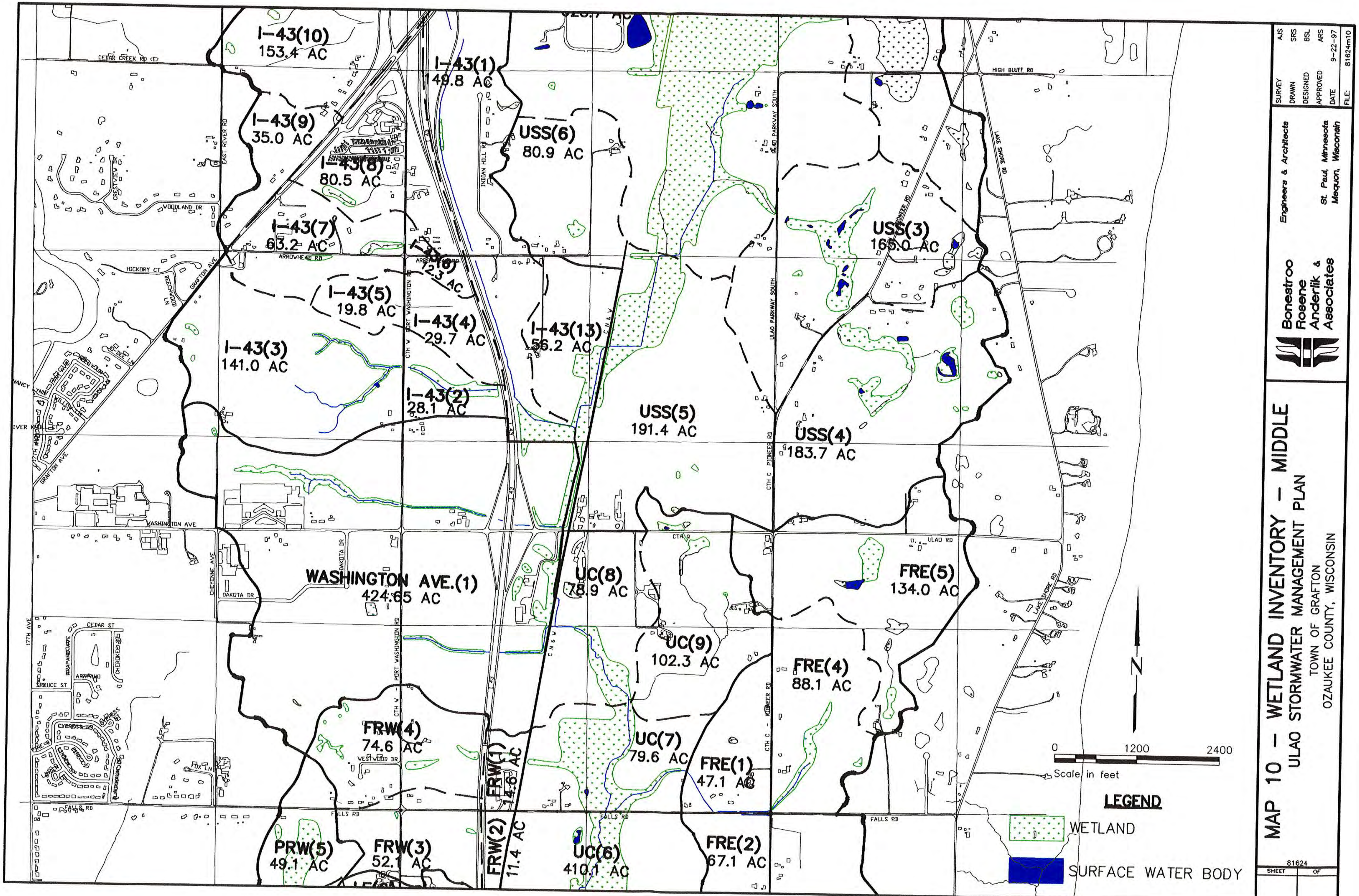
Engineers & Architects
ST. Paul, Minnesota
Mequon, Wisconsin

SURVEY	AJS
DRAWN	KAY
DESIGNED	BSL
APPROVED	ARS
DATE	9-22-97
FILE	81624m08.cdr

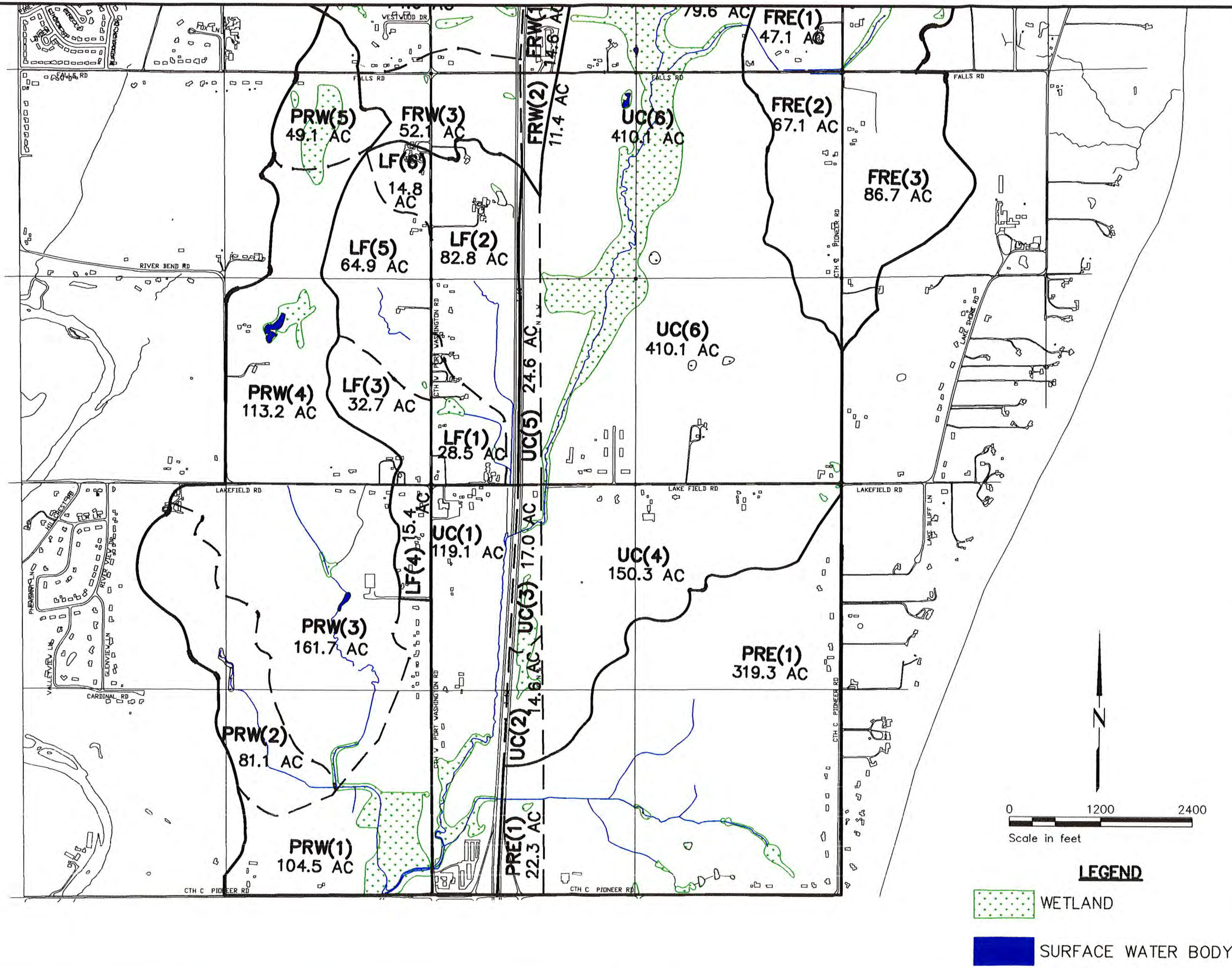
SHEET OF 81624



MAP 9 - WETLAND INVENTORY - NORTH
ULAO STORMWATER MANAGEMENT PLAN
TOWN OF GRAFTON
OZAUKEE COUNTY, WISCONSIN
Bonestroo Rosene Anderlik & Associates
Engineers & Architects
St. Paul, Minnesota
Mequon, Wisconsin
SURVEY AJS
DRAWN SRS
DESIGNED BSL
APPROVED ARS
DATE 9-22-97
FILE: 81624m09
81624
SHEET
OF
LEGEND
WETLAND
SURFACE WATER BODY
0
1200
2400
Scale in feet
USN(7)
89.7 AC
USN(5)
109.5 AC
9.1 AC
USN(6)
165.2 AC
USN(8) 26.9 AC
USN(2)
USN(1)
529.6 AC
USN(9)
105.1 AC
USN(4)
77.8 AC
USN(3)
47.3 AC
I-43(12)
142.7 AC
I-43(11)
140.0 AC
USS(2)
162.7 AC
USS(1)
625.7 AC
I-43(10)
153.4 AC
I-43(1)
149.8 AC
I-43(9)
35.0 AC
USS(6)
SAUK RD
TRAIL WAY DR
TRAIL WAY CT
CTH O
EAST RIVER RD
EDGEWATER DR
EDGEWATER CT
MARYGLADE DR
TERMINAL RD
CEDAR CREEK RD
CTH V PORT WASHINGTON RD
RIDGEWOOD RD
WOODVIEW
ULAO PARKWAY
STH 32
PIONEER RD
CTH C
STONECROFT DR
KARA RD
LANCASTER CT
HIGH BLUFF RD
ULAO PARKWAY SOUTH



MAP 10 – WETLAND INVENTORY – MIDDLE
ULAO STORMWATER MANAGEMENT PLAN
TOWN OF GRAFTON
OZAUKEE COUNTY, WISCONSIN
Bonestroo Rosene Anderlik & Associates
Engineers & Architects
St. Paul, Minnesota
Mequon, Wisconsin
SURVEY AJS
DRAWN SRS
DESIGNED BSL
APPROVED ARS
DATE 9-22-97
FILE: 81624m10
81624
SHEET OF
LEGEND
WETLAND
SURFACE WATER BODY
0 1200 2400
Scale in feet
N
I-43(10) 153.4 AC
I-43(1) 149.8 AC
I-43(9) 35.0 AC
I-43(8) 80.5 AC
I-43(7) 63.2 AC
I-43(6) 12.3 AC
I-43(5) 19.8 AC
I-43(4) 29.7 AC
I-43(3) 141.0 AC
I-43(2) 28.1 AC
I-43(13) 56.2 AC
USS(6) 80.9 AC
USS(3) 165.0 AC
USS(5) 191.4 AC
USS(4) 183.7 AC
WASHINGTON AVE.(1) 424.65 AC
UC(8) 78.9 AC
UC(9) 102.3 AC
UC(7) 79.6 AC
UC(6) 410.1 AC
FRE(5) 134.0 AC
FRE(4) 88.1 AC
FRE(1) 47.1 AC
FRE(2) 67.1 AC
FRW(4) 74.6 AC
FRW(1) 14.6 AC
FRW(2) 11.4 AC
FRW(3) 52.1 AC
PRW(5) 49.1 AC
CEDAR CREEK RD (E)
HIGH BLUFF RD
EAST RIVER RD
INDIAN HILL RD
PARKWAY SOUTH
ULAO PARKWAY SOUTH
LAKE SHORE RD
PIONEER RD
CTH C PIONEER RD
WOODLAND DR
CRESTVIEW
ARROWHEAD RD
HICKORY CT
GRAFTON AVE
BEECHWOOD LN
CTH V PORT WASHINGTON RD
C N & W
WASHINGTON AVE
CHEYENNE AVE
DAKOTA DR
CTH Q
ULAO RD
CEDAR ST
17TH AVE
SPRUCE ST
CHEROKEE DR
ARAPAHO
CYPRESS DR
WESTWOOD DR
FALLS RD
43



MAP 11 – WETLAND INVENTORY – SOUTH

ULAO STORMWATER MANAGEMENT PLAN

TOWN OF GRAFTON

OZAUKEE COUNTY, WISCONSIN

Bonestroo Rosene Anderlik & Associates

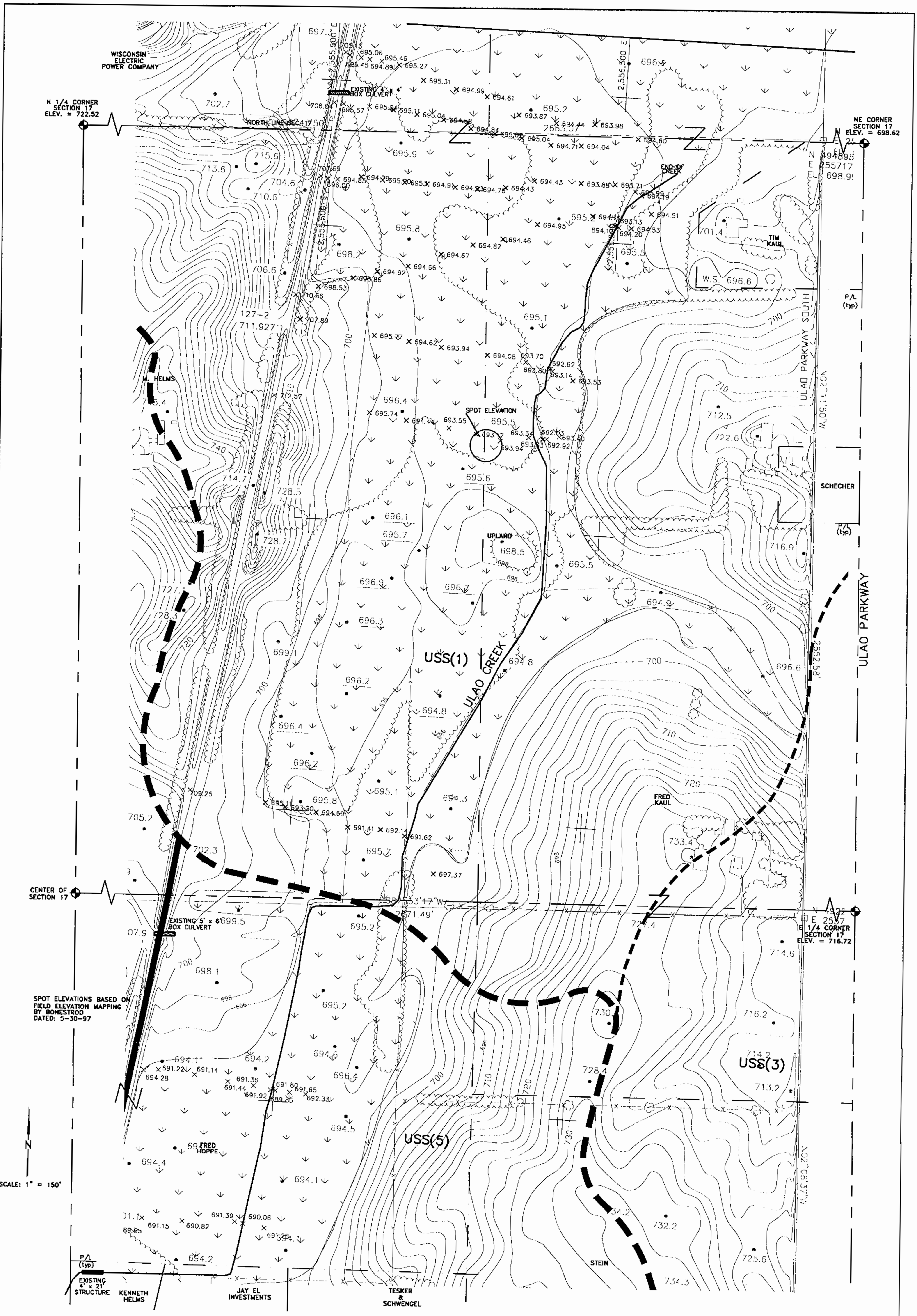
Engineers & Architects

St. Paul, Minnesota
Mequon, Wisconsin

SURVEY	AJS
DRAWN	SRS
DESIGNED	BSL
APPROVED	ARS
DATE	9-22-97
FILE:	81624m11

81624

SHEET OF



MAP 12

ULAO SWAMP SURVEY

ULAO CREEK WATERSHED

OZAUKEE COUNTY, WISCONSIN

Bonestroo Rosene Anderlik & Associates

Engineers & Architects

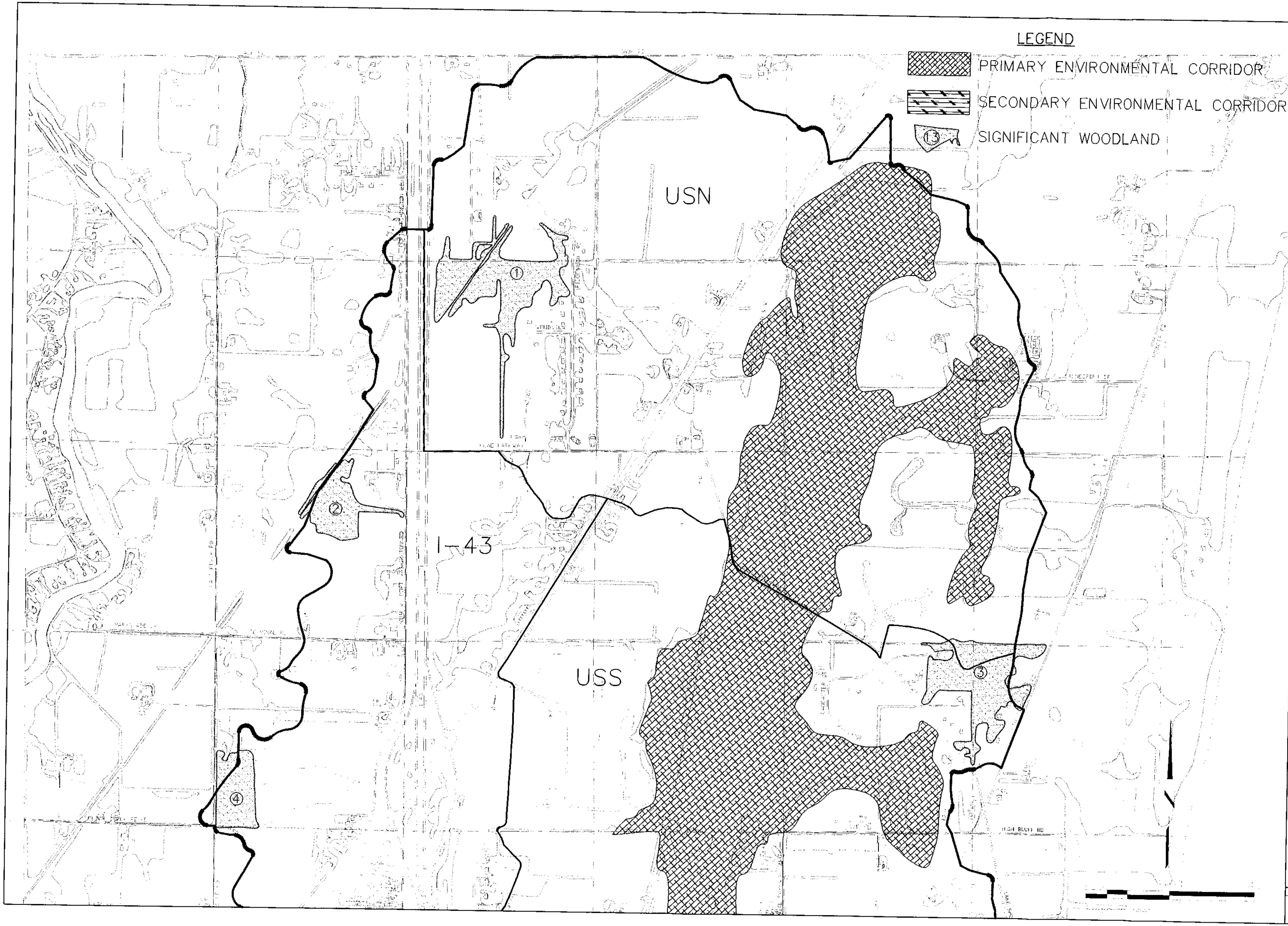
St. Paul, Minnesota
Mequon, Wisconsin

SURVEY	AJS
DRAWN	SRS
DESIGNED	AJS
APPROVED	ARS
DATE	6-17-97
COMM.	85203

REVISION	DATE

K:\CAD\852\85203\85203m12

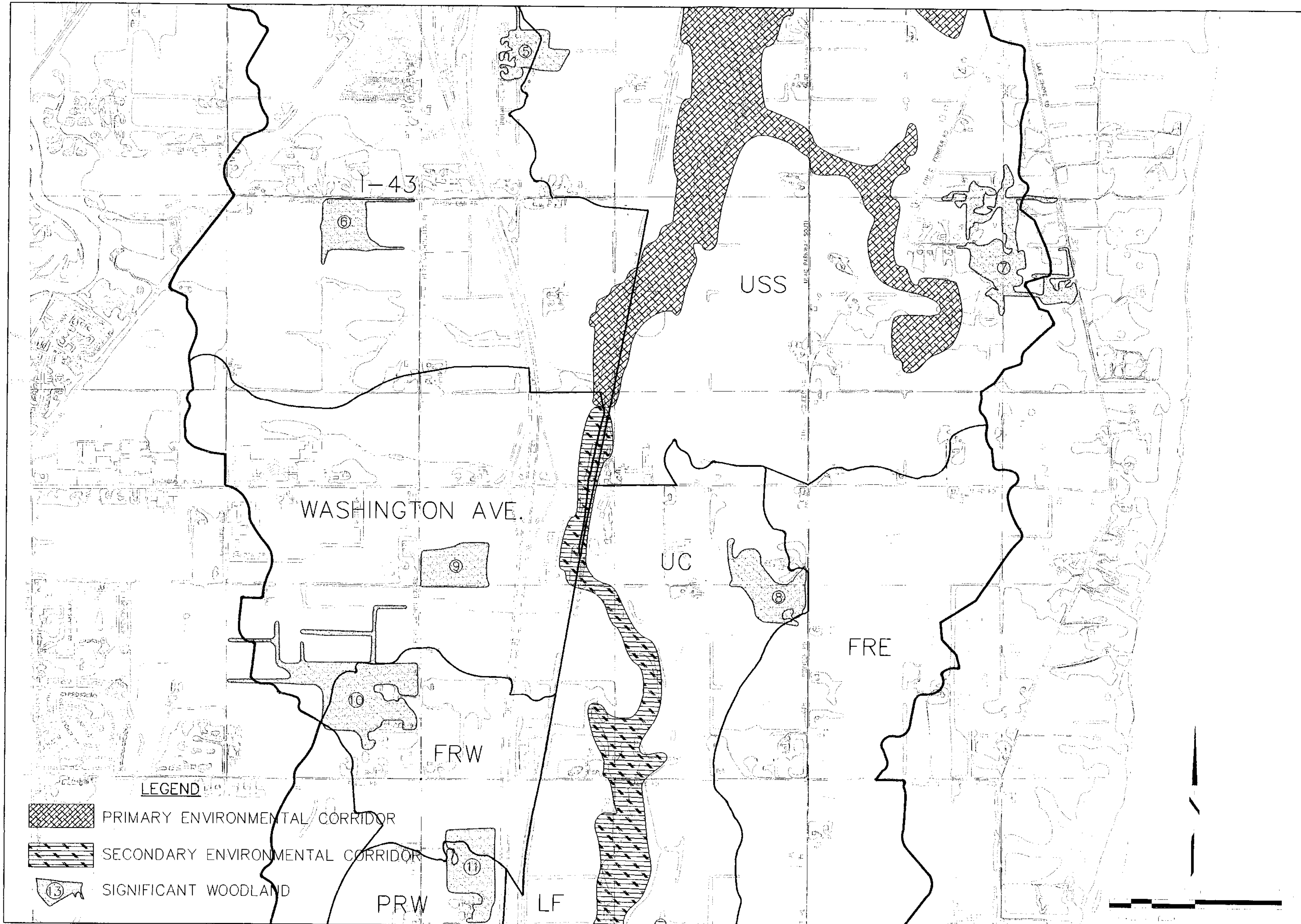
SHEET 85203 OF



MAP 13–ENVIRONMENTAL CORRIDOR – NORTH

ULAO STORMWATER MANAGEMENT PLAN
TOWN OF GRAFTON
OZAUKEE COUNTY, WISCONSIN

Bonestroo Rosene Anderlik & Associates
Engineers & Architects
St. Paul, Minnesota
Mequon, Wisconsin



MAP 14–ENVIRONMENTAL CORRIDOR – MIDDLE

ULAO STORMWATER MANAGEMENT PLAN

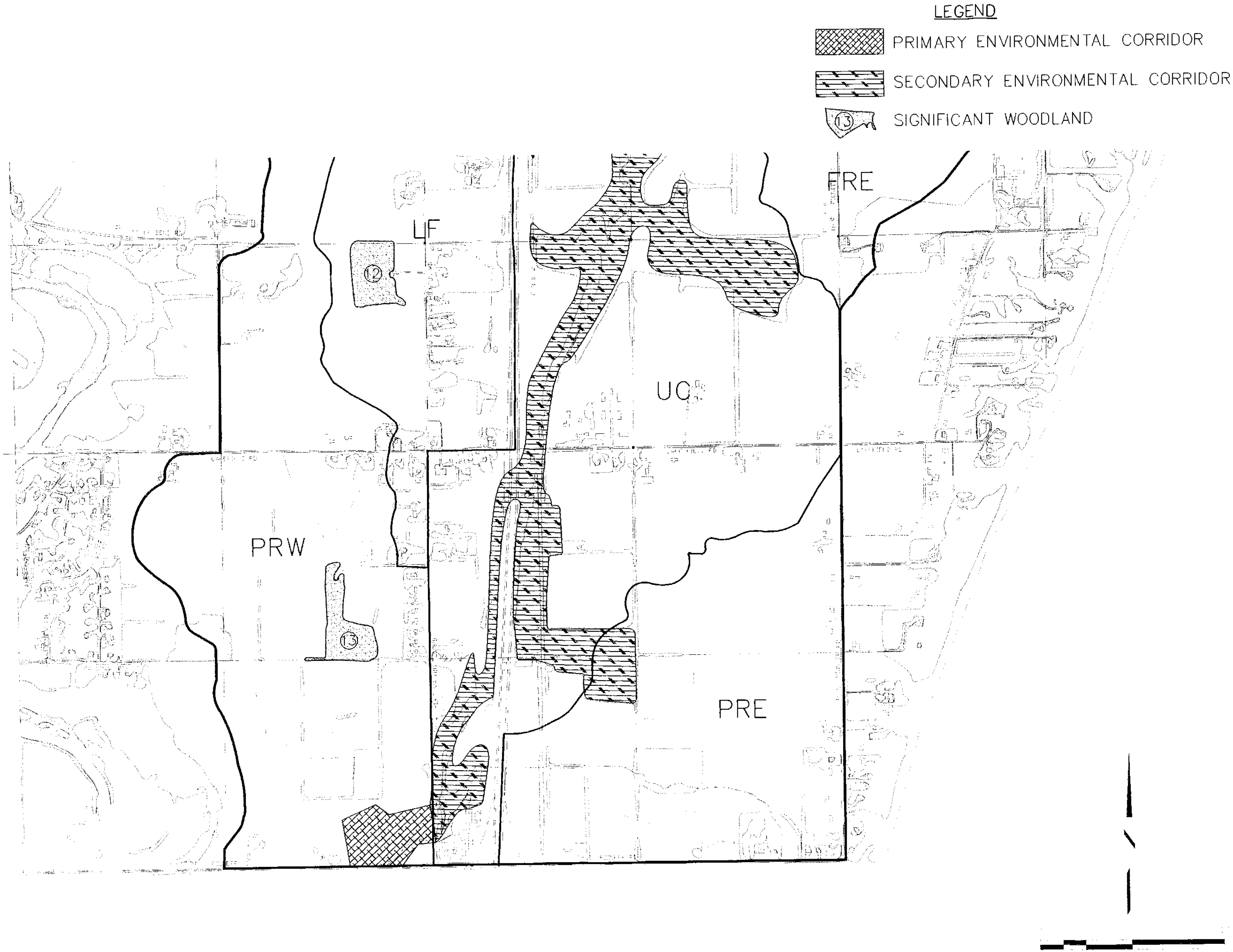
TOWN OF GRAFTON

OZAUKEE COUNTY, WISCONSIN

Bonestroo Rosene Anderlik & Associates

Engineers & Architects

St. Paul, Minnesota
Mequon, Wisconsin



MAP 15- ENVIRONMENTAL CORRIDOR - SOUTH

ULAO STORMWATER MANAGEMENT PLAN

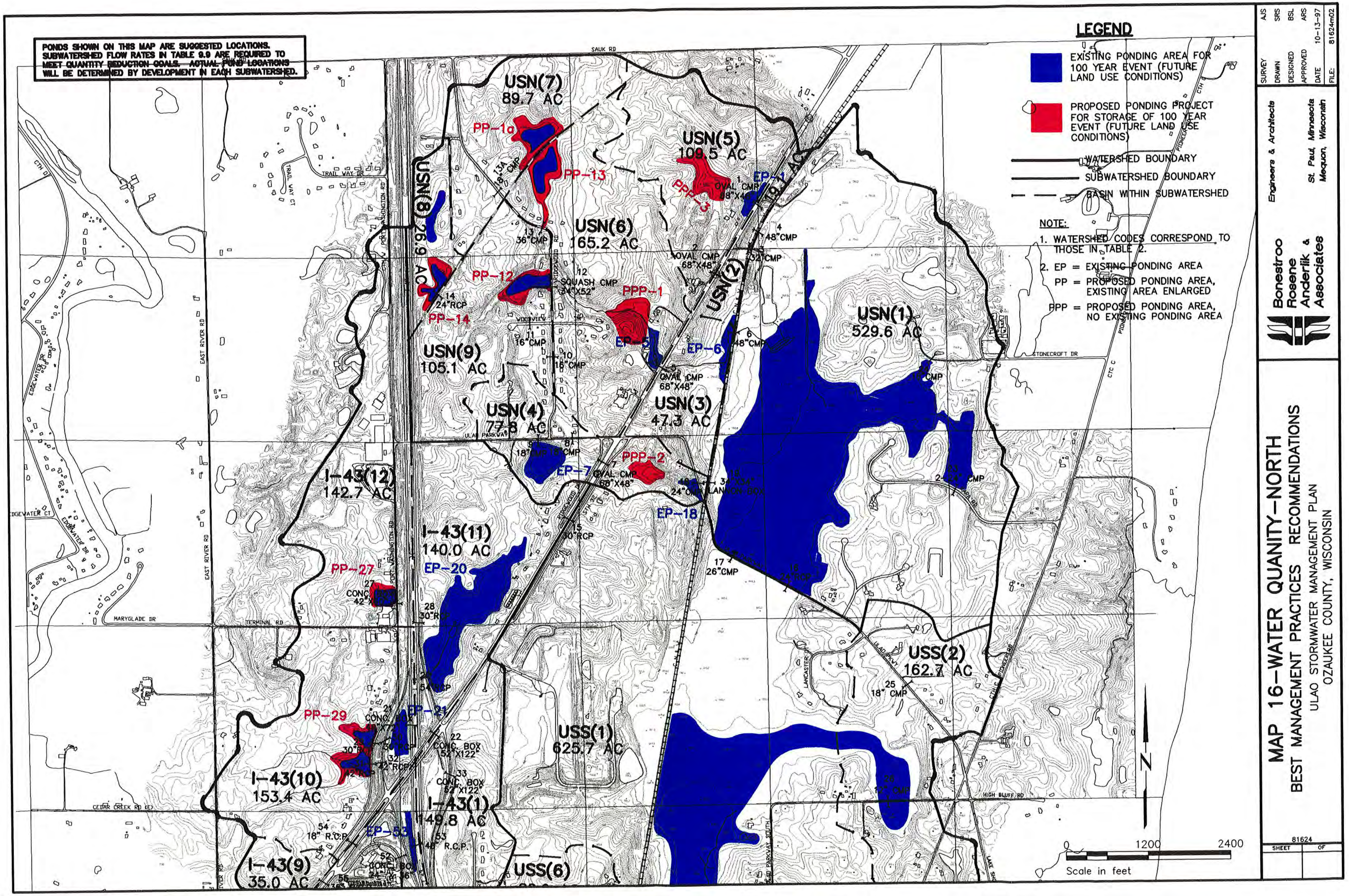
TOWN OF GRAFTON

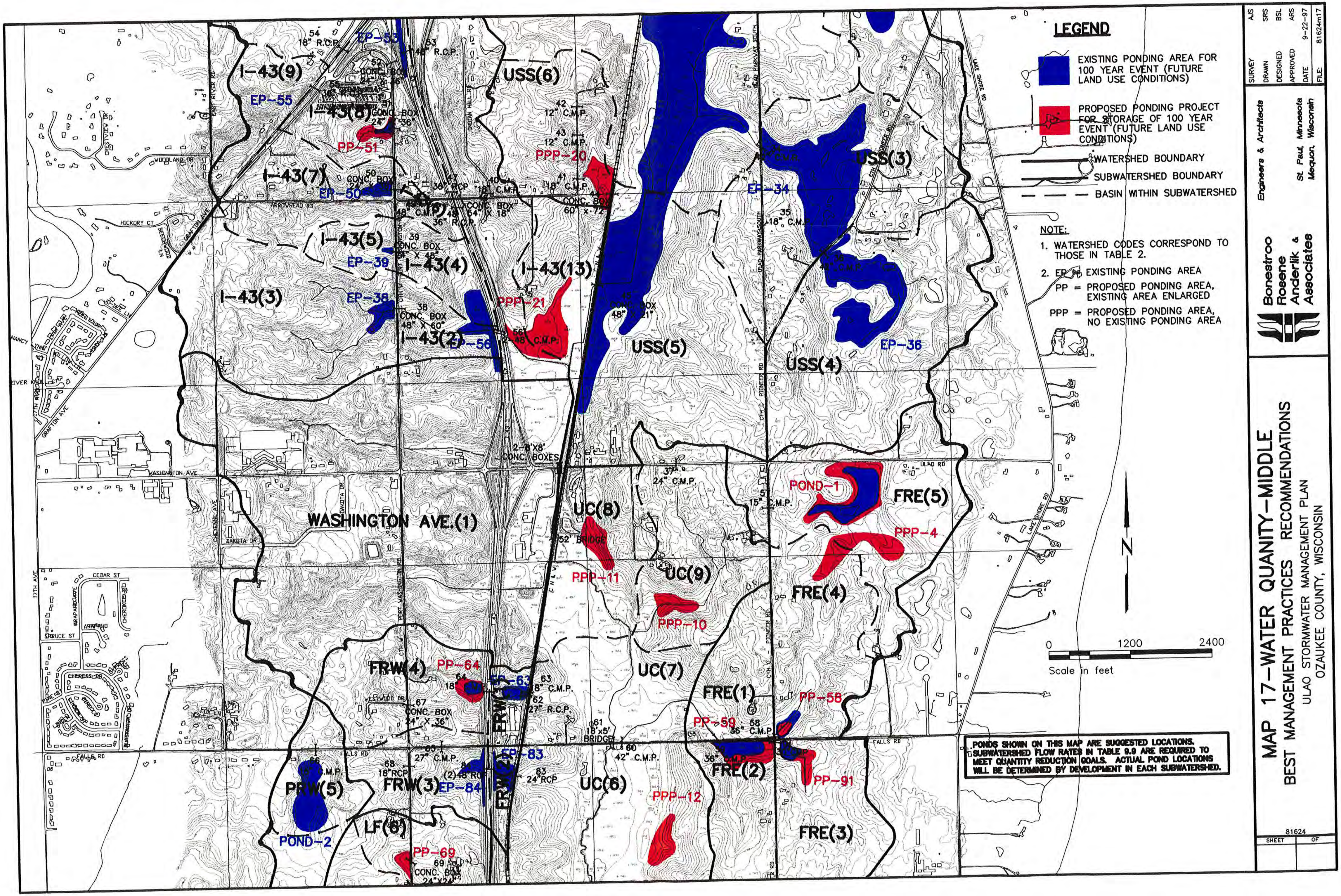
OZAUKEE COUNTY, WISCONSIN

Bonestroo Rosene Anderlik & Associates

Engineers & Architects

St. Paul, Minnesota
Mequon, Wisconsin

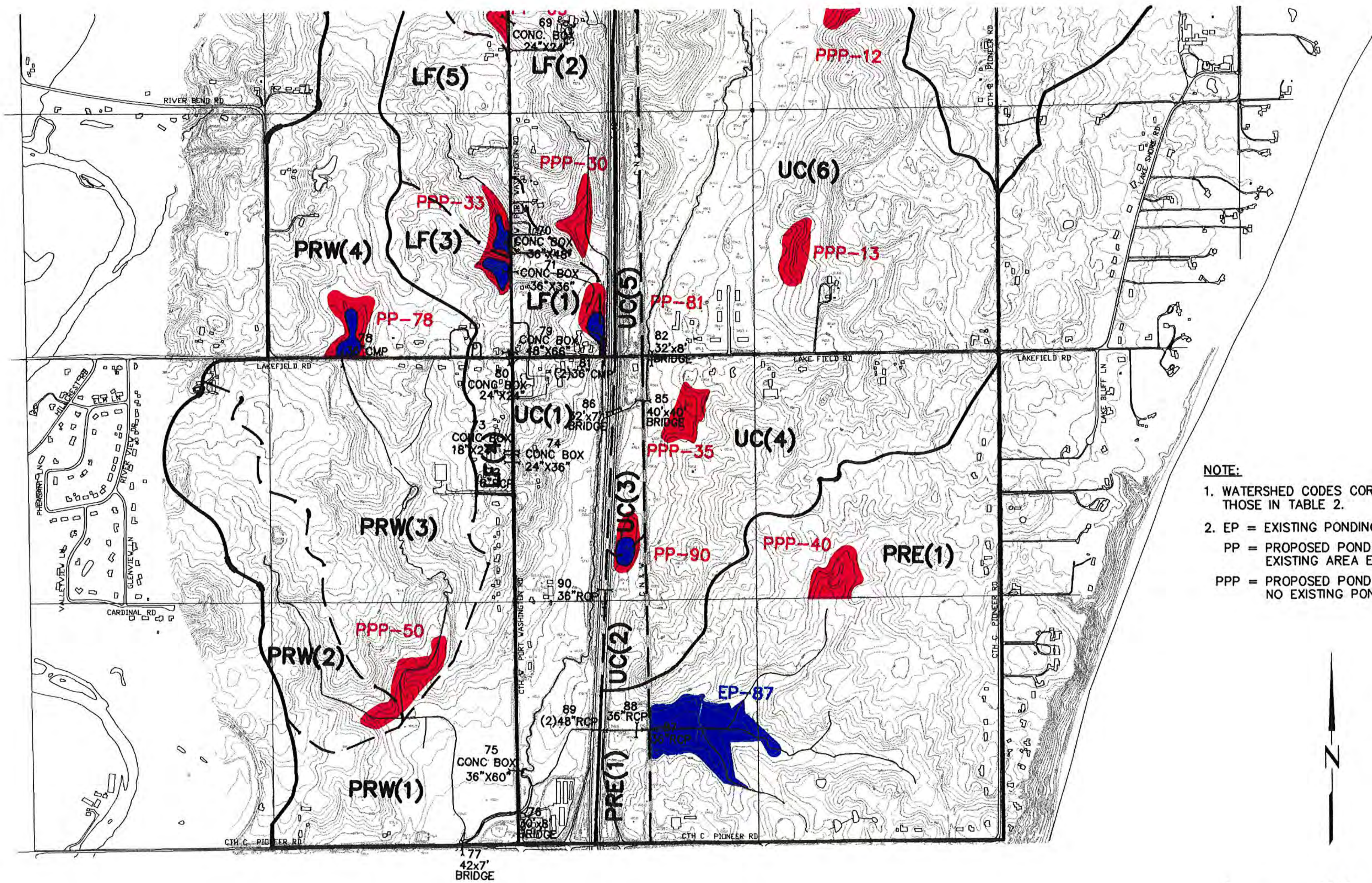

PONDS SHOWN ON THIS MAP ARE SUGGESTED LOCATIONS. SUBWATERSHED FLOW RATES IN TABLE 9.9 ARE REQUIRED TO MEET QUANTITY REDUCTION GOALS. ACTUAL POND LOCATIONS WILL BE DETERMINED BY DEVELOPMENT IN EACH SUBWATERSHED.
LEGEND
EXISTING PONDING AREA FOR 100 YEAR EVENT (FUTURE LAND USE CONDITIONS)
PROPOSED PONDING PROJECT FOR STORAGE OF 100 YEAR EVENT (FUTURE LAND USE CONDITIONS)
WATERSHED BOUNDARY
SUBWATERSHED BOUNDARY
BASIN WITHIN SUBWATERSHED
NOTE:
1. WATERSHED CODES CORRESPOND TO THOSE IN TABLE 2.
2. EP = EXISTING PONDING AREA
PP = PROPOSED PONDING AREA, EXISTING AREA ENLARGED
PPP = PROPOSED PONDING AREA, NO EXISTING PONDING AREA
USN(7) 89.7 AC
USN(5) 109.5 AC
USN(6) 165.2 AC
USN(8) 76.9 AC
USN(2) 19.1 AC
USN(1) 529.6 AC
USN(9) 105.1 AC
USN(4) 77.8 AC
USN(3) 47.3 AC
I-43(12) 142.7 AC
I-43(11) 140.0 AC
I-43(10) 153.4 AC
I-43(1) 149.8 AC
I-43(9) 35.0 AC
USS(1) 625.7 AC
USS(2) 162.7 AC
USS(6)
PP-1a
PP-13
PP-3
PP-12
PP-14
PPP-1
PPP-2
PP-27
PP-29
EP-1
EP-5
EP-6
EP-7
EP-18
EP-20
EP-21
EP-53
SAUK RD
TRAIL WAY DR
TRAIL WAY CT
EDGEWATER DR
EDGEWATER CT
EAST RIVER RD
MARYGLADE DR
TERMINAL RD
CEDAR CREEK RD (E)
ULAO PARKWAY
STONECROFT DR
HIGH BLUFF RD
LANCASTER
0 1200 2400
Scale in feet
N
MAP 16-WATER QUANITY-NORTH
BEST MANAGEMENT PRACTICES RECOMMENDATIONS
ULAO STORMWATER MANAGEMENT PLAN
OZAUKEE COUNTY, WISCONSIN
Bonestroo Rosene Anderlik & Associates
Engineers & Architects
St. Paul, Minnesota
Mequon, Wisconsin
SURVEY AJS
DRAWN SRS
DESIGNED BSL
APPROVED ARS
DATE 10-13-97
FILE: 81624m02
SHEET 81624 OF


LEGEND
EXISTING PONDING AREA FOR 100 YEAR EVENT (FUTURE LAND USE CONDITIONS)
PROPOSED PONDING PROJECT FOR STORAGE OF 100 YEAR EVENT (FUTURE LAND USE CONDITIONS)
WATERSHED BOUNDARY
SUBWATERSHED BOUNDARY
BASIN WITHIN SUBWATERSHED
NOTE:
1. WATERSHED CODES CORRESPOND TO THOSE IN TABLE 2.
2. EP = EXISTING PONDING AREA
PP = PROPOSED PONDING AREA, EXISTING AREA ENLARGED
PPP = PROPOSED PONDING AREA, NO EXISTING PONDING AREA
0 1200 2400
Scale in feet
PONDS SHOWN ON THIS MAP ARE SUGGESTED LOCATIONS. SUBWATERSHED FLOW RATES IN TABLE 9.9 ARE REQUIRED TO MEET QUANTITY REDUCTION GOALS. ACTUAL POND LOCATIONS WILL BE DETERMINED BY DEVELOPMENT IN EACH SUBWATERSHED.
MAP 17–WATER QUANITY–MIDDLE
BEST MANAGEMENT PRACTICES RECOMMENDATIONS
ULAO STORMWATER MANAGEMENT PLAN
OZAUKEE COUNTY, WISCONSIN
Bonestroo Rosene Anderlik & Associates
Engineers & Architects
St. Paul, Minnesota
Mequon, Wisconsin
SURVEY AJS
DRAWN SRS
DESIGNED BSL
APPROVED ARS
DATE 9-22-97
FILE: 81624m17
81624
SHEET OF
I-43(9)
I-43(8)
I-43(7)
I-43(5)
I-43(4)
I-43(3)
I-43(2)
I-43(13)
USS(6)
USS(5)
USS(4)
USS(3)
WASHINGTON AVE.(1)
UC(8)
UC(9)
UC(7)
UC(6)
FRE(5)
FRE(4)
FRE(1)
FRE(2)
FRE(3)
FRW(4)
FRW(3)
PRW(5)
LF(6)
EP-53
EP-55
EP-50
EP-39
EP-38
EP-56
EP-34
EP-36
EP-63
EP-83
EP-84
PP-51
PPP-20
PPP-21
POND-1
PPP-4
PPP-11
PPP-10
PP-64
PP-58
PP-59
PP-91
PPP-12
POND-2
PP-69
WASHINGTON AVE
ULAO RD
FALLS RD
LAKE SHORE RD
PIONEER RD
CEDAR ST
SPRUCE ST
HICKORY CT
WOODLAND DR
ARROWHEAD RD
GRAFTON AVE
2-8'X8' CONC. BOXES
52' BRIDGE

PONDS SHOWN ON THIS MAP ARE SUGGESTED LOCATIONS. SUBWATERSHED FLOW RATES IN TABLE 9.9 ARE REQUIRED TO MEET QUANTITY REDUCTION GOALS. ACTUAL POND LOCATIONS WILL BE DETERMINED BY DEVELOPMENT IN EACH SUBWATERSHED.

LEGEND

- EXISTING PONDING AREA FOR 100 YEAR EVENT (FUTURE LAND USE CONDITIONS)
- PROPOSED PONDING PROJECT FOR STORAGE OF 100 YEAR EVENT (FUTURE LAND USE CONDITIONS)
- WATERSHED BOUNDARY
- SUBWATERSHED BOUNDARY
- BASIN WITHIN SUBWATERSHED



NOTE:

1. WATERSHED CODES CORRESPOND TO THOSE IN TABLE 2.
2. EP = EXISTING PONDING AREA

   PP = PROPOSED PONDING AREA, EXISTING AREA ENLARGED

   PPP = PROPOSED PONDING AREA, NO EXISTING PONDING AREA

0 1200 2400

Scale in feet

SURVEY	AJS
DRAWN	SRS
DESIGNED	BSL
APPROVED	ARS
DATE	9-22-97
FILE:	81624m18

Engineers & Architects

St. Paul, Minnesota
Mequon, Wisconsin

Bonestroo Rosene Anderlik & Associates

MAP 18 - WATER QUANITY - SOUTH

BEST MANAGEMENT PRACTICES RECOMMENDATIONS

ULAO STORMWATER MANAGEMENT PLAN

OZAUKEE COUNTY, WISCONSIN

81624

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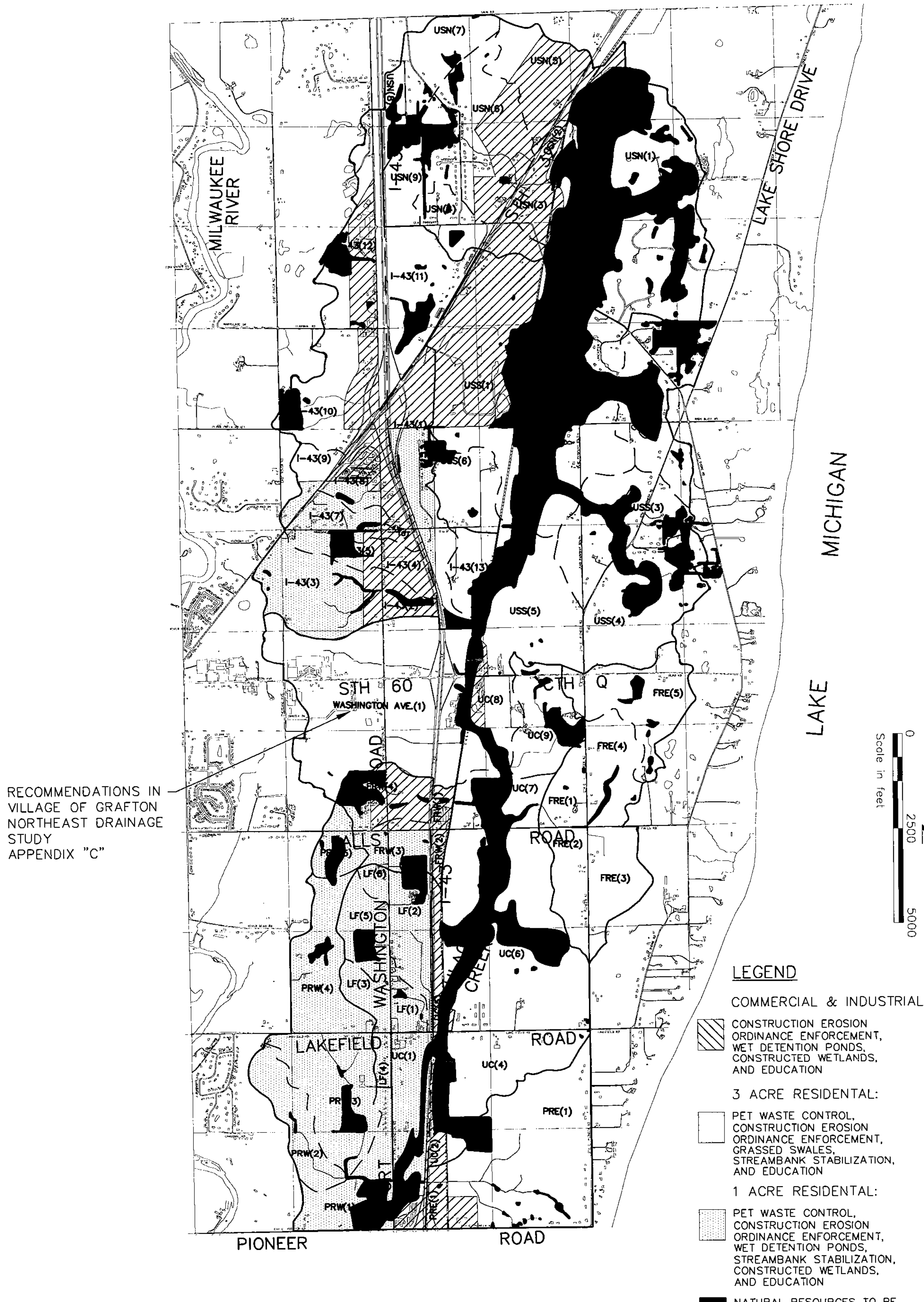


MAP 19 – ULAO CREEK WATER QUALITY

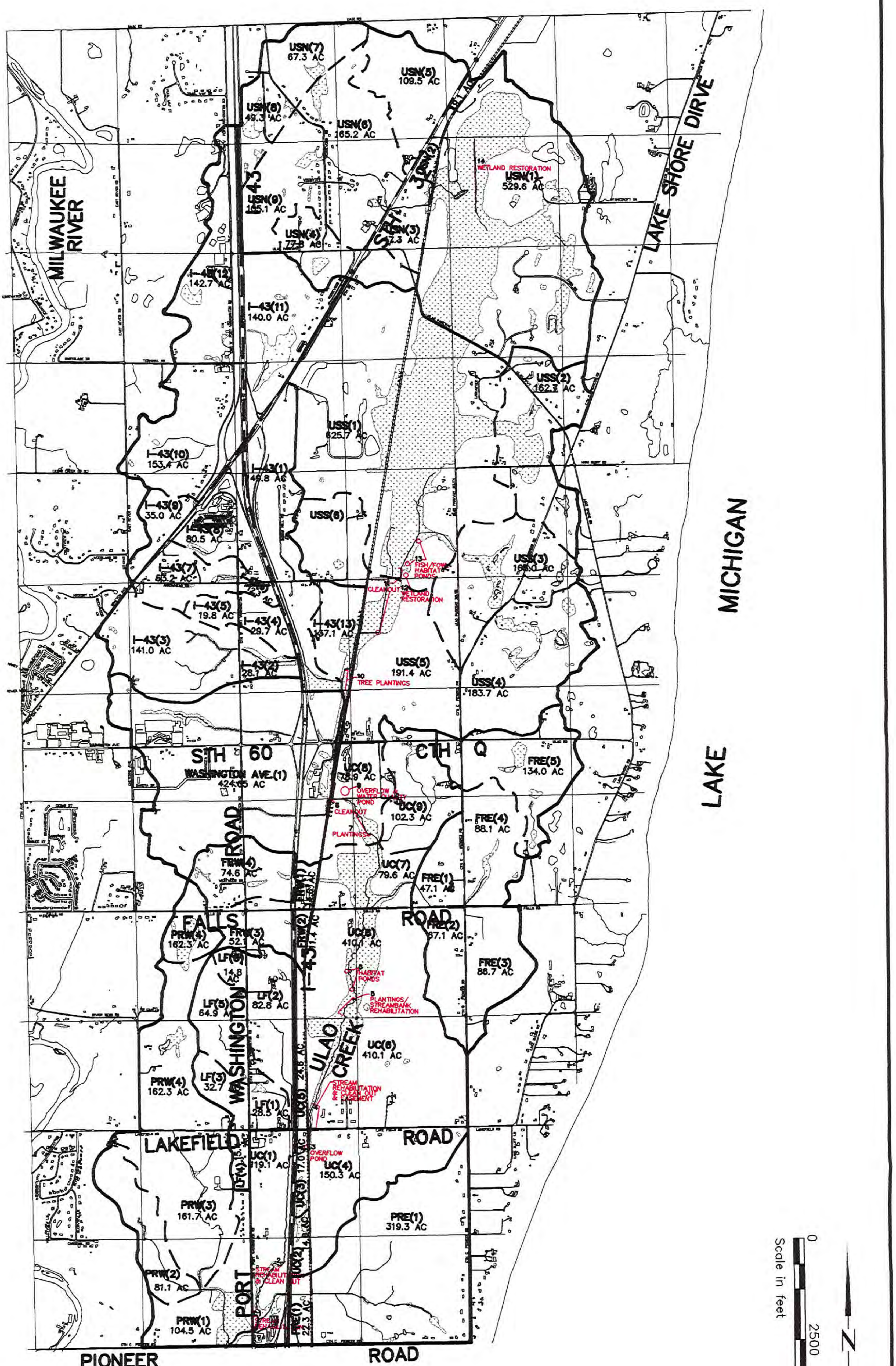
BEST MANAGEMENT PRACTICES RECOMMENDATIONS

TOWN OF GRAFTON
OZAUKEE COUNTY, WISCONSIN

SHEET 81624 OF

Bonestroo Rosene Anderlik & Associates
Engineers & Architects
St. Paul, Minnesota
Mequon, Wisconsin

SURVEY	AJS
DRAWN	SRS
DESIGNED	BSL
APPROVED	ARS
DATE	10-13-97
FILE:	81624m19



MAP 20 – ULAO CREEK CORRIDOR

BEST MANAGEMENT PRACTICES RECOMMENDATIONS

TOWN OF GRAFTON
OZAUKEE COUNTY, WISCONSIN

Bonestroo Rosene Anderlik & Associates

Engineers & Architects

St. Paul, Minnesota
Mequon, Wisconsin

SURVEY	AJS
DRAWN	SRS
DESIGNED	BSL
APPROVED	ARS
DATE	10-13-97
FILE:	81624m20

SHEET 81624 OF

APPENDIX C

HYDROGEOLOGY OF THE ULAO CREEK WATERSHED

GRAFTON, WISCONSIN

October 30, 1997
(Revised March 23, 1998)

Northern Environmental[SM]
Hydrologists • Engineers • Geologists

1214 West Venture Court
Mequon, WI 53092
Fax 1-414-241-8222
1-414-241-3133
1-800-776-7140

HYDROGEOLOGY OF THE ULAO CREEK WATERSHED GRAFTON, WISCONSIN

October 30, 1997
(Revised March 23, 1998)

Prepared For:

The Ulao Creek Partnership
Post Office Box 994
Port Washington, Wisconsin 53074

Prepared By:

Northern Environmental Technologies, Incorporated
1214 West Venture Court
Mequon, Wisconsin 53092

Project Number: BRA141725

Dale J. Buser, PE, CGWP
Principal Hydrogeologist

DJB/lmh

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PLATES

Northern Environmental℠
Hydrologists • Engineers • Geologists

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Mequon, WI 53092
Fax 1-414-241-8222
1-414-241-3133
1-800-776-7140

1.0 EXECUTIVE SUMMARY

Ulao Creek drains approximately 16 square miles of southeastern Ozaukee County, Wisconsin. This area is immediately north of Milwaukee, and is poised for rapid urbanization. During late 1996, a study was initiated by a coalition of public agencies, local government, and concerned citizens (the Ulao Creek Partnership) to help protect and enhance natural resources of the Ulao Creek Watershed. The Town of Grafton commissioned Northern Environmental Technologies, Incorporated (Northern Environmental) and Bonestroo and Associates, to complete a storm-water management plan in the portion of the Ulao Creek Watershed in the Town and Village of Grafton (the Watershed).an important component of the study was stabilization of the creek's highly variable flow. Preliminary study revealed that ground-water resources could help this effort. Therefore, published information and a limited amount of newly collected data were gathered and closely examined to characterize ground-water/surface-water interactions in the Watershed.

The Watershed is underlain by complexly interlayered fine-grained and coarse-grained unconsolidated sediments. The unconsolidated deposits are composed primarily of till, lacustrine sediments, and fluvial sediments deposited by glacial action approximately 12,000 to 16,000 years ago. Relatively thin veneers of post-glacial alluvium and organic deposits are found along major water courses and wetlands. Small deposits of pre-glacial sediment may also fill some bedrock valleys. In general, the unconsolidated sediments are finer grained and thicker near Lake Michigan. Many areas northwest of State Highway 32/County Highway V are underlain by substantial thicknesses of sand and gravel. Glacial sediments rest unconformably upon Devonian-age dolomite and shaly dolomite in the southeastern half of the Watershed, and upon Silurian-age dolomite in the northwestern part of the Watershed. A regionally-recognized fault crosses the Watershed with approximately 80 feet of relief expressed in bedrock underlying the Watershed. Bedrock surface topography is quite irregular, with prominent bedrock valleys and ridges found in some areas, particularly in the northern half of the Watershed near the fault.

The various material properties, topographic relationships, and unique structural features create areas which are decidedly more conducive to ground-water flow. In the northern reaches of the Watershed, sand-and-gravel layers hydraulically connect the Milwaukee River to the Ulao Swamp. In these areas, water can flow from the Milwaukee River to the Ulao Swamp. Farther south, these sand-and-gravel deposits also extend to Lake Michigan, but are largely segregated by a clay layer from Ulao Creek. Here, ground water probably still discharges to the creek, but with less vigor. Between Ulao Road and somewhere south of Falls Road, the potentiometric head in the Dolomite Aquifer and interconnected portions of the sand and gravel is below the elevation of water in Ulao Creek. In these areas, the creek probably loses a portion of its flow to deeper strata which in turn discharge to Lake Michigan.

Data collected as part of this study revealed the following important surface-water/ground-water relationships. Ground water discharges to the surface in several areas. Important ground-water discharge areas include:

Milwaukee • St. Paul • Green Bay

- The western flank of the Ulao Swamp, particularly north of Ulao Parkway.
- The wetland and intermittent stream paralleling Interstate 43 north of Ulao Road.
- Small areas adjacent to Ulao Creek near the intersection of County Trunk Highways W and C.

In other areas, surface-water features lose flow to ground water. Such features include:

- Various stretches of the Milwaukee River, especially those upstream of dams and north of the Village of Grafton.
- Eastern portions of the Ulao Swamp.
- Northern-most portions of the Ulao Swamp.
- Ulao Creek between Ulao Road and Falls Road.

Ground-water/surface-water interactions can be used to reduce storm-water runoff and support dry-weather baseflow. The techniques and modifications needed to implement these possibilities complement traditional storm-water management options. Northern Environmental recommends that the Ulao Creek Partnership follow a phased approach to increase dry-weather baseflow and decrease storm-water runoff volume.

Primary attention should be given to options which minimize dry-weather loss of stream flow to ground water. Specific management options include attenuating the effect of gravel mining and agricultural drainage at the extreme north end of the Ulao Swamp, decreasing dry-weather infiltration under eastern portions of the Ulao Swamp, and assuring that newly constructed stream channel modifications, wetlands, and ponds are designed to prevent surface-water backflow and infiltrations during dry weather.

In addition to preventing dry-weather loss of surface flow, attention should immediately be given to alternatives which detain flood water or transfer it out of the Watershed. Detained storm water will be released slowly to the creek. Options to detain storm water include storage in granular deposits paralleling Ulao Creek, modifying agricultural drainage tile and ditch systems to promote temporary storage in low areas, and infiltrating water in uplands west of Ulao Creek. Water can be transferred from the Watershed by maximizing storm-water infiltration under areas east of Ulao Creek and the Ulao Swamp, and encouraging infiltration in the Ulao Creek floodplain between Ulao Road and Falls Road.

After management options which decrease dry-weather water losses from the creek and detain storm water for slow release are implemented, the quantity and quality of water in Ulao Creek should be re-evaluated. If insufficient water is available during dry periods to reach management objectives, artesian ground water could be used to supplement Ulao Creek's flow. Most supplemental water is available in the western half of the wetlands north of Ulao Road. Wells, intercepter trenches, and/or discharging ponds/wetlands could be developed to promote ground-water discharge.

2.0 INTRODUCTION AND STUDY GOALS

Ulao Creek drains approximately 16 square miles in southeastern Ozaukee County, Wisconsin. Its drainage basin covers most of the Town of Grafton and the northeastern portion of the City of Mequon (Figure 1). During November 1996, the Ozaukee County Land Conservation Department (the LCD) solicited proposals to complete a storm-water management plan for the Ulao Creek Watershed. The LCD served as lead coordinating agency for a cooperative group composed of Ozaukee County, the Town of Grafton, the Village of Grafton, the Wisconsin Department of Natural Resources (WDNR), the City of Mequon, and the Ulao Creek Partnership. The Ulao Creek Partnership is an alliance of concerned citizens, landowners, and public and private organizations who wish to protect and enhance water quality and natural habitat in the Ulao Creek Watershed. The request for proposal listed the following as the group's primary objectives.

- Reduce flood risks and damages
- Preserve and improve water quality
- Reduce erosion, sedimentation, and pollution from surface runoff
- Assess existing and forecast future pollutant loadings and water quality
- Enable municipal staff to specify best management practices
- Protect and enhance fish and wildlife habitat
- Prescribe preventative measures and retrofit existing drainage facilities to help improve water quality and reduce flooding
- Promote and improve ground-water recharge
- Enhance the natural beauty of the watershed and the quality of primary and secondary environmental corridors, including floodplains, woodlands, wetlands, wildlife and aquatic life habitat, and agricultural lands
- Assess existing and forecast future water quality flows on main stem

After Northern Environmental Technologies, Incorporated (Northern Environmental) completed preliminary data review and project scoping work, it became apparent that ground water could possibly be used to stabilize stream-flow volumes and enhance water quality. Preliminary analyses suggested that significant volumes of surface-water runoff could possibly be stored in granular sediments along the upper and middle reaches of Ulao Creek. Additionally, artesian ground-water conditions likely occur near the Ulao Swamp. Stored flood water and artesian ground water could potentially be used to augment Ulao Creek's meager dry-weather flow.

To determine if groundwater-related issues could help achieve project goals, Northern Environmental, in affiliation with Bonestroo and Associates (Bonestroo), proposed a study covering the portion of the Ulao Creek Watershed in the Village and Town of Grafton (the Watershed). The proposed study would examine existing information to develop a working hypothesis of the study area's geology and ground-water hydrology.

This report explains how we conducted research, presents the study findings using text and relevant illustrations, develops conclusions, and uses these conclusions to develop an appropriate action plan.

3.0 PROJECT METHODOLOGIES

3.1 Data Collection

To identify ground-water's historical, current, and potential influence on the flow characteristics of Ulao Creek, the Watershed's hydrogeology was studied in detail. Technical or unusual terms needed to describe the Watershed's hydrogeology are defined in Appendix A. The first step of this study was locating relevant documents and individuals intimately familiar with the Watershed's conditions and history. Pertinent references are cited in Section 9.0 of the report. By closely examining data sources, the following information was garnered.

- The physical properties, lateral extent, thickness, and genesis of various unconsolidated sediments
- The water-bearing characteristics of the upper portions of the bedrock and unconsolidated deposits
- The historical and present locations of springs and seasonally intermittent stretches of Ulao Creek
- The location and effect of areas where surface water and ground water interact
- Depth to ground water
- Ground-water quality
- Surface topography

A regional working hypothesis of the lithology, stratigraphy, and hydraulic properties of unconsolidated sediments and upper bedrock layers was developed by consulting other studies completed in southeastern Wisconsin. Next, Watershed-specific data were closely examined to evaluate the validity of the regional model. Of particular importance to the effort were well constructor reports, state geologic logs, and hydrogeologic data from the Wisconsin Electric Power Company (WEPCO) Highway 32 Ash Landfill site (the Ash Landfill). Even though well constructor reports contain relatively little data, they are available throughout the Watershed. Information from these logs was extracted and tabulated (Appendix B). Most of the over 280 well locations were field verified and plotted on available topographic contour maps. The topographic contour maps were then consulted to determine wellhead elevation in reference to mean sea level datum.

State geologic logs and Ash Landfill data are somewhat detailed. Moreover, the Ash Landfill data cover an area of complex geology. These detailed site-specific data helped allow the general descriptions of the well constructor reports to be substantiated and correlated with more reliable geotechnical interpretations.

3.2 Ground-Water Elevation

Ground-water elevations were derived from four sources:

- Direct measurements at the Ash Landfill
- Regional studies (e.g., Young and Batten, 1980; Skinner and Borman, 1973)
- Well constructor logs
- Certain surface-water features illustrated on topographic contour maps

Of these data sources, well constructors' data were the only source available throughout the Watershed. Unfortunately, it is also the source with the lowest accuracy. Consequently, the ground-water elevations derived from the source were individually judged for credibility, and were supplemented wherever possible by data from the other three data sources. Nevertheless, the water-level contours should only be considered accurate within 5 to 10 feet, and can only be related to potentiometric elevations in the Niagara and Sand-and-Gravel Aquifers. Other localized perched water tables exist throughout the Watershed at shallow depths. However, these perched water tables typically are not laterally extensive and do not contribute significantly to the volume of lateral ground-water flow.

3.3 Ground-Water Flowpath Evaluation

Stratigraphic relationships identified from Watershed-specific data were compared to the regional working hypothesis. Using these data jointly, the lateral extent, thickness, and hydraulic properties of the various stratigraphic units were estimated and plotted.

To evaluate geology's influence on local ground-water flow, the properties of lithostratigraphic units which could significantly influence surface-water/ground-water interaction within the Watershed were examined. The estimated hydraulic conductivity and thickness of each unit can allow the equivalent vertical and horizontal hydraulic conductivities to be calculated. To simplify the process, units were divided into the following seven hydrostratigraphic units.

- Weathered dolomite bedrock
- Dolomite bedrock (mudstone facies)
- Dolomite bedrock (grainstone - packstone facies)
- Clayey till
- Sandy till
- Lacustrine sediments
- Alluvium and outwash

Although rocks of two different formations underlie glacial sediments in the Watershed, literature reports that they have comparable hydraulic properties (Rovey, 1990). Therefore, no effort was made to differentiate the hydraulic properties of Silurian-age rock from Devonian-age rock. Nevertheless, Rovey also reports that weathering and varying depositional environments near the Waukesha Fault profoundly alter the hydraulic properties of the uppermost bedrock.

To evaluate hydraulic properties of shallow bedrock and the Sand-and-Gravel Aquifer, specific capacity from residential well constructor logs was used to estimate hydraulic conductivity using the following empirical relationship (Driscoll, 1986).

$$Q = \frac{Kbs}{1800}$$

where

Q	=	well yield in gallons per minute
s	=	well drawdown in feet
K	=	hydraulic conductivity in feet per day
b	=	aquifer thickness in feet (which was assumed to equal the well's completion interval to simplify computation)
1800	=	a constant (assumes a semi-confined aquifer)

Hydraulic conductivities were computed for all wells, and were converted to commonly used metric equivalents (centimeter per second [cm/sec]). The resultant values are listed in Appendix B.

Recent studies report that various stratigraphic layers in the bedrock have dramatically differing hydraulic properties. The uppermost 20 feet of bedrock reportedly has universally higher hydraulic conductivity values (Rovey, 1990). Therefore, the geometric mean of the hydraulic conductivities from shallow wells completed exclusively in the uppermost 20 feet of bedrock were used to assign a watershed-specific hydraulic conductivity for the weathered bedrock underlying the Watershed. The Racine dolomite reportedly undergoes a facies change in the Watershed. Therefore, hydraulic conductivity values from wells completed in the Lake Church Formation and Racine Formation dolomite were contoured to study variations in hydraulic properties. The efforts yield the following Watershed-specific average values.

Weathered dolomite	$2x10^{-3}$ cm/sec
Lake Church/Racine Formation Dolomite (Mudstone Facies)	$1x10^{-4}$ cm/sec
Lake Church/Racine Formation Dolomite (Grainstone-Packstone Facies)	$3x10^{-4}$ cm/sec

Although the hydraulic conductivity of the rock layers is probably greater in the horizontal plane compared to the vertical plane, insufficient data were available to evaluate this difference. The above values likely represent horizontal hydraulic conductivity values.

To evaluate discharge/recharge relationships, the vertical gradient between an imaginary shallow surface-water body and the dolomite aquifer was calculated. Vertical gradient was calculated by comparing ground surface or water-body elevation with the potentiometric surface at a given point. The equivalent average vertical hydraulic conductivity for interlayered unconsolidated sediments was also computed to help evaluate specific discharge. The computed vertical gradients are listed in Appendix B.

3.4 Stream Gaging

The original workplan only included funds for collecting and examining published hydrogeologic data. However, as the project evolved, some components of the working hypothesis explaining ground-water flow could best be tested by directly measuring Ulao Creek's flow. If measured during an extended dry period, creek-flow data help confirm if ground water is discharging to the stream, or if the stream is losing water to ground water.

To measure dry-weather stream flow, Northern Environmental used two Baski Cutthroat Flumes with 4- and 8-inch throat widths. Accurate use of these flumes requires a moderately steep stream gradient, and a moderately deep, well-defined channel. The chosen flume sites were upstream of the Port Washington Road bridge (station F1), downstream of the Chicago and Northwestern Railway bridge (F2), upstream of the Falls Road bridge (F3), and several hundred feet upstream of the Ulao Road bridge (F4). The locations of these stations are illustrated in Figure 2.

Frequent heavy rain throughout much of the summer prevented collection of accurate measurements. Finally, during early September, 7 days passed without measurable precipitation. Therefore, stream flows were measured on September 6, 1997. Measurements were first taken at the station furthest downstream and proceeded north (upstream). Several measurements were collected to ensure that backwater conditions at each flume were stable. The resultant data are compiled in Table 1.

3.5 Agricultural Drain Tile Identification

The irregular topography and clayey soil of the Watershed cause many areas to be excessively wet or seasonally flooded. Consequently, many farms were tiled to improve productivity and accessibility. To evaluate the locations of the agricultural drain tiles, Mr. Steve Narveson of the Ozaukee County Department of Health was consulted. Mr. Narveson attempted to locate records of early drainage districts within the Watershed. Unfortunately, even though many records survive for other portions of Ozaukee County, none were found for areas within the Watershed.

After failing to locate drainage district records, Mr. Narveson explained that he carefully examines aerial photographs to speculate tile locations when other methods fail. Photographs are available through the Southeastern Wisconsin Regional Planning Commission (SEWRPC) and were taken during early Spring 1963, 1967, 1970, 1975, 1980, 1985, 1990, and 1995. Since the aerial photographs are taken in early spring, soils are usually wet, but thawed.

Mr. Narveson explained and demonstrated with examples the technique he uses to speculate the location of drain tiles. The drain tiles appear as lighter (drier) narrow lineations in otherwise dark (wet) fields. They are most visible in cultivated fields, but can also be seen in areas of sparse vegetative cover. Since photographs from multiple years are available, fields can be examined under a variety of moisture and crop conditions, increasing the possibility of detection. The tile lines typically follow dendritic patterns and often run perpendicular to topographic contour lines. Other surface disturbances (e.g., wheel marks) usually do not consistently follow these patterns. The speculated locations of drain tiles visible using this method were highlighted, and probable tiled fields were plotted on available maps.

4.0 LOCAL PHYSIOGRAPHY

Ulao Creek drains an elongated oval-shaped watershed covering approximately 16 square miles in the Town of Grafton, the Village of Grafton, and the City of Mequon, Wisconsin (Figure 1). In the Town of Grafton, the Watershed averages approximately 1½ to 2 miles wide (east to west), and is 6 miles long (north to south). In most areas, the eastern limit of the Watershed is less than half a mile inland from Lake Michigan.

The main stem of Ulao Creek occupies a flat-bottomed, oftentimes swampy valley near the center of the Watershed. Prominent rolling uplands flank the valley. The topography of these uplands is quite irregular in some areas, yielding closed depressions, permanent and intermittent wetlands, and a few vernal ponds. No major natural lakes occur within the Watershed. Even though many small streams are tributary to Ulao Creek, few flow perennially.

Most land in the Watershed is used for agricultural purposes. Wetlands cover 769 acres of the Watershed, with the Ulao Swamp, at the headwater of Ulao Creek, comprising approximately 52 percent of the total. Although many residences are within the Watershed, the homes have fairly large lots which yield a relatively low population density. A comparatively high percentage of land is used for transportation. A railway and an interstate expressway bisect the Watershed on a north-south axis. Commercial and industrial land uses are very limited in extent and are concentrated at the intersections of major highways. The Watershed will likely rapidly urbanize since it is less than 20 miles north of Milwaukee, Wisconsin and is situated near convenient transportation corridors.

5.0 GEOLOGY

The goal of this study is to evaluate if the Watershed's ground-water resources could help stabilize Ulao Creek's flow. To evaluate this possibility, ground-water flowpaths must be identified, which necessitate a thorough comprehension of the study area's geology. By using available reports, articles, data, and unpublished literature, sufficient data were assembled to characterize the lithology, stratigraphy, and hydraulic properties of the sediments important to this study. The findings of this effort are described in this section.

5.1 Bedrock

5.1.1 Regional Lithology and Stratigraphy

Up to 2000 feet of Paleozoic-age sedimentary rock overlies Precambrian-age crystalline rocks in Ozaukee County. The material properties of these rocks are used to differentiate the various strata and assign formation names. These formations are grouped into two major hydrostratigraphic units: the deep Sandstone Aquifer and the shallow Niagara/Glacial Aquifer. These aquifers are separated by a thick shale aquitard and are not in good hydraulic connection. Since the Ulao Creek Watershed is situated in an area where the shale aquitard is thick, the Sandstone Aquifer probably does not have a significant influence on the hydrology of the Watershed. Consequently, only the strata forming the Niagara/Glacial Aquifer were studied in detail.

5.1.1.1 Silurian-Age Rocks

The uppermost bedrock under most of southeastern Wisconsin is composed of Silurian-age dolomite. In parts of Washington, Waukesha, and Walworth Counties, the Silurian-age dolomite has been removed by erosion, leaving Ordovician-age shales, dolomites, and sandstones as the uppermost bedrock units. In southeastern Wisconsin, all sedimentary rock units dip to the east.

The Silurian-age dolomite is generally subdivided into five units in southeastern Wisconsin. These units are listed below in descending order.

- Waubakee Formation
- Racine Formation
- Manistique Formation
- Byron Formation
- Mayville Formation

Waubakee Formation dolomite is exposed in and near the Milwaukee River near Fredonia and Milwaukee. The Waubakee Formation is known to underlie glacial sediments under north-central Milwaukee, and central and northwestern Ozaukee Counties. These occurrences are not believed to be contiguous (Rovey, 1990). The

Waubakee dolomite is described as a dense brittle dolomite with alternating light gray and dark gray laminations, emitting a strong petroleum-like odor when freshly broken (Mikulic and Kluessendorf, 1988).

The Racine dolomite is the uppermost bedrock unit under much of southeastern Wisconsin. It is typically composed of an upper undifferentiated sequence of non-porous dolomitic mudstone and a basal granular dolomitic packstone. The basal packstone is referred to as the Romeo Member, and is usually quite porous. Both units are found throughout eastern Wisconsin, with a known combined thickness ranging between 60 and 350 feet. Near the Waukesha Fault, the undifferentiated upper Racine becomes more granular and more porous. The Romeo Member also undergoes a facies change north of the Waukesha Fault, becoming finer grained and indistinguishable from the upper portions of the Racine Formation. Both the Racine Formation and the Romeo Member reach their maximum thickness near the Waukesha Fault (Rovey, 1990).

The Manistique Formation is composed of three members: the Waukesha, Brandon Bridge, and Franklin Quarry Members. The Manistique Formation is generally described as a gray, thinly-bedded dolomitic mudstone. The Brandon Bridge Member can exhibit reddish and greenish hues. The Manistique Formation's thickness is conjectured, but is speculated to range from 50 to 160 feet, with the thickest accumulation immediately north of the Waukesha Fault. This formation also undergoes a facies change, becoming a coarser-textured packstone north of the Waukesha Fault. The coarser-textured facies extends north at least as far as Manitowoc County (Rovey, 1990).

The Byron Formation is an extremely hard, thick-bedded, nearly-white, fine-textured dolomitic mudstone. It is exposed along the Niagara Escarpment. The Byron Formation is less than 3 feet thick south of central Milwaukee County. The unit thickens northwest of the Waukesha Fault to a total thickness of over 50 feet. The Byron Formation does not undergo a facies change north of the fault (Rovey, 1990).

The Mayville Formation is described as thick-bedded dolomite composed of alternating mudstone and granular layers. The mudstone layers are more prevalent in Illinois. It has a fairly consistent thickness of 70 to 80 feet south of central Milwaukee County, thickening to around 200 feet to the north and west (Rovey, 1990).

5.1.1.2 Devonian-Age Rocks

Devonian-age shaly dolomite and dolomite underlie a narrow band along Lake Michigan from Milwaukee north to Sheboygan. Devonian-age rocks are subdivided into four formations. These formations are listed below in descending order.

- Antrim Formation
- Milwaukee Formation

- Thiensville Formation
- Lake Church Formation

The Antrim Shale (also locally known as the "Kenwood Shale") is only known to underlie an elliptically-shaped area north of downtown Milwaukee between Lake Park and the Milwaukee River. It consists of fissile black to gray silty mudstone with some brown, green, and blue-gray layers. Its maximum known thickness is approximately 50 feet. The Antrim Shale may underlie substantial portions of Lake Michigan (Mikulic and Kluessendorf, 1988).

The Milwaukee Formation underlies a narrow band adjacent to Lake Michigan from downtown Milwaukee to just north of the Milwaukee/Ozaukee County line. It does not extend more than 3½ miles west of Lake Michigan, except as an isolated outlier on the Milwaukee/Ozaukee County line. The Milwaukee Formation is comprised of three members. These members are listed below in descending order.

North Point Member, Milwaukee Formation

The North Point Member is not exposed at the surface in southeastern Wisconsin. This member is composed predominantly of dolomitic siltstone and is estimated to be approximately 50 feet thick.

Lindwurm Member, Milwaukee Formation

The Lindwurm Member is exposed at the surface near and under the Milwaukee River near Estabrook Park in Milwaukee. It is between 15 and 45 feet thick and grades upward from an argillaceous dolomite to a slightly dolomitic siltstone.

Berthelet Member, Milwaukee Formation

The Berthelet Member is the lowermost unit of the Milwaukee Formation, and is exposed at and near the Milwaukee River in Estabrook Park, Milwaukee. The Berthelet Member is composed of a few feet of very hard argillaceous dolomite underlain by shaly dolomite and dolomite. The Berthelet Member is approximately 20 feet thick.

The Thiensville Formation ranges from 50 to 75 feet thick and grades from shaly sediment near the base to purer dolomite at the top. Color ranges from white to light brown, with darker sediments emitting a petroleum-like odor when freshly broken. The Thiensville Formation is the uppermost bedrock in a narrow band paralleling the western margin of the Milwaukee Formation, beginning in downtown Milwaukee and extending north into southern Ozaukee County. At the Ozaukee/Milwaukee County line, the Thiensville Formation is the uppermost bedrock in much of a 4-mile wide band of Devonian-age rocks paralleling the Lake Michigan shoreline. An outlier of the Thiensville Formation was exposed in a roadcut along State Highway 57 approximately

2 miles north of Thiensville until Summer 1989. The Thiensville Formation is 52 feet thick north of the Village of Thiensville (Rovey, 1990).

The Lake Church Formation is approximately 35 feet thick and is subdivided into two members. The uppermost member is named the Ozaukee Member and is approximately 27 feet thick. The lower unit is named the Belgium Member and is approximately 8 feet thick (Roberts, 1972). In general the Lake Church Formation is characterized as a brown to gray dolomite, with scattered shale laminations. The Lake Church Formation is exposed at the surface at Harrington Beach State Park east of the Village of Belgium, along Sauk Creek just north of Port Washington, and as low outcrops along Lake Michigan. The Lake Church Formation thins to the south, pinching out near the Ozaukee/Milwaukee County line (Nelson, 1977). The Lake Church Formation is 42 feet thick near Harrington Beach State Park and 22 feet thick near Thiensville (Rovey, 1990).

5.1.2 Regional Structure

Silurian- and Devonian-age rocks generally dip east to southeast at approximately 20 to 30 feet per mile. These rocks are thickest near Lake Michigan, with over 600 feet noted in wells in Sheboygan County.

A regional fault trends northeast to southwest across southeastern Wisconsin. This fault is mapped from Port Washington, extends through Grafton, Cedarburg, Menomonee Falls, and Waukesha, and continues to at least the Illinois State line (Young and Batten, 1980) (Sverdrup, et al., unpublished). The locations of many locally notable bedrock features (waterfalls, bedrock dells, quarries) parallel the fault. This fault has been named the "Waukesha Fault". The Waukesha Fault is believed to be a high-angle normal fault, dowthrown to the southeast, with a maximum vertical displacement of 1500 feet at depth. The displacement of Silurian and Devonian rocks is believed to be 30 to 100 feet.

The bedrock surface was heavily eroded by pre-glacial streams. Bedrock surface topography is often quite irregular, with pre-glacial drainage patterns evident as dendritic incisions in the bedrock surface. Notable examples of these pre-glacial bedrock valleys include the southwest-trending Troy Valley in southern Waukesha and Walworth Counties, and an unnamed bedrock valley underlying central Washington, northwestern Waukesha, and southern Jefferson Counties. Smaller bedrock valleys are found throughout southeastern Wisconsin. These smaller bedrock valleys are typically oriented perpendicular to major bedrock valleys or Lake Michigan. Lake Michigan occupies a large pre-glacial bedrock valley. Of particular interest to this study is a fairly prominent bedrock valley, starting near the Ozaukee County/Washington County line west of Grafton. This feature continues east across Ozaukee County and passes below the Ulao Swamp. The valley becomes less well-defined east of the Waukesha Fault (Young and Batten, 1980).

5.1.3 Local Lithology and Structure

Both Devonian- and Silurian-age dolomite underlie glacial sediment in the Watershed. Devonian-age dolomite of the Lake Church Formation underlies portions of Sections 4, 9, 17, 20, and 30; and all of Sections 16, 21, 28, 29, 31, 32, and 33 (Figure 3). Geologic logs from Stonecraft Village (Stonecraft) in Section 4 indicate shaly layers in the upper 60 feet of the bedrock, which may correspond to the thickness of the Lake Church Formation at this location. Silurian-age dolomite of the Racine Formation underlies the remainder of the Watershed. Although the Racine dolomite reportedly undergoes a textural change near the Waukesha Fault (Rovey, 1990), insufficient watershed-specific data are available to evaluate this hypothesis.

According to available literature (Sverdrup, et al., unpublished) (Rovey, 1990), the Waukesha Fault crosses the northern portion of the Watershed, roughly following the alignment of County Highway V/State Highway 32 (Figure 3). Bedrock elevation contours and cross sections reveal a fairly conspicuous escarpment, the top of which is often east of the regional plot of the fault's location. This escarpment parallels the known trend of the Waukesha Fault, and may be a more accurate depiction of the fault's true location. The escarpment exhibits approximately 80 feet of vertical relief, well within the 30 to 100 foot vertical displacement range the Waukesha Fault reportedly displays in Silurian bedrock.

Overall, the bedrock surface slopes to the east-southeast. However, the topography of the bedrock surface is quite irregular (Figure 3). Over 220 feet of relief exists between an irregularly shaped bedrock ridge just north of Grafton, and the lowest elevation area found in a prominent buried bedrock valley near the Lake Michigan shoreline directly east of Grafton.

Two prominent bedrock valleys are discernable under the northern and central portion of the Watershed. One valley enters the Watershed in Sections 6 and 7 north of Grafton. This valley is concordant with the location of the bedrock valley illustrated in regional references (Young and Batten, 1980), and likely extends at least 6 miles west beyond the Watershed. This valley leads directly east and disappears at the Waukesha Fault. East of the Waukesha Fault in Section 9, this valley again becomes pronounced and continues northeast out of the Watershed and under Lake Michigan. A broad, moderately-deep bedrock valley begins under Section 17. This valley turns abruptly east near the center of Section 20, continuing in an east-northeast direction towards Lake Michigan. Near and likely below Lake Michigan, this valley becomes deeply incised, with the lowest bedrock elevation recorded anywhere in the Watershed.

Other small bedrock valleys are also noticeable in the Watershed. A shallow, yet laterally continuous, bedrock valley begins as a small swale in the bedrock high in Sections 7 and 18 near Grafton. This small swale leads essentially directly east through Sections 17, 16, and 15 to Lake Michigan. The valley is also not well defined near the Waukesha Fault. Other smaller buried bedrock valleys occur throughout the Watershed. At least one prominent bedrock valley appears to parallel the Milwaukee River just west of Sections 19 and 30, an area beyond the Watershed study boundaries.

The bedrock surface under the southern third of the Watershed exhibits little relief compared to the areas east and northeast of Grafton. In general, the bedrock in the southern third of the Watershed slopes gradually and rather uniformly to the southeast. The Waukesha Fault is likely responsible for the greater topographic relief of the bedrock surface under the northern portion of the Watershed.

5.2 Unconsolidated Sediments

5.2.1 Description of Regionally Recognized Stratigraphic Units

Southeastern Wisconsin was repeatedly glaciated, with the most recent glacial advances retreating less than 12,000 years ago. These multiple advances deposited a multi-layered sequence of clay, silt, sand, and gravel. Sediments deposited directly by glaciers are typically poorly-sorted amalgams of clay, silt, sand, gravel, and boulders; and are termed "till." Other glacial sediments are deposited by or in water and are generally well sorted. Higher energy environments (e.g., streams and rivers) typically yield well-sorted coarse-grained sediment (sand and gravel). Glacially-deposited sediments of this type are called "outwash" or "glaciofluvial deposits." Sediments deposited by glaciers into standing water can be composed of sand, silt, and/or clay, oftentimes in distinct layers, and are termed "glaciolacustrine deposits." In many instances, it is difficult to distinguish the fine-grained tills of southeastern Wisconsin from associated fine-grained glaciolacustrine deposits. Additionally, some glacial sediments, particularly those deposited near the terminus of a glacier, have transitional properties. For example, mass wasting of sediment into a glacial lake will produce crudely stratified sediments with material properties intermediate to till and glaciolacustrine deposits. Therefore, the term "diamicton" is often used to collectively describe undifferentiated fine-grained glacial sediments.

In many areas, various glacial deposits form layer cake-like sequences of sediments with various material properties. Glaciofluvial and/or glaciolacustrine deposits often separate the various till units, adding more layers. Individual layers can be laterally extensive, and can persist under many square miles. Other layers can be discontinuous, not extending more than a few feet. Typically, areas near terminal moraines are more complexly interlayered with less continuity of individual layers.

More than 300 feet of glacial sediments are present in some portions of southeastern Wisconsin. The thickest deposits typically occur at the terminus of a glacial advance, where a terminal or lateral moraine is deposited. The Kettle Moraine in neighboring Washington County is a well-known moraine deposited at a point where two ice sheets (the Green Bay Lobe and the Lake Michigan Lobe) met.

Deeply incised bedrock valleys also commonly contain thick layers of unconsolidated sediment. Sediment in these valleys may pre-date glaciation. Glacial deposits are thin to absent in isolated areas throughout southeastern Wisconsin. Such rock outcrops are often the site of rock quarries.

At least five named glacially-deposited formations underlie southeastern Wisconsin (Mickelson and Syverson, unpublished) (Mickelson, et al., 1984). Tills of these deposits exhibit recognizably different material properties. These formations are listed below from youngest to oldest.

- Kewaunee Formation
- Oak Creek Formation
- Holy Hill Formation
- Zenda Formation
- Walworth Formation

Some of these formations have been subdivided into several members. The individual members of each formation are sometimes difficult to distinguish because they were deposited by multiple advances of a particular ice sheet, and consequently have similar material properties. The various formations and members are described below.

Kewaunee Formation

Till of the Kewaunee Formation is composed of pebbly clayey silt with varying amounts of sand. Although the Kewaunee Formation is composed of nine members, only the oldest member (the Ozaukee Member) is found south of Sheboygan County (Mickelson, et al., 1984).

The Ozaukee Member is reddish-brown to pinkish-gray to light gray, and contains very little sand. Fluviolacustrine sediment layers may be present within this unit. It is usually the surficial glacial deposit near Lake Michigan from just south of the mouth of the Milwaukee River to the Ozaukee/Sheboygan County line. As a very simplified generalization, the Milwaukee River demarks the western extent of this unit in Milwaukee and southern Ozaukee Counties. Regionally, it is up to 65 feet thick, averaging about 30 feet thick in exposures along Lake Michigan. According to local studies completed along the Ozaukee County shoreline of Lake Michigan (Rovey and Borucki, 1995) (Mickelson and Syverson, unpublished), the Kewaunee Formation typically consists of a single layer of glacial till ranging from 30 to 80 feet thick. In some areas, the till is underlain by a fairly thick layer of pro-glacial outwash deposited during the advance of the Kewaunee Glacier. In other areas, it is overlain by outwash deposited during the most recent glacier retreat (Mickelson and Syverson, unpublished).

Oak Creek Formation

The Oak Creek Formation underlies most areas east of the Fox River in southeastern Wisconsin, and is the surficial unit in most areas where the Kewaunee Formation is absent. The Oak Creek Formation is composed of a sequence of tills, none of which have been formally subdivided as members. Readily-recognizable moraines mark the outermost margins of several advances. These moraines include the Valparaiso

Moraine, the Tinley Moraine, and Lake Border Moraine systems. The Tinley Moraine is recognizable across Ozaukee County as a north-south ridge crossing the western portion of the City of Mequon and central portions of the Towns of Cedarburg, Saukville, and Fredonia. The Lake Border Moraines are only exposed in southern Ozaukee County. The Lake Border Moraines are visible as hills in western and central portions of the City of Mequon and small areas near the eastern limits of the Towns of Cedarburg and Saukville. The Lake Border Moraines are buried under Kewaunee Formation sediment farther east and north of the Town of Saukville (Schneider, 1983).

The Oak Creek Formation is composed of silty clay glacial till with interbeds of glaciolacustrine clay, silt, and sand, and some glaciofluvial sand and gravel. The glaciolacustrine and glaciofluvial deposits are more common near Lake Michigan. Even though several separate advances are known to compose the Oak Creek Formation, it has not been formally subdivided into members. However, recent work speculates five separate till units and two stratified glacial diamicton units within the formation. Only the basal diamicton and oldest till layer are believed to underlie areas north of Milwaukee County (Rovey and Borucki, 1995). Oak Creek till is typically dark gray, oxidizing to a yellowish-brown color (Mickelson, et al., 1984). However, the older portions of Oak Creek Formation that underlie Ozaukee County exhibit a decidedly pinkish hue, not unlike younger Kewaunee Formation sediment.

Based upon the extent of Tinley and Lake Border Moraines, at least two, and possibly three, facies of Oak Creek Formation till are present in Ozaukee County. These till facies may be separated by glaciolacustrine sediments. Studies of the stratigraphy of glacial sediment exposed in bluffs along the Lake Michigan shoreline concluded that the Oak Creek Formation in Ozaukee County is composed of the following units, listed downward from the surface (Mickelson, et al., 1977) (Rovey and Borucki, 1995).

- Undifferentiated Lake Sediment: A thick layer (40 to 60 feet) of undifferentiated lake sediment is found between the basal diamicton of the Oak Creek Formation and the Kewaunee till in the northern part of the Town of Grafton. These sediments are stratified, grayish, and composed largely of silt and clay. The lake sediments are segregated into two layers by a layer of till from the center of the Town of Grafton south to the Ozaukee/Milwaukee County line.

- Till: The till is a thin (e.g., 10-foot thick) layer of pinkish-gray silty clay till. This till is reportedly present only to the north of Section 21 in the Town of Grafton. In the northern-most exposures, it directly underlies Kewaunee Formation till. Farther to the south, it is separated from Kewaunee Formation till by a variable thickness (e.g., 5 to 20 feet) of undifferentiated lake sediment.

- Diamicton: The basal water-laid diamicton is composed of dark gray, clayey silt between 5 and 8 feet thick, resting directly upon Holy Hill Formation sediments.

Holy Hill Formation

The Holy Hill Formation is a newly-proposed name for sediments now assigned to the Horicon or New Berlin Formation (Mickelson and Syverson, unpublished). The Holy Hill Formation is composed of three members: the Waubeka Member, the New Berlin Member, and the Horicon Member. The Horicon Member does not exist east of the Kettle Moraine, and therefore is not discussed in this study.

The Waubeka Member has been proposed to name a unit with properties intermediate between the younger Oak Creek Formation and the older New Berlin Member of the Holy Hill Formation (Mickelson and Syverson, unpublished). The till of the Waubeka Formation is characterized as gray to brown gravelly, clayey, sandy silt. The Waubeka Formation is the surficial unit in areas west of the Tinley Moraine. Sediments of the Waubeka Formation are exposed at the surface under much of western Ozaukee County.

The New Berlin Member is composed of two members: an upper till unit and a lower sand-and-gravel unit (Mickelson, et al., 1984). Till of the New Berlin Member is a gravelly sandy loam which ranges in color from grayish-brown (unoxidized) to yellowish-brown (oxidized). Both the till and outwash contain large amounts of dolomite. The New Berlin Member is the surficial unit under much of Walworth and Waukesha Counties, and limited areas of Washington County. In all areas, it forms the eastern flank of the Kettle Moraine. The New Berlin Member is exposed at the surface in isolated areas in western and northwestern Ozaukee County. It probably extends east for an undetermined distance, buried below the Waubeka Member and other more recently deposited sediments.

Walworth and Zenda Formations

These formations occur in southeastern Wisconsin, but probably do not underlie Ozaukee County. The Walworth Formation is subdivided into three members: the Fox Hollow Member, the Allens Grove Member, and the Clinton Member. The Clinton Member is exposed at the surface south of the Kettle Moraine in portions of Walworth and Rock Counties. The Fox Hollow and Allens Grove Members extend north and east under more recently deposited sediments. The Walworth Formation is the oldest mapped glacial deposit in southeastern Wisconsin. Walworth Formation till is generally characterized as a clayey silty sand (Mickelson, et al., 1984).

The Zenda Formation overlies the Walworth Formation and underlies the Holy Hill Formation. It is exposed at the surface in Walworth County. The Zenda Formation is subdivided into two members: the Capron Member and the Tiskilwa Member. Both members consist of pinkish, sandy, clayey silt. The Tiskilwa Member was buried by more recent sediments of the Oak Creek and Holy Hill Formations. It exists in the subsurface north and east of Walworth County at least as far as Milwaukee (Mickelson, et al., 1984).

5.2.2 Watershed Conditions

Essentially all unconsolidated sediments in the Watershed were deposited by glacial action between 12,000 and 16,000 years ago. A thin veneer of post-glacial sediments has been deposited in some areas. Examples of these post-glacial sediments include alluvial silt, sand, and gravel along portions of the Milwaukee River, Ulao Creek, and major tributaries; and organic mucks and peats found in wetlands, notably the Ulao Swamp. In addition to a thin layer of modern sediments, bedrock valleys likely contain pre-glacial alluvial silt, sand, and gravel. Deeply incised bedrock valleys, such as those under the northwest and central portions of the Watershed, are more likely to contain preglacially-deposited alluvium.

The Watershed is in an area which was repeatedly overridden by glaciers, and is positioned near the terminus of at least one glacial advance. At the terminus of an ice sheet, small temperature variations (e.g, seasons) cause the ice to repeatedly advance and retreat. Therefore, in such areas, sediments are often intricately interlayered. Additionally, significant erosion and deposition can occur over protracted periods in areas where glacial advances stall. Collectively, these and other factors produce very complex sediment interlayering in the Watershed. The arrangement of the various sediment layers is illustrated in Plate 1. Plate 2 locates areas where granular deposits are found at the surface.

5.2.2.1 Genesis of Surficial Glacial Deposits

One of the Watershed's most prominent features is the pair of hills paralleling Ulao Creek and forming its valley. These hills are two end moraines of the Ozaukee Member of the Kewaunee Formation, and are readily visible to the casual observer. The terminus of the Western Moraine roughly parallels the course of the Milwaukee River (hereafter referred to as the Western Moraine). County Highway W rides the crest or eastern flank of the Western Moraine. Thick deposits of sand-and-gravel outwash overlie the older till of the Oak Creek Formation west of the Western Moraine.

A second moraine is oriented essentially north-south nearer the Lake Michigan shoreline (hereafter referred to as the Eastern Moraine). Except for a small area in the southern-most portion of the Watershed, the Eastern and Western Moraines are superimposed upon one another. These moraines are sometimes separated by a layer of outwash, particularly in the northern portions of the Watershed. In some areas, outwash outcrops at the surface.

In Sections 29, 31, and 32, a small wedge of relatively flat ground moraine separates the two moraines. Similarly, gently sloping ground moraine is found between the Eastern Moraine and Lake Michigan in the northeastern corner of the Watershed. Post-glacial erosion of streams entering Lake Michigan directly has superimposed some steep slopes onto the flat ground moraine in this area.

Melt water from the Eastern Moraine flowed west across the ground moraine until contacting the Western Moraine. From here, it flowed south. This melt water stream incised a channel into glacial sediments (i.e., Kewaunee Formation diamicton and fluvial sand and gravel) and deposited granular outwash. Ulao Creek is a misfit stream occupying the channel of this former glacial stream. Consequently, surficial sediments along Ulao Creek are composed primarily of glacially-derived sand and gravel.

In the extreme northwestern corner of the Watershed, isolated areas of Oak Creek Formation till are possibly exposed at the surface, or are present below a relatively thin veneer of Kewaunee Formation till and/or outwash. These exposures are likely prominences of the Lake Border Moraine System which are buried below Kewaunee Formation till and/or outwash. Alternatively, these exposures are the tops of Oak Creek Formation drumlins which Kewaunee Formation deposits encircled, but did not overtop. Streamlined landforms composed of Oak Creek Formation diamicton are present 1 to 2 miles north of this area.

Relatively thin surficial deposits of post-glacial alluvium are scattered throughout the Watershed. Alluvium parallels the bed of Ulao Creek and a few of its major tributaries. Organic deposits consisting predominantly of muck and peat overlie glacially-deposited sediments under wetlands. Some lowlying areas are also capped with topsoil and other sediments eroded from adjacent uplands.

Relatively small areas may be underlain by sediments pre-dating Pleistocene-age glacial deposits. These older sediments may occur in incised bedrock valleys, and consist of pre-glacial stream sediment. Additionally, a thin veneer of boulders and other coarse gravel sediment may rest upon the bedrock surface. These extremely coarse-grained deposits remained after the finer-grained matrix had been removed by erosion. Available information was not sufficiently detailed to differentiate these deeply buried deposits.

5.2.2.2 Ongoing Research

Ongoing state-funded research is focused on the glacial stratigraphy of Ozaukee and Washington Counties (Mickelson and Syverson, unpublished). Draft cross sections prepared as part of the Mickelson and Syverson study pass east to west under the northern, central, and southern portions of the Watershed. These cross sections readily distinguish till and outwash of the Ozaukee Member of the Kewaunee Formation. A less well-distinguished complexly-layered sequence of till and water-laid deposits is found below Kewaunee Formation sediments. These complexly-interlayered sediments belong to the Oak Creek and Holy Hill Formations.

According to Mickelson and Syverson, Kewaunee Formation sediments blanket the entire Watershed with the thickest deposits found near Lake Michigan. Kewaunee Formation till is exposed at the surface in all areas not covered with Kewaunee Formation outwash. Kewaunee outwash is found at the surface under the Milwaukee River, Ulao Creek, and portions of the Ulao Swamp. Fluvial sand-and-gravel layers are also shown to be sandwiched between Kewaunee and underlying older sediments, forming a laterally continuous sheet. In the north and south portions of the Watershed, Kewaunee Formation or undifferentiated fluvial sand and gravel extend in the subsurface from the Milwaukee River to Lake Michigan. In the center of the Watershed, these outwash layers do not extend to the Milwaukee River. Instead, the sand-and-gravel layer leads from Ulao Creek to Lake Michigan. Ulao Creek and the Ulao Swamp are not shown to be in contact with sand-and-gravel layers at the northern and southern boundaries of the Watershed.

Older glacial deposits underlying the Kewaunee Formation in the Watershed have proven difficult to differentiate (Mickelson and Syverson, unpublished). In the central and southern portions of the Watershed, Oak Creek and Waubeka diamicton, gravel, and sand are not differentiated, but collectively underlie Kewaunee or undifferentiated fluvial sand and gravel. In the southern part of the Watershed, research indicates that New Berlin Member diamicton, sand, and gravel underlie undifferentiated Oak Creek/Waubeka sediments, rest upon bedrock. In the northern part of the Watershed, Oak Creek diamicton underlies Kewaunee Formation fluvial sand and gravel. The Oak Creek diamicton rests upon undifferentiated Holy Hill diamicton, sand, and gravel, which in turn rests upon bedrock.

5.2.2.3 Detailed Stratigraphic Analysis

Although limited data are available to evaluate the lithology and stratigraphy of the Watershed sediments, regional studies and interpretations provide sufficient information to frame possible relationships. After studying well constructor reports, the Ash Landfill geotechnical data, surficial soils, and land forms, five glacial stratigraphic units were differentiated under all or parts of the Watershed.

- Diamicton, Ozaukee Member, Kewaunee Formation
- Diamicton, Oak Creek Formation
- Diamicton, Holy Hill Formation
- Sand and gravel (presumed to be outwash or beach deposits)
- Lacustrine sand and silt

Because of the limited distribution, thickness, and their consequent general lack of significance to this study, no effort was made to differentiate pre-glacial or post-glacial sediments.

Stratigraphic interpretations are illustrated in Plate 1. The Watershed-specific stratigraphic interpretations agree reasonably well with regional hypothesis. One divergence from regional interpretations regards the composition and position of Oak Creek Formation sediments. This formation has many interlayers of fine-grained water-laid sediment, layers which are not distinguishable from till on most well constructor logs. Another prime difference regards the lateral continuity of silt/sand/gravel deposits found below Ozaukee Member diamicton. Watershed-specific data do not support laterally continuous sand-and-gravel layers extending across the northern portion of the Watershed. Also, much of the coarse-textured facies proposed by regional models appear to be composed primarily of complexly interlayered silt and sand, a finding which greatly influences the water transmitting properties of these layers.

In the northern portion of the Watershed, sand and gravel are not believed to connect the Milwaukee River to Lake Michigan. Kewaunee Formation fluvial sand and gravel underlies and borders the Milwaukee River. This fluvial sand and gravel extends east below the intervening clayey morainal hills, and is again exposed just west and below the Ulao Swamp. This outwash accounts for the sand-and-gravel deposits exposed at the surface near the northwest corner of the Ulao Swamp. Much of this sand and gravel is below the elevation of the Milwaukee River and the Ulao Swamp. Therefore, the sand-and-gravel layer in this area could allow water to flow between the Milwaukee River and the Ulao Swamp.

Regional interpretations suggest that the central portion of Ulao Creek is underlain by sand and gravel, which is laterally continuous and leads to Lake Michigan. Watershed-specific data corroborate this finding, but also suggest that the sand-and-gravel layer continues well to the west, and is in direct contact with bedrock and possibly the Milwaukee River. This stratigraphic arrangement could allow ground water to either discharge to the creek, or could allow creek water to infiltrate into the ground.

Available interpretations suggest that the sand-and-gravel outwash forming the bed of Ulao Creek in the southern part of the Watershed is segregated by clayey till from laterally continuous serial sediment layers. However, a few well logs in south-central Section 32 report sand-and-gravel layers within 30 feet of the land surface. Glacial melt water scoured the channel of Ulao Creek, incising a valley more than 20 feet into the surficial clayey tills. Therefore, if erosion incised a slightly deeper channel in some areas, it could have removed all clay diamicton separating the fluvial sand and gravels underlying the creek bed from the laterally-continuous sand-and-gravel layer at the base of the Ozaukee Member. Consequently, there is a good possibility that Ulao Creek is connected to buried fluvial sand-and-gravel layers in limited areas under the extreme southern portion of the Watershed.

6.0 GROUND-WATER HYDROLOGY

6.1 Aquifers of Southern Ozaukee County

In southeastern Wisconsin, three aquifers supply water for residences, industry, and municipalities. The commonly used names of these aquifers are listed below in descending order from the land surface.

- Sand-and-Gravel Aquifer
- Niagara Aquifer
- Sandstone Aquifer

The attributes of each aquifer are summarized below.

6.1.1 Sand-and-Gravel Aquifer

The Sand-and-Gravel Aquifer is composed of unconsolidated sediments, most of which were deposited by glacial action. Although the aquifer's name suggests that it is composed entirely of sand and gravel, it is actually composed of a complexly interlayered sequence of gravel, sand, silt, and clay. Obviously, it is only an "aquifer" where significant deposits of saturated permeable sediment (i.e., sand and gravel) occur. Therefore, the "Sand-and-Gravel Aquifer" is generally only used to describe saturated granular deposits such as glacial outwash, alluvium, and coarse-grained lacustrine deposits (e.g., beach deposits). Nevertheless, the distribution and properties of non-aquifer sediments must also be examined to evaluate ground-water flow and flux. The hydraulic properties of non-aquifer components of the unconsolidated deposits are examined in Section 6.2.

Well yields from the Sand-and-Gravel Aquifer are highest where thick saturated fluvial sand-and-gravel deposits are present. These deposits are most typically found near the Kettle Moraine. Smaller deposits are also found in buried bedrock valleys. The Sand-and-Gravel Aquifer is usually recharged by direct infiltration of incident precipitation. In some areas, it is recharged by discharge from underlying bedrock aquifers, and by infiltration from overlying lakes, rivers, and wetlands. The Sand-and-Gravel Aquifer is usually unconfined, but can be confined by overlying layers of clayey sediment. Water elevations are typically a subdued expression of surface topography.

Much of Ozaukee County is underlain by relatively impermeable silty and clayey sediment. Few significant sand-and-gravel deposits occur. Consequently, the Sand-and-Gravel Aquifer provided less than 2 percent of ground water used in Ozaukee County during 1975. In contrast, in Washington County, where thick saturated sand-and-gravel deposits abut the Kettle Moraine, the Sand-and-Gravel Aquifer provided over 46 percent of the county's ground-water supply during the same period (Young and Batten, 1980). Of the 281 well constructor reports collected for this study, fifteen are Sand-and-Gravel Aquifer wells (5.3 percent of the total wells). Many of the Sand-and-Gravel Aquifer wells are newer, having been installed within the past 10 years. Twelve of the fifteen Sand-and-Gravel Aquifer wells are less than

1 mile from the Ulao Swamp. In addition to the known wells, many old sand point-type wells and older undocumented wells likely draw water from the Sand-and-Gravel Aquifer in the Watershed.

The Sand-and-Gravel Aquifer often lies directly upon the Niagara Aquifer. In these situations, the two aquifers are hydraulically connected and commonly behave as one aquifer. The Sand-and-Gravel Aquifer commonly outcrops at the surface, and therefore interacts with surface water bodies. Most springs and seeps in southeastern Wisconsin issue from the Sand-and-Gravel Aquifer. This aquifer has great influence on local surface-water features such as Ulao Creek.

Because surface-water supplies are readily available and productive bedrock aquifers are found at relatively shallow depths throughout eastern Wisconsin, comparatively little research has been focused at the water-bearing characteristics of the Sand-and-Gravel Aquifer. Indeed, most ground-water/surface-water interaction studies ignore the contribution of unconsolidated sediments. Nevertheless, in a small localized flow system (such as Ulao Creek), unconsolidated sediments can have a profound influence on ground-water/surface-water interaction.

The hydraulic conductivity of the Sand-and-Gravel Aquifer likely varies considerably with depth and location. This presumption is based upon the known facies changes which occur in the unit across eastern Wisconsin. For example, in some areas, this aquifer is composed of boulders and gravel. In other areas, it consists of fine sand. The hydraulic conductivity of the Sand-and-Gravel Aquifer in 24 wells in Ozaukee and Washington Counties ranged from 7×10^{-3} to 0.5 cm/sec (Young and Batten, 1980). Unfortunately, of the fifteen Sand-and-Gravel Aquifer wells in the Watershed, only two record sufficient construction information to enable estimation of aquifer hydraulic conductivity. One well is on Trailway Drive, between the Milwaukee River and the Ulao Swamp. Another is on Lancaster Court, a short distance east of the Ulao Swamp. Data from both wells suggest that the hydraulic conductivity of the Sand-and-Gravel Aquifer under the Watershed is 4×10^{-3} cm/sec.

6.1.2 Niagara Aquifer

6.1.2.1 General

The uppermost carbonate bedrock in southeastern Wisconsin is referred to as the "Niagara Aquifer." The Niagara Aquifer is composed primarily of Silurian-age dolomite, although areas near Lake Michigan include saturated portions of overlying Devonian-age dolomite and shaly dolomite (Figure 4). The Niagara Aquifer underlies all of Ozaukee County, but it is absent in areas to the west where it has been removed by erosion. The Niagara Aquifer exists under confined and water-table conditions. In areas overlain by thick clay layers, the aquifer can be confined.

Hydraulic conductivities for 534 wells in Ozaukee and Washington Counties range from 4×10^{-6} to 0.2 cm/sec (Young and Batten, 1980). Young and Batten speculate that lower well yields result from for the presence of Devonian-age rocks. When Devonian-age shale and dolomite is present, the underlying Silurian-age dolomite was thought to have been protected from pre-glacial erosion and weathering that increased the water-transmitting capability of the Silurian-age dolomite in most areas. Recent research (Rovey, 1990) proposes an alternative hypothesis. Rovey speculates that the various layers composing the Niagara Aquifer exhibit different hydraulic properties. The properties of the various hydrostratigraphic units are summarized in Figure 4. Applying this hypothesis leads one to believe that the lower well yields found in southern Ozaukee County are likely related to the presence of low permeability bedrock of the Berthelet Member of the Milwaukee Formation.

The Niagara Aquifer provided nearly 80 percent of Ozaukee County's ground-water supply during 1975 (Young and Batten, 1980). The Niagara Aquifer is particularly important to Ozaukee County's households, providing 95 percent of all privately-supplied ground water during this period. Other than the Sand-and-Gravel Aquifer wells discussed in Section 6.1.1, all residential wells in the Watershed draw water from the Niagara Aquifer. The Niagara Aquifer underlying the Watershed also supplies potable water to the Village of Grafton.

Although the Niagara Aquifer is a very important component of the near-surface flow system, it is only occasionally exposed at the surface. Nevertheless, it is fairly well exposed in Ozaukee County, in many places forming the bed of the Milwaukee River. Rocks of the Niagara Aquifer form the bed of:

- The Milwaukee River near Fredonia and Grafton
- Cedar Creek in Cedarburg
- Sauk Creek near Port Washington
- Pigeon Creek north of Thiensville
- Portions of Lake Michigan east of Belgium

Moreover, in many parts of eastern Wisconsin, permeable sand and gravel lie directly upon the bedrock surface. In many places, the Niagara Aquifer and Sand-and-Gravel Aquifer are commonly in good hydraulic connection and behave as one aquifer. The Sand-and-Gravel Aquifer and the Niagara Aquifer are in direct contact under the north-central and central portions of the Watershed (Plate 1). Therefore, the Niagara Aquifer likely has a important influence on surface-water bodies, including streams of local significance such as Ulao Creek.

6.1.2.2 Hydraulic Properties

6.1.2.2.1 Regional Values

Until recently, secondary porosity (e.g., fractures, solution channels) were thought to be the primary means by which ground water entered and moved through the Niagara Aquifer. Furthermore, since secondary porosity was believed to control ground-water movement, the influence of the various formations' matrix properties was not recognized.

During the late 1980s and early 1990s, research concluded that primary porosity (porosity resulting from a sediment's original depositional environment and composition) greatly influenced the hydraulic properties of the various formations comprising the Niagara Aquifer (Rovey, 1990) (Rovey and Cherkauer, 1994a, 1994b). This research concluded that the Niagara Aquifer should be subdivided into several hydrostratigraphic units based upon the hydraulic properties of the various formations (Figure 4). Important hydrostratigraphic units of the Niagara Aquifer are listed below.

- Weathered Zone
- Lindwurm
- Berthelet
- Thiensville
- Lake Church-Racine
- Romeo
- Waukesha-Byron
- Mayville

The weathered zone reportedly comprises the upper 20 feet of the Niagara Aquifer, and can be composed of any of the Silurian or Devonian dolomites. Dissolution elevates the effective porosity of the weathered zone, yielding a high hydraulic conductivity which averages $1.6x10^{-4}$ cm/sec in Milwaukee County. This unit's hydraulic conductivity is not related to jointing, and it behaves similarly to a porous media (Rovey, 1990) (Rovey and Cherkauer, 1994a).

The Thiensville, Romeo, and Mayville units are composed of coarse-textured sediment yielding higher hydraulic conductivities which are not dependent upon jointing. In Milwaukee County, these coarser-textured rocks exhibit relatively high hydraulic conductivity. The estimated values are listed below (Rovey and Cherkauer, 1994a).

- Thiensville $5x10^{-3}$ cm/sec
- Romeo $1x10^{-4}$ cm/sec
- Mayville $1x10^{-4}$ cm/sec

These units can be considered aquifers, units capable of transmitting significant quantities of water.

The Lindwurm, Berthelet, Lake Church-Racine, and Waukesha-Byron units are finer-textured, relatively non-porous, and depend upon jointing to transmit water. The hydraulic conductivity of the units measured in Milwaukee County are listed below (Rovey and Cherkauer, 1994a).

▲	Lindwurm	$6x10^{-7}$ cm/sec
▲	Berthelet	$4x10^{-5}$ cm/sec
▲	Waubakee	$2x10^{-6}$ cm/sec
▲	Undifferentiated Racine	$1x10^{-6}$ cm/sec
▲	Waukesha-Byron	$1x10^{-6}$ cm/sec

The hydraulic conductivities of these units classify them as aquitards, units which do not transmit significant quantities of water. The dolomite of the Lake Church Formation reportedly has properties similar to the Undifferentiated Racine (Rovey, 1990).

Some of the Silurian-age formations undergo lateral facies changes, which can significantly alter hydraulic properties (Rovey, 1990) (Rovey and Cherkauer, 1994b). The Mayville Formation is considerably finer textured in Illinois, resulting in decreasing porosity and hydraulic conductivity to the south of Wisconsin. The Manistique Formation grades to a coarser-textured facies north of the Waukesha Fault, which increases the hydraulic conductivity of the upper portion of the Waukesha-Byron hydrostratigraphic unit to the 10^{-4} cm/sec range, classifying it as an aquifer in this area. This change persists at least as far north as Manitowoc County, where it again reverts to the finer texture as seen in Door County.

The basal Romeo Member of the Racine Formation is consistently more permeable than the remainder of the Racine Formation between Chicago and Milwaukee. However, the Romeo Member thickens north across the Waukesha Fault, grading into a finer-textured facies indistinguishable from the upper undifferentiated portions of the Racine Formation. Consequently, even though the Romeo Member is considered an aquifer south of the Waukesha Fault, it is an aquitard in areas significantly north of the fault.

The upper undifferentiated fine-textured dolomites of the Racine Formation are generally aquitards. However, these sediments reportedly undergo a facies change at the Waukesha Fault. In a 6- to 10-mile wide band paralleling the fault, the upper undifferentiated layers of the Racine Formation dramatically increase in thickness and grade to a more granular texture. The granular facies exhibit a relative high hydraulic conductivity in the order of 10^{-4} cm/sec (Rovey and Cherkauer, 1994a, 1994b).

The influence of the Waukesha Fault on the water-bearing characteristics of the Niagara Aquifer in Ozaukee County was explored during the mid-1990s (Rovey and Cherkauer, 1994b). After normalizing for completion interval differences, Niagara Aquifer wells immediately north and paralleling the Waukesha Fault had specific capacities three times greater than wells south of the fault and farther to the north.

6.1.2.2.2 Watershed-Specific Values

Specific-capacity data from throughout the Watershed were used to estimate the hydraulic conductivity of the upper portions of the Racine dolomite and Lake Church Formation. Plotting the resultant data (Figure 5), one can see that the Lake Church-Racine hydraulic conductivity is considerably higher in areas paralleling the Waukesha Fault. Hydraulic conductivities are three times higher in areas near the fault, as predicted by Rovey's regional hypothesis. Areas of lower hydraulic conductivity roughly correlate with buried bedrock valleys. This may be explained by pre-glacial erosion removing the more highly-weathered surficial rock layers in these areas.

An area of higher hydraulic conductivity bedrock is also found in the southeastern corner of the Watershed, an area relatively distant from the Waukesha Fault. This feature roughly corresponds to a broad, gently-sloping bedrock high which crosses the Watershed under Sections 28, 29, and 30. In Mequon, such ridges are often capped with Thiensville Formation dolomite (Nader, 1990). If the same phenomenon persists into the Town of Grafton, this ridge would also be capped with Thiensville Formation dolomite, a rock unit with substantially higher hydraulic conductivity. Such a rock unit would transmit between 10 and 1000 times more water than Lake Church-Racine dolomite at a set gradient and fixed cross-sectional area.

6.1.3 Sandstone Aquifer

The Sandstone Aquifer is a confined aquifer underlying all of southeastern Wisconsin. This aquifer is segregated from the Niagara and Sand-and-Gravel Aquifers by a thick layer of relatively impermeable shale. Heavy pumping in major metropolitan areas (e.g., Milwaukee, Waukesha, Chicago) reduced the original potentiometric head by hundreds of feet in some areas. The Sandstone Aquifer's primary recharge area is beyond the western margin of the Niagara Aquifer. Hydraulic conductivity of the aquifer is estimated to be $8x10^{-4}$ cm/sec. The Sandstone Aquifer was only used for public, commercial, and industrial supplies in Ozaukee County as of 1975. Since it is not in good communication with the Sand-and-Gravel or Niagara Aquifers, it usually does not significantly influence local surface-water bodies in eastern Wisconsin.

6.2 Hydraulic Properties of Non-Aquifer Unconsolidated Deposits

Comparatively little data are available to evaluate the hydraulic properties of non-aquifer unconsolidated sediments in the Watershed. Grain-size analyses and other laboratory tests are available for various sediments at the Ash Landfill site. WEPCO's consultant segregated the clayey soils they encountered at the site into Ozaukee Member, Kewaunee Formation, and Oak Creek formation till (WEPCO, 1979-1997). This division was chosen largely on color; however, more recent research has speculated that the Oak Creek Formation and Ozaukee Member of the Kewaunee Formation have similar colors (pinkish-gray). The Ash Landfill data show the two "layers" have essentially identical gradation. Regional stratigraphic relationships fairly conclusively demonstrate the surficial clays are diamicton of the Ozaukee Member of the Kewaunee Formation. Consequently, all of the upper clayey sediments at the Ash Landfill are believed to be diamicton of the Ozaukee Member of the Kewaunee Formation

The Ozaukee Member diamicton at the Ash Landfill contained considerably more sand and silt than has been characterized regionally. At the Ash Landfill, it averages 3 percent gravel, 22 percent sand, 51 percent silt, and 24 percent clay, with a plasticity index of 15 (using a sand/silt boundary of 0.05 millimeters and a silt/clay boundary of 0.002 millimeters to allow comparison to Rovey and Borucki, 1995). Falling head laboratory permeability tests were run on relatively undisturbed diamicton samples. These tests yielded a vertical hydraulic conductivity ranging from $2x10^{-7}$ cm/sec to $8x10^{-9}$ cm/sec, with a geometric average of $2x10^{-8}$ cm/sec.

Empirical relationships relate a granular sediment's hydraulic conductivity to its texture. The most applicable method for the sand-and-gravel layers at the Ash Landfill takes into its account the silty nonuniform nature (Masch and Denny, 1966). This method yields a hydraulic conductivity of $4x10^{-3}$ cm/sec for sand-and-gravel layers at the Ash Landfill. Interestingly, this value agrees exactly with the Sand-and-Gravel Aquifer's hydraulic conductivity computed from specific-capacity data (Section 6.1.1).

Unfortunately, laboratory tests best estimate vertical hydraulic conductivity, while estimates based on grain-size analyses only yield average values. Since sediments are often deposited in horizontal layers, laboratory test values usually underestimate horizontal hydraulic conductivity by at least one order of magnitude. Consequently, literature and professional judgement were used to assign hydraulic conductivity values to the unconsolidated sediments underlying the Watershed. Four hydrostratigraphic units were distinguished. These units are listed below with their genetic origin and estimated horizontal hydraulic conductivity.

Unit	Genesis	Estimated Horizontal Hydraulic Conductivity (cm/sec)
Clayey Diamicton	Kewaunee and Oak Creek Formation Diamicton	$1x10^{-7}$
Sandy Diamicton	Holy Hill Formation Diamicton	$1x10^{-5}$
Sand and Gravel	Outwash, Alluvium, Beach Sand	$4x10^{-3}$
Interlayered Silt and Sand	Lacustrine Sediment and Fine-Grained Alluvium	$3x10^{-5}$

Hydraulic conductivity estimates for clayey diamicton were based upon the laboratory tests at the Ash Landfill increased by one order of magnitude to account for layering. The hydraulic conductivity value assigned to Holy Hill Formation diamicton was based upon experience with New Berlin Member till at other sites in southeastern Wisconsin. These values represent unweathered diamicton. Weathering produces fractures which can increase hydraulic conductivity in the upper 15 feet. Sand-and-gravel values were computed using the specific-capacity method (Section 3.3) on two wells completed in the Sand-and-Gravel Aquifer in the Watershed and by empirical grain-size relationships. Lacustrine sand and silt was assumed to be horizontal layers of silt and sand similar to those commonly encountered near the lakeshore in Sheboygan County. Therefore, the lacustrine sediments were presumed to exhibit hydraulic conductivities equivalent to Sheboygan County sediments (Northern Environmental, 1990).

6.3 Ground-Water Elevation and Flowpaths

6.3.1 Regional Studies

In southeastern Wisconsin, ground-water elevation is usually a subdued expression of surface topography. Generally, highlands are recharge areas. Rivers, streams, wetlands, and lakes occupying topographically lower areas are normally discharge areas. Consequently, near-surface ground water often flows perpendicular to topographic contour lines. Water in the Sand-and-Gravel Aquifer and much of the Niagara Aquifer follows this general rule. Water in deeper portions of the Niagara Aquifer and the Sandstone Aquifer follows more regional flowpaths. Under natural conditions, regional flow is east toward Lake Michigan. However, heavy pumping has altered natural flow directions, particularly in the Sandstone Aquifer.

Shallow ground-water flow direction under the Town of Grafton has been examined as part of regional studies (Young and Batten, 1980). Ground water under the northeastern portion of the Town of Grafton, and immediately along the lakeshore, reportedly flows east-southeast under a horizontal hydraulic gradient of 0.02 foot per foot. In the western and southern portion of the Town of Grafton, horizontal hydraulic gradients are gentler, ranging from 0.003 to 0.005 foot per foot. Ground water flows in a more southern direction immediately southeast of Grafton.

Ground-water elevations are at or below the elevation of Lake Michigan near the lakeshore in Section 28. In these areas, lake water could be induced to flow inland. In the southeastern portion of the City of Mequon, ground-water flow directions are variable and are heavily influenced by localized phenomenon such as pumping (Bues, 1983) (Zviblemen, 1983). Lake water has been demonstrated to flow inland to recharge heavy anthropogenic ground-water withdrawals in this area.

6.3.2 Watershed Conditions

To better understand the flowpaths which ground water follow in the Watershed, ground-water elevations in the Niagara/Sand-and-Gravel Aquifer were contoured (Figure 6). Examining Figure 6, one can see that ground water moves generally to the east-southeast in most parts of the Watershed. Horizontal hydraulic gradients are gentle in the northwest and southwest corners of the Watershed (0.002 to 0.003 foot per foot). The steepest horizontal hydraulic gradients are found near the Lake Michigan shoreline, generally averaging 0.02 foot per foot. Particularly steep gradients are present near Lake Michigan in Sections 21 and 28. Horizontal hydraulic gradients in these areas range from 0.04 to 0.06 foot per foot.

The most notable ground-water recharge and discharge areas appear to correspond to surface water features such as the Milwaukee River, Ulao Creek, the Ulao Swamp, and Lake Michigan. These features are discussed in more detail in Section 6.4.3. Many of these features do not appear to correspond to surficial features or topographic variations. Comparing the geologic information generated in Section 5.0 with the ground-water elevation contour map, the stratigraphy and lithology of buried sediment likely influences ground-water flow.

If aquifer properties were homogenous and isotropic, one would expect that ground-water elevation contours in the Watershed would be relatively regular and would parallel the Lake Michigan shoreline. Instead, water-elevation contours in the Sand-and-Gravel/Niagara Aquifer are convoluted, and do not correspond to surface-water features or topography. Such ground-water contour patterns help identify significant ground-water flow pathways. For example, permeable sediments which are hydraulically connected to substantial surface-water bodies will likely cause the elevation of this surface water to extend into the subsurface considerable distances. Therefore, in ground-water recharge areas, permeable sediments in contact with a surface-water body will likely have higher ground-water elevations and will act as preferred paths for surface water to infiltrate into the earth. In ground-water discharge areas, permeable sediments will act as "drains", depressing ground-water elevations if connected to a significant discharge point. In both situations, permeable sediments provide ground-water flow pathways.

Ground-water flow lines typically converge on transmissive strata in discharge areas, and diverge from transmissive strata in recharge area. By closely examining the potentiometric contours illustrated in Figure 6, and comparing them to bedrock structure (Figure 3), bedrock hydraulic properties (Figures 4 and 5), and the layering of Watershed sediments (Plate 1), the following subsurface features are believed to significantly influence ground-water flow in the Watershed:

- Sand-and-gravel layers, especially in the northern third of the Watershed
- Bedrock material property changes caused by the Waukesha Fault
- Bedrock relief and attendant material property changes

The influence of these features on ground-water flow in various portions of the Watershed are discussed below.

6.3.2.1 Northern Areas

Most glacial sediments under the Watershed are silty and clayey, and do not have the ability to transmit large volumes of ground water. However, a laterally-continuous layer of sand and gravel underlies surficial diamicton under much of the Watershed. In general, sand-and-gravel deposits are thickest and coarsest in the northern reaches of the Watershed, and grade to thinner layers of finer-textured sediments to the south.

A thick coarse-textured layer of sand and gravel underlies the northwestern portion of the Watershed. One layer is commonly over 40 feet thick, and is continuous in the subsurface between the Milwaukee River and the Ulao Swamp. This sand-and-gravel layer hydraulically connects the Milwaukee River (with a water-surface elevation of approximately 745 feet above mean sea level [feet msl]) to the Ulao Swamp (with a water elevation of approximately 700 feet msl). Therefore, water infiltrates into the bed of the Milwaukee River, and can re-emerge as springs and seeps along the western edge of the Ulao Swamp. Ground water likely takes approximately 90 years to migrate from the river to the swamp (assuming an effective porosity of 25 percent, a gradient of .0055 foot/foot, and a hydraulic conductivity of $4x10^{-3}$ cm/sec).

Ground water in the shallow sand-and-gravel layer, which does not discharge to the Ulao Swamp, is forced downward through a relatively thin clayey layer into the Niagara Aquifer. From here, water either re-enters a deeper sand-and-gravel layer, or continues towards Lake Michigan in the bedrock. Ground water in bedrock preferentially flows to areas near the northern borders of the Watershed and to areas near the south end of the Ulao Swamp in response to bedrock permeability differences created by rock facies changes near the Waukesha Fault.

Another sand-and-gravel layer is discontinuous, and is only present under the Milwaukee River and east of the Ulao Swamp. This layer is in contact with permeable bedrock under the river and under the Ulao Swamp, and is likely exposed near the base of the bluffs along Lake Michigan. Ground water likely discharges from bedrock to these deeply buried granular layers under and east of the Ulao Swamp. Water in this sand-and-gravel area then discharges to Lake Michigan.

6.3.2.2 Central Areas

The shallow sand-and-gravel layer noted in the northern portion of the Watershed also underlies the central portion of the Watershed. The deeper sand-and-gravel layer appears to be absent. In this area, the sand-and-gravel layer appears to be laterally continuous between the Milwaukee River and Lake Michigan, rising to the surface under Ulao Creek and the major tributary to Ulao Creek near the State Highway 32/Interstate Highway 43 interchange. The elevation of the Milwaukee River begins to decrease rapidly south of Grafton, decreasing the available head which causes water to migrate from the river to the east. Consequently, water flux from the river to ground water is expected to decrease to the south. Ulao Creek probably does not receive substantial contributions of ground water from the sand-and-gravel layer south of the center of Section 20, and probably loses water to the sand and gravel in this area during extended dry periods.

Water in the sand-and-gravel layer which does not discharge to Ulao Creek or the Ulao Swamp likely continues east to Lake Michigan in the sand-and-gravel layers. These layers likely outcrop near the base of the bluffs in this area. Since the sand and gravel appears to become finer textured to the east, it will be less capable of transmitting water. Some water is expected to migrate downward into bedrock.

Somewhere near the southern border of Section 20, sand-and-gravel layers become less extensive, and the sand and gravel underlying Ulao Creek is no longer in hydraulic communication with deeper layers. In this area, little ground-water/surface-water interaction is expected to take place

Water flow in the bedrock appears to be influenced by variations in the bedrock's texture which are related to the Waukesha Fault, and possibly by the unmapped presence of Thiensville Formation rocks. Water in the bedrock is drawn towards more permeable areas, portions of which are found below Sections 16, 17, 28, and 29, which are hydraulically connected to Lake Michigan (the regional ground-water discharge area). These permeable rock areas probably transmit substantial quantities of ground water to Lake Michigan, possibly explaining the deeply depressed ground-water elevations noted in these areas.

6.3.2.3 Southern Areas

Although the bed of Ulao Creek is paralleled and underlain by sand-and-gravel deposits in the southern third of the Watershed, these deposits are not known to be in good hydraulic connection with the Milwaukee River or Lake Michigan. A deeply buried sand-and-gravel layer does underlie most of this area. However, under portions of Section 20 and 29, it is in contact with a permeable bedrock unit which drains to Lake Michigan. Consequently, much of the ground water in the sand and gravel appears to enter this bedrock and drain to Lake Michigan.

In the extreme southern portions of the Watershed, a gravel, sand, and silt layer is found directly below Kewaunee Formation diamicton. This granular area becomes finer grained to the east, losing its ability to transmit water. This sand-and-gravel layer is also separated from the bedrock by non-permeable diamicton. Moreover, the bedrock in the southern portions of the Watershed is comparatively impermeable. Since the sand-and-gravel layer is believed to be hydraulically connected to the Milwaukee River, and since it is not connected to a known discharge area, it likely does not transmit large volumes of water.

The shallow sand-and-gravel layer is not known to be in extensive contact with the sand and gravel underlying Ulao Creek. However, the separating clayey layers are likely missing in limited areas, creating "windows" between the buried sand-and-gravel layer and surficial sand and gravel along Ulao Creek. Ground water likely discharges to the surficial sand and gravel forming the bed of Ulao Creek through these windows. Consequently, Ulao Creek likely receives ground water in these areas.

6.4 Ground-Water/Surface-Water Interaction

6.4.1 Regional Interpretations

According to regional references, essentially all major watersheds in eastern Wisconsin receive flow from ground water (Skinner and Borman, 1973). According to Skinner and Borman, watersheds which lose water are normally occupied by extensive wetlands, which transpire large volumes of water. The Milwaukee River and its tributaries are fed by ground water in all reaches north of Saukville. In the Town of Grafton, and between Thiensville and Milwaukee, regional ground-water contours and streamflow records demonstrate that the Milwaukee River loses flow to ground water (Young and Batten, 1980) (Skinner and Borman, 1973).

The volume of water the Milwaukee River loses to ground water in the Town of Grafton can be estimated from regional data. The Grafton-area losing subbasin includes the Milwaukee River channel between State Highway 33 and County Highway C; Cedar Creek from State Highway 60 downstream to its confluence with the Milwaukee River; and Mole Creek. This area covers approximately 25 square miles. Between October 2 and 4, 1968, this subbasin lost 0.18 cubic feet per second (cfs) per square mile (Skinner and Borman, 1973). This period was rather dry, when streamflow was maintained by slow release from ground-water storage. Consequently, the Milwaukee River lost at least 4.5 cfs to ground water in the Saukville to Grafton reach.

The actual volume of river-water recharge lost to ground water in the Saukville to Grafton subbasin is likely higher than 4.5 cfs. Some of the actual loss is offset by contributions from Mole Creek, the Grafton and Saukville Sanitary Treatment Plants, and small seeps and tributaries which are known to enter the river from the west just south of Saukville. By making additional calculations and assumptions, a better estimate of the volume of river water recharging ground water during early October 1968 can be computed.

The combined discharge of Saukville's and Grafton's Waste Treatment Plants averaged 0.9 cfs during 1967 (SEWRPC, 1970). Ground water actively discharges to the Milwaukee River's west bank south of Saukville and to Mole Creek. Consequently, these areas undoubtedly contribute water to the river during dry weather. If we presume that the area west of the Milwaukee River contributes water at the same rate as an adjacent basin (0.08 cfs per square mile), Mole Creek, and direct discharge to the Milwaukee River south of Saukville, add 0.8 cfs to the river's flow. With these adjustments, the Milwaukee River between Grafton and Saukville lost 6.2 cfs (2800 gallons per minute [gpm]) to ground water during early October 1968.

The volume of ground water discharging to Lake Michigan along the Wisconsin shoreline has been estimated (Rovey, 1990). The Town of Grafton is near the juncture of two modeled reaches. Ozaukee County's shoreline north of the Waukesha Fault was estimated to discharge approximately 20 gallons per day per foot of shoreline. The shoreline south of the fault was estimated to discharge less, approximately 13 gallons per day per foot of shoreline. The Town of Grafton has approximately 6.2 miles of Lake Michigan shoreline, all of which is south of the Waukesha Fault, yielding a discharge of 0.7 cfs. Even with the higher discharge estimate of 20 gpm/foot, the total ground-water discharge to Lake Michigan along the Town of Grafton shoreline is only 1.0 cfs.

Comparing Rovey's estimate with the computed water loss to the Milwaukee River, one will see that between 5.2 and 5.5 cfs (between 2300 and 2500 gpm) of ground water are "unaccounted." One probable explanation is underestimation of the contribution of glacial sediments and surface-water recharge in Rovey's model. Another probably more important factor is that much of the water lost by the Milwaukee River in the Town of Grafton re-enters the river to the south of the Town of Grafton. Nevertheless, these comparisons demonstrate that substantial quantities of ground water may discharge, or could discharge, to the surface in the Watershed.

6.4.2 Historical Information

According to long-time residents of the Watershed, perennial springs were formerly common in the valley north of Ulao Road. Some residents recall that a fairly large spring discharged from an area now buried by the eastern abutment of the Arrowhead Road/Interstate Highway 43 overpass. This spring ceased flowing after construction of Interstate Highway 43, although numerous attempts were needed to quell the flow.

Flowing wells were present at the WEPCO Ash Landfill. According to WEPCO records, a 6-inch diameter borehole drilled near the marsh and directly east of the landfill flowed approximately 120 gpm. This water was believed to issue from a buried sand-and-gravel layer. This borehole was abandoned by filling with concrete during the mid-1980s.

Water elevations in WEPCO's eastern-most monitoring wells continue to be above grade, demonstrating that artesian conditions persist at the site. Additionally, during early 1997, construction dewatering at a flow rate of over 100 gpm for cell construction appears to lower the water table to a depth no less than the adjacent Ulao Swamp, again suggesting artesian conditions persist.

Watershed residents state that even though the headwater portions of Ulao Creek flow perennially, a stretch south of Ulao Road ceases flowing during droughts. This asserts that the stretch of Ulao Creek south of Ulao Road loses flow to ground water during all or parts of the year.

6.4.3 Watershed Conditions

In the Town of Grafton, ground water interacts with surface water, either supplying dry-weather stream flow or reducing stream flow. Table 2 summarizes important interactions, segregating them into two groups: areas where surface water infiltrates the ground, and areas where ground water discharges to the surface as springs, seeps, and wetlands.

One of the most important findings of this study is that the Milwaukee River appears to lose significant volumes of water to ground water in the Town of Grafton, corroborating regional findings (Young and Batten, 1980) (Skinner and Borman, 1973). Watershed-specific ground-water elevation contours (Figure 6) show that water leaves the Milwaukee River above the Grafton Dam. Some of the water likely re-enters the river downstream of the dam, but much flows east and southeast. The river again loses water in a short stretch near its confluence with Cedar Creek, but begins gaining water from regional flowpaths at the extreme southern edge of the study area. An artesian well present near the Milwaukee River in the extreme southwest corner of Section 31 further evidences that ground water actually discharges to the Milwaukee River in this area.

Ground-water elevations and measured creek discharge volumes reveal that ground water discharges to Ulao Creek in the northern half of the Watershed. Much of this discharging ground water is believed to be the water lost from the Milwaukee River, a short distance to the west. A thick continuous sand-and-gravel layer exposed below and near the Milwaukee River extends below intervening highlands, and is exposed as surficial sand-and-gravel deposits near the north end of the Ulao Swamp. For illustration, one outcropping of this layer is presently being mined at the extreme northern end of the Ulao Swamp (Section 4). This granular layer hydraulically interconnects the Milwaukee River to the western flank of the northern portion of the Ulao Swamp. Consequently, water infiltrating into the bed of the Milwaukee River can re-emerge and accumulate into the Ulao Swamp.

Farther to the south, the sand-and-gravel layer is buried by clayey diamicton and organic sediment below the swamp, impeding ground-water discharge. The sand and gravel does outcrop just east of Interstate Highway 43, which probably accounts for the former springs at the Arrowhead Road overpass, and possibly for the current "wet field" conditions noted on the Helmer property. Furthermore, since the sand and gravel is "capped" by impermeable clays under the southern portions of the swamp, the artesian conditions noted by WEPCO in a buried sand-and-gravel layer are likely a known expression of this phenomenon.

Variations in sediment layering make it difficult to estimate the total flux of ground water to the Ulao Swamp. However, the geologic cross sections suggest that the sand-and-gravel lenses connecting the Milwaukee River to the Ulao Swamp are as little as 10 feet thick. With the known gradient and hydraulic conductivity, such a thin layer would only be able to transmit slightly more than 3 gallons per lineal foot per day. Assuming that the Ulao Swamp extends 15,000 feet north to south, the sand-and-gravel layer could deliver approximately 47,000 gallons per day (33 gpm) to the swamp from the river. This value is substantially lower than Ulao Creek's discharge at the south end of the Ulao Swamp measured on September 6, 1997 (92 gpm). Since the sand-and-gravel layer is in direct contact with the Niagara Aquifer in some areas, or is separated from it by a relatively thin sheet of clayey till, water from the Niagara Aquifer must also discharge to the sand-and-gravel layer and then to the swamp.

An interesting corollary to the Milwaukee River/Ulao Creek discharge relationship relates to the perceived increase of the extent and level of saturation of wetlands in the northern reaches of the Watershed. The Grafton Dam creates a millpond with a surface elevation approximately 16 feet higher than the original river bed. This backwater area undoubtedly accentuates water loss from the river. In the past, ground water likely discharged to deeply incised portions of the Milwaukee River. The backwaters created in these areas by the Grafton Dam, the Chair Factory Dam, and the Lime Kiln Dam reversed flow, causing water to leave the river channel. Therefore, the dams likely increased the volume of water lost from the Milwaukee River, increasing the volume of water which could be transmitted east to Lake Michigan and the Ulao Swamp.

Evaluating ground-water flowpaths and surface elevations, the most pronounced increase in discharge to the Ulao Swamp would likely occur south of Ulao Parkway and north of Ulao Road. Ground-water flow velocities imply that it takes approximately 90 years for water infiltrating into the bed of the river to re-emerge at the Ulao Swamp (Section 6.3.2.1). The present dam was built during 1861, replacing an earlier dam built during 1847 (SEWPRC, 1970), both of which were built upon bedrock. Consequently, the initial increase in ground-water flux to the Ulao Swamp should have been evident sometime between the 1940s and the 1950s.

Since the river channel and dam rest upon bedrock, the river is likely in good hydraulic communication with the Niagara Aquifer. Assuming that the Grafton Dam millpond extends 1 mile upstream, that the average increase in water depth is 8 feet, and that 40 feet of elevation difference formerly existed between the original water surface of the Milwaukee River and the Ulao Swamp, backwatering caused by the dam would increase discharge of water from the river to the southern portion of the swamp by at least 20 percent. This estimate is likely low because it does not account for ground-water flowpath changes upstream and downstream of the Grafton Dam, and does not account for the other Grafton-area dams.

Stream gaging reveals that ground water discharges to Ulao Creek in the very southern portion of the Watershed. This ground water is likely migrating through sand-and-gravel layers from the Milwaukee River. This flow increase may also represent ground water migrating in granular soils paralleling the creek. The cross sectional area of sand-and-gravel deposits paralleling the creek decreases to the south decreasing their ability to transmit water, likely forcing some ground water to the surface.

Interestingly, ground-water contours do not suggest a strong discharge of water to the Ulao Swamp as a whole but instead suggest a flow-through situation. Coupling this finding with other data suggests that ground water discharges to the western edge of the swamp, some of which flows south forming the headwaters of Ulao Creek. However, much of the water likely re-enters the ground under the eastern edge of the swamp, particularly under the eastern appendages of the swamp which extend to areas near Stonecraft (Section 4), Lancaster Court (Section 9), and the Waterfowl Refuge (Section 16). Even though clayey soils underlie the eastern portions of the Ulao Swamp, a strong downward vertical gradient and large surface area still allow substantial volumes of water to infiltrate into soil. Referencing soils data (USDA, 1970), the surficial weathered clayey soil of the Kewaunee Formation exhibit hydraulic conductivities no less than 4×10^{-5} cm/sec. Assuming a maximum vertical hydraulic gradient of 1 and that the eastern portions of the Ulao Swamp rest upon weathered Kewaunee Formation clay, these areas could lose up to approximately 0.9 gallons per day per square foot (27 gpm per acre).

Some of the ground water that formerly discharged to the Watershed is likely diverted north by drainage ditches excavated near the northern edge of the Ulao Swamp. Topographic maps suggest that drainage ditches were cut east to west across the very northern edge of the forested portion of the Ulao Swamp, draining water from the swamp to topographically lower areas in the extreme northern edge of Section 4. Even though these ditches do not likely divert significant volumes of surface water from the Watershed, they likely drain soils, lowering ground-water elevations. These ditches extend to areas near the western flank of the Ulao Swamp, a strong ground-water discharge area. Consequently, by lowering the water table, these ditches could possibly divert significant portions of the total available ground-water discharge from the Ulao Creek Watershed to the Mineral Springs Creek Watershed.

A pond has recently been constructed at the northern edge of the Ulao Swamp as part of a gravel-quarrying operation. The present pond configuration is not illustrated on available maps. However, since portions of the pond are built within the strong ground-water discharge area just west of the Ulao Swamp, it undoubtedly influences ground-water flow. Topographic maps prepared during Spring 1994 show the pond during its initial phases, with a water-surface elevation just slightly above the elevation of water in the Ulao Swamp (i.e., 0.3 foot). Since these maps were prepared, the pond was greatly enlarged to the east, closer to the headwater of Mineral Springs Creek. Now the pond extends from a strong ground-water discharge area in the Ulao Creek Watershed to a gravelly area in the Mineral Springs Creek Watershed. Ground water in the Mineral Springs Creek Watershed likely flows north under a moderately steep horizontal gradient, a gradient much steeper than that found to the south under the Ulao Swamp. Therefore, ground water discharging to the pond would be more likely to migrate north towards Mineral Springs Creek, diverting flow from the Ulao Swamp. Consequently, the flux of ground water to the Mineral Springs Creek Watershed has likely been increased, decreasing flow to the Ulao Creek Watershed. Much of the flow transferred to the north is not visible at the surface, but instead flows through the extensive sand-and-gravel deposits which continue north to Port Washington and Lake Michigan. Therefore, the increased discharge of water to the Mineral Springs Creek Watershed would not necessarily be evident as visibly increased flow in Mineral Springs Creek.

7.0 WATERSHED MANAGEMENT IMPLICATIONS

The primary goals of this study were to identify techniques to reduce flooding, increase dry-weather baseflow, and improve summer stream water quality. Possible strategies to achieve these goals are discussed in the following sections.

7.1 Flood Reduction

The Watershed's hydrogeologic resources can be used to help reduce flood-water volume and increase the time of concentration of surface runoff. Most management alternatives complement traditional storm-water management options. Opportunities exist to store storm water for later release, and to pass storm water to the subsurface and out of the Watershed.

7.1.1 Temporarily Store Flood Water as Ground Water

Three methods can be used to temporarily store flood water as ground water. One option utilizes the unsaturated sand-and-gravel deposits which are primarily found along the western flank of the Ulao Swamp, Ulao Creek itself, and at the mouths of the creek's major tributaries. Another option involves modifying agricultural drainage ditches and tile systems. The third option involves maximizing storm- and melt-water infiltration in areas west of Ulao Creek.

Detain Water in Granular Deposits

Unsaturated sand-and-gravel deposits have significant volumes of pore space which are occupied by air. Many deposits in the Watershed are so situated that they never contact significant quantities of water. The locations of these sand-and-gravel deposits are illustrated in Plate 2. Since many of the unsaturated sand-and-gravel deposits are near the mouths of major tributaries, storm-water detention ponds, low dams, or other structures could be located and designed to divert surface-water flow into these deposits. Water could be detained in the granular deposits and slowly released. Available data suggest that up to 150 acre-feet of storm water could theoretically be detained in this manner.

Unfortunately, many of the best unsaturated sand-and-gravel deposits were mined, or have been selected as sites for development. Furthermore, many of the remaining undeveloped/unmined sites are located in areas which are difficult to utilize for storm-water storage. Consequently, even though these deposits could theoretically store 150 acre-feet of storm water, the actual volume which can be stored with existing Watershed conditions is probably much less. Some of the best remaining opportunities for storing storm water are found in the following areas.

- On the western flank of the Ulao Swamp in southeastern Section 5 and northeastern Section 8.
- In southeastern Section 20, east of Ulao Creek at the mouth of a major tributary.

- In southeastern Section 32, east of Ulao Creek, at and near the mouth of a major tributary.

Small pockets of unsaturated granular deposits flank many portions of the lower reaches of Ulao Creek, primarily in Sections 17, 29, and 32. These deposits are not located at the mouths of major tributaries, and are therefore not well positioned for extensive development. However, these deposits could be used to store runoff entering the creek from minor tributaries without intensive effort. For example, simply removing or thinning overlying fine-grained layers, slowing surface-water velocity, and/or increasing channel length or width may allow significant portions of surface water to enter these granular deposits.

Modify Agricultural Drainage Systems

Agricultural drainage tiles and ditches lower ground-water elevations to improve field access and production. Drainage systems could be modified to delay transport of storm and melt water from fields to the creek without completely defeating their purpose. For example, flow restrictors could be installed in tiles and ditches to limit peak flow, causing temporary backwatering and storm-water storage in lowlying areas, yet allowing drainage within a reasonable time period.

Plate 2 identifies fields which exhibit soil coloration suggestive of tile networks. Individual tile locations can be identified by carefully reviewing aerial photographs.

Promote Surface-Water Infiltration

Most of the Watershed is covered with relatively thick layers of low permeability clay. Even though the clay does not have high unit-area infiltration rates when compared to granular sediment, it does cover extensive areas. Consequently, the overall flux of water infiltrated through clayey soils can be appreciable, if infiltration is encouraged over large areas. As previously calculated (Section 6.4.3), weathered clayey soils of the Kewaunee Formation can accept approximately 27 gpm per acre. Ground water underlying areas between the Milwaukee River and Ulao Creek discharges to the Ulao Swamp, Ulao Creek, the Milwaukee River, or to Lake Michigan. Encouraging infiltration, particularly in the northwestern corner of the Watershed (Sections 5 and 6, and to a lesser extent, Sections 7 and 8), increases the volume of water available to discharge to the Watershed and reduces runoff volumes. Many methods can be developed to encourage infiltration. Methods which slow runoff give soils more time to absorb water, increasing infiltration and decreasing storm-water flow to Ulao Creek. Example techniques are listed below.

- Alter agricultural drainage tile and ditches. Detain water in tiles, ditches, and lowlying areas as long as practical, giving the water as long as possible to percolate into deeper sediment.

- ▲ Maximize the Watershed area occupied by tributary channel beds, flood plains, wetlands, and ponds. Intermittent tributaries should be as long and as broad as practical. Narrow, straight ditches should be discouraged.

- ▲ Delay runoff as long as possible in existing depressions and wetlands.

Detaining water in granular deposits, in tiled and lowland areas, in wetlands and ponds, and in the sediments underlying the western uplands increases watershed time of concentration. This stored water would be released slowly, increasing dry-weather flow.

7.1.2 Transfer Flood Water Out of The Watershed

In most of the eastern portion of the Watershed, surface water which infiltrates to the Niagara/Sand-and-Gravel Aquifer discharges directly to Lake Michigan. This phenomena could be utilized to reduce the volume of storm or melt water discharging from the Watershed via Ulao Creek. Many areas are well suited to help transfer flow out of the Watershed. Many of the techniques and modifications needed to promote transfer complement traditional storm-water detention techniques. Example applications are listed below.

Detain Water in the Eastern Appendages of the Ulao Swamp

The eastern margin of the Ulao Swamp is punctuated with at least three significant embayments. These embayments are believed to lose water via ground-water infiltration directly to Lake Michigan. Since the mouths of the embayments are rather narrow, limited earthwork would be needed to construct detention ponds in the areas. These ponds would be designed to slow runoff and hold water, allowing increased infiltration. Since the embayments cover approximately 110 acres, and since available information suggests that underlying soils can infiltrate 27 gpm per acre, this management alternative could reduce storm flows by approximately 3000 gpm (6.7 cfs). Actual peak flows would be further reduced by the buffering effect of storm-water storage in the detention ponds.

Slow Runoff from Areas East of Ulao Creek and the Ulao Swamp

Even though most soils under the Watershed are clayey, the total area underlain by clayey sediment can absorb large volumes of water. Much of the water which infiltrates in the ground east of Ulao Creek migrates directly to Lake Michigan. Slowing runoff gives soils more opportunity to absorb water, increasing infiltration and decreasing storm-water flow to Ulao Creek. Many techniques could help increase infiltration. Example techniques are listed below.

- ▲ Alter agricultural drainage tile and ditches. Detain water in tiles, ditches, and lowlying areas as long as practical, giving the water as long as possible to percolate into deeper sediment.

- Maximize the Watershed area occupied by tributary channel beds, flood plains, wetlands, and ponds. Intermittent tributaries should be as long and as broad as practical. Narrow, straight ditches should be discouraged.

- Encourage flood-water infiltration along Ulao Creek in southern Section 20 and northern Section 29. Granular sediments in these areas are hydraulically connected to Lake Michigan. Removing or thinning surficial fine-grained sediment would increase infiltration rates. Excavated off-stream ponds and wetlands would provide ideal infiltration basins. These areas must not be directly connected to the creek to avoid reducing dry-season flow.

- Delay runoff as long as possible in existing depressions and wetlands.

7.2 Base-Flow Augmentation

Ulao Creek's dry-weather flow is very low and reportedly becomes intermittent in southern Section 20. The creek contains considerable numbers of fish, including game fish (Johnson, 1996). Low flow stresses this fish population. Increasing dry-weather flow should improve water quality and benefit the existing fish population.

Many options are available to increase the volume of water flowing in Ulao Creek during dry periods. These options can be segregated into two groups: options which decrease dry-weather water losses from the Watershed, and options which increase the volume of ground water discharging to the Watershed.

7.2.1 Decrease Dry-Weather Infiltration

Many of the techniques which could be used to divert storm and melt water out of the Watershed could potentially decrease Ulao Creek's dry-weather flow. However, careful modification could allow these features to continue to divert storm and melt water yet not reduce Ulao Creek's dry-weather flow. Examples of possible management techniques are described below.

Minimize Ground-Water Diversion to Mineral Springs Creek Watershed

As discussed in Section 6.4.3, drainage ditches and gravel quarrying has likely influenced ground-water flowpaths in the northern-most reaches of the Watershed. Whereas ground water formerly discharged to the Ulao Swamp, the ground-water table has probably been depressed and now slopes to the Mineral Springs Creek Watershed. Ground-water diversion to the Mineral Springs Creek Watershed would be reduced if ground water is intercepted and provided with a preferential flowpath discharging far into the Ulao Swamp. Although this could be accomplished in a multitude of ways, perhaps the simplest and least intrusive method would involve forming a low permeability barrier at the extreme northern boundary of the Watershed. This barrier could be constructed physically (such as burying a geomembrane vertically, filling a trench with clay, or forming a grout curtain) or hydraulically (by forming a perennial wetland or pond which in turn raises the water table). A buried impermeable barrier would not alter surface-water flowpaths, but would likely raise the ground-water table to the south, enhancing or expanding wetlands.

Ditches, pipes, or other means could also be used to alter ground-water flow directions by providing a preferred flowpath to topographically low areas well into the center of the Ulao Swamp. Obviously, such an approach would likely necessitate significant excavation in the Ulao Swamp, which is not desirable for many reasons. Nevertheless, the north-south trenching ditch that <u>already</u> exists in the center of the Ulao Swamp, in the southwest quarter of Section 4, probably does enhance ground-water discharge to the Watershed. Therefore, this ditch should <u>not</u> be blocked unless the Ulao Creek Partnership determines that decreasing dry-weather creek flow is acceptable.

<u>Reduce Dry-Weather Flow to Eastern Portions of the Ulao Swamp</u>

The Ulao Swamp has at least three major embayments which extend to the east. These appendages act as tributaries during wet periods, contributing flow to Ulao Creek. However, water in the eastern portion of the Ulao Swamp infiltrates into the ground discharging directly to Lake Michigan. Available data suggest that during dry periods, surface water stops flowing from eastern portions of the Ulao Swamp and instead flows east out of the main body of the swamp. This water then infiltrates into the ground and passes directly to Lake Michigan. This finding suggests that a significant portion of the water available to support Ulao Creek's dry-weather baseflow is being lost to ground water.

Although it is not practical or feasible to significantly reduce infiltration under the main body of the Ulao Swamp, infiltration could easily be reduced under the swamp's eastern appendages by preventing backflow into these areas during low water periods. This could be accomplished by constructing low dams where these appendages open to the Ulao Swamp. This strategy complements flood and storm-water management as discussed in Section 7.1.2.

If artificial channels, wetlands, ponds, or other structures are constructed in or near the Ulao Swamp, these features should be constructed on or near its western periphery. If water is stored or conveyed in the eastern portions of the swamp, structures must be designed to control surface-water infiltration during dry periods.

<u>Minimize Dry-Weather Losses from Ulao Creek</u>

In southern Section 20, a laterally continuous sand-and-gravel lens forms the bed of Ulao Creek and is believed to draw water from the creek, transferring it to Lake Michigan. This sand-and-gravel lens causes the stream to completely cease flowing during dry weather. Although it is not practical or likely desirable to modify this relationship, it should be kept in mind when designing new wetlands, ponds, or channel modifications in this area. Such features must be designed to minimize low-flow infiltration of creek water. Therefore, they should prevent backflow of water from the creek during low flow.

7.2.2 Increase Ground-Water Discharge

Ground-water discharge is the sole source of water to Ulao Creek during dry periods. Several opportunities exist which could be developed to increase ground-water discharge to the Ulao Swamp, Ulao Creek, and certain tributaries.

Promote Artesian Ground-Water Discharge Near Ulao

The Milwaukee River loses significant volumes of water to bedrock and granular layers in the Town of Grafton. Bedrock facies changes promote upward ground-water flow, also promoting ground-water discharge. Although ground water can freely discharge to the surface under the northern portions of the Ulao Swamp, a surficial clay layer hinders discharge in Section 17 and portions of Section 8. Moreover, construction of Interstate 43 capped natural discharge areas, and erosion of fine-grained soils with attendant redeposition in lowlands near Ulao Creek further restricts ground-water discharge.

Data available from the WEPCO Ash Landfill demonstrate that the sand-and-gravel layer is not buried deeply in Section 8, and can produce at least 100 gpm over sustained periods from a single point. Undoubtedly, the sand-and-gravel layer can support several such discharge points if they are strategically located. Ground-water discharge from the sand-and-gravel layer can be promoted by several methods. The suitability of each method depends upon how deeply the sand and gravel is buried and by the surface elevation of the area of interest. Examples of strategies to increase artesian discharge include:

- Complete wells in the sand-and-gravel layer. These wells would need to be drilled in areas where surface elevation is low (e.g., less than 700 feet msl), or would need to be piped to a low elevation discharge point. Some existing wells could be utilized, if modified.

- Install interceptor drains. In areas where the sand and gravel is buried less than 15 or 20 feet, piping could be laid to intercept water and transmit it to a suitable low elevation discharge point.

- Remove impermeable overburden. In some areas, granular sediments are present below lowlying areas, but are capped by clay and silt. In such areas, the capping impermeable sediment could be breached by elongating and/or widening stream channels, or by excavating ponds or wetlands and providing them with low elevation discharge points.

Developing the artesian-water resources near Ulao would likely decrease the diffuse discharge to perennially wet areas, such as low areas of the Helmer property. This change will likely decrease evapotranspiration, also increasing flow available to support Ulao Creek during dry periods.

Promote Ground-Water Discharge Near Lakefield

In Sections 29 and 32, Ulao Creek is underlain by sand-and-gravel deposits which parallel the creek, but which are not believed to be hydraulically connected to more deeply buried, laterally extensive permeable layers. Consequently, ground-water flow in the sand and gravel parallels Ulao Creek, ultimately discharging to the Milwaukee River south of the Town of Grafton.

The baseflow of Ulao Creek could be increased by forcing some of the water flowing in the sand and gravel paralleling Ulao Creek to the surface. This could be done by excavating a trench perpendicularly across the deposits, and installing an impermeable material, such as clay or a geomembrane. Alternately, grout could be injected to form an impermeable zone. The impermeable zone would extend from the gravel/clay interface to near the surface. Ground water would thereby be forced to rise to the surface and discharge to the creek. This modification should not significantly alter flood-water flow in the Watershed.

Available data suggest that approximately 2 gpm of flow could be induced to flow into the creek at Lakefield Road. This flow is essentially negligible, making the utility of the approach questionable at Lakefield Road. Some of this water, which is forced to discharge, will re-enter the sand and gravel downstream of the diversion. Nevertheless, such structures would help guarantee that at least some stretches of the creek will always flow perennially. A series of structures could be used to assure perennial flow in all stretches of the creek. Substantial site-specific study would be needed to fully evaluate this possibility.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The Watershed has naturally occurring resources which could be used to help reduce flooding and increase dry-weather baseflow and water quality. Many of the approaches to develop these resources complement traditional storm-water and watershed management practices. Careful selection of sites for storm-water detention and wildlife ponds, channel modifications, drain tile and ditch modifications, wetland restorations, and other features will produce manifold benefits. Furthermore, relatively small efforts focused at strategic features can substantially increase ground-water discharge to the Watershed.

To stabilize the flow of Ulao Creek, Northern Environmental recommends that the following approach be followed in the order listed.

1. Minimize Dry-Weather Losses of Stream Flow to Ground Water

   As discussed in Section 7.2.1, several strategies would reduce dry-weather infiltration of surface water. If infiltration is reduced, dry-weather flow will increase. These options should not significantly affect flood volume.

   Methods to reduce dry-weather stream flow losses to ground water include addressing the artificially enhanced ground-water discharge to the Mineral Springs Creek Watershed, discouraging dry-weather flow of surface water to infiltration areas such as the eastern appendages to the Ulao Swamp, and assuring that perennial sections of the creek are not modified to enhance dry-weather losses. The ditch in the center of the Ulao Swamp in Section 4 probably limits dry-season ground-water flow diversion from the Watershed and should not be blocked.

2. Maximize Storm-Water Infiltration

   Urbanization typically causes storm-water runoff volume to increase by decreasing the ability of a watershed to pass surface water to ground water. This effect can be partially offset by enhancing infiltration in remaining conducive areas. In the Watershed, many opportunities exist to pass surface water to ground water. Very generally, water infiltrated west of Ulao Creek will partially re-emerge as increased dry-weather creek baseflow, while storm water infiltrated east of Ulao Creek will discharge directly to Lake Michigan. Water can also be detained in granular sediments which parallel Ulao Creek and will enter the creek gradually.

   Although development has occupied or irreversibly modified some of the best infiltration areas, storm-water detention ponds, channel modifications, wetland restorations, and drain tile/ditch modifications should be designed to maximize interaction with ground water. These features may need special provisions (e.g., forebays, treatment wetlands) to avoid compromising ground-water quality in certain areas.

3. Enhance Ground-Water Discharge

Ample opportunity exists to supplement Ulao Creek's baseflow. However, supplementing flow may be unnecessary to achieve acceptable dry-weather flow conditions for the indigenous cool-water species. Consequently, we do not recommend expending money or effort to enhance ground-water discharge unless the management options listed in items 1 and 2 have not improved conditions to acceptable levels.

If additional ground-water discharge is needed to achieve watershed management goals, the most effective approach would be to tap the buried sand-and-gravel lens located a short distance north of Ulao, or enhance flow to the Watershed further north where the sand and gravel is at or near the surface. Although the actual flow available from the sand and gravel is uncertain, data strongly suggest that it could perennially contribute at least 1 cfs. This supplemental flow alone is enough to enhance the existing cool-water habitat conditions, and would not significantly alter flood flows.

Regardless of the management options which are finally implemented in the Watershed, a critical component of evaluating and demonstrating progress is routine collection of relevant data. At present, no data are regularly and methodically collected in the Watershed which document the creek's hydraulic characteristics or water quality. Useful physical data which should be collected with volunteer help at little expense include:

- Flow volume
- Dissolved oxygen
- Temperature

A variety of other data, such as sediment load, water turbidity, chemical data (e.g., contaminant and nutrient concentrations), biological data (e.g., speciation of aquatic flora and fauna), watershed development and demographic trends, and streambank evaluation, would help document the effect of the various management options.

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FIGURES

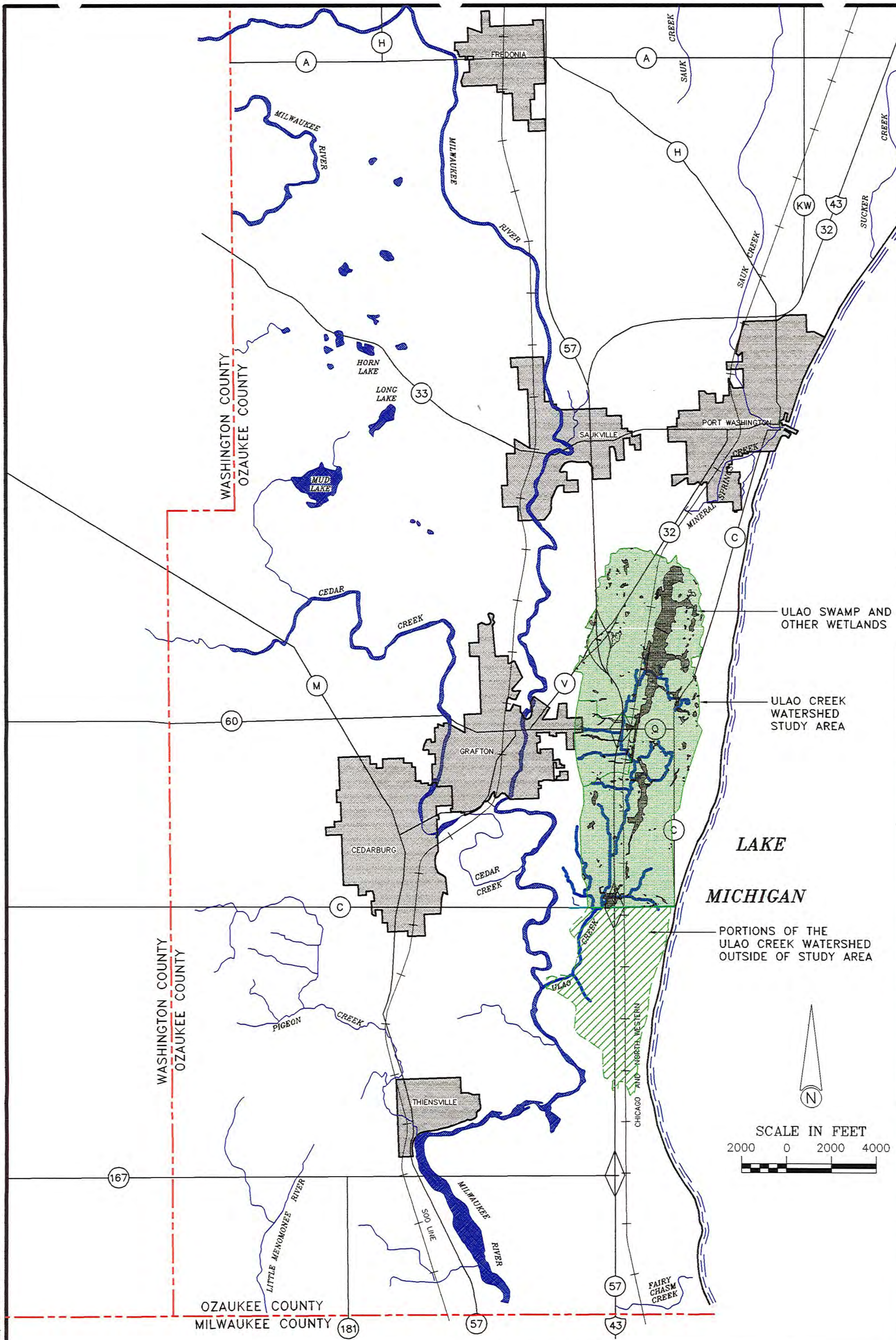

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FIGURE 1

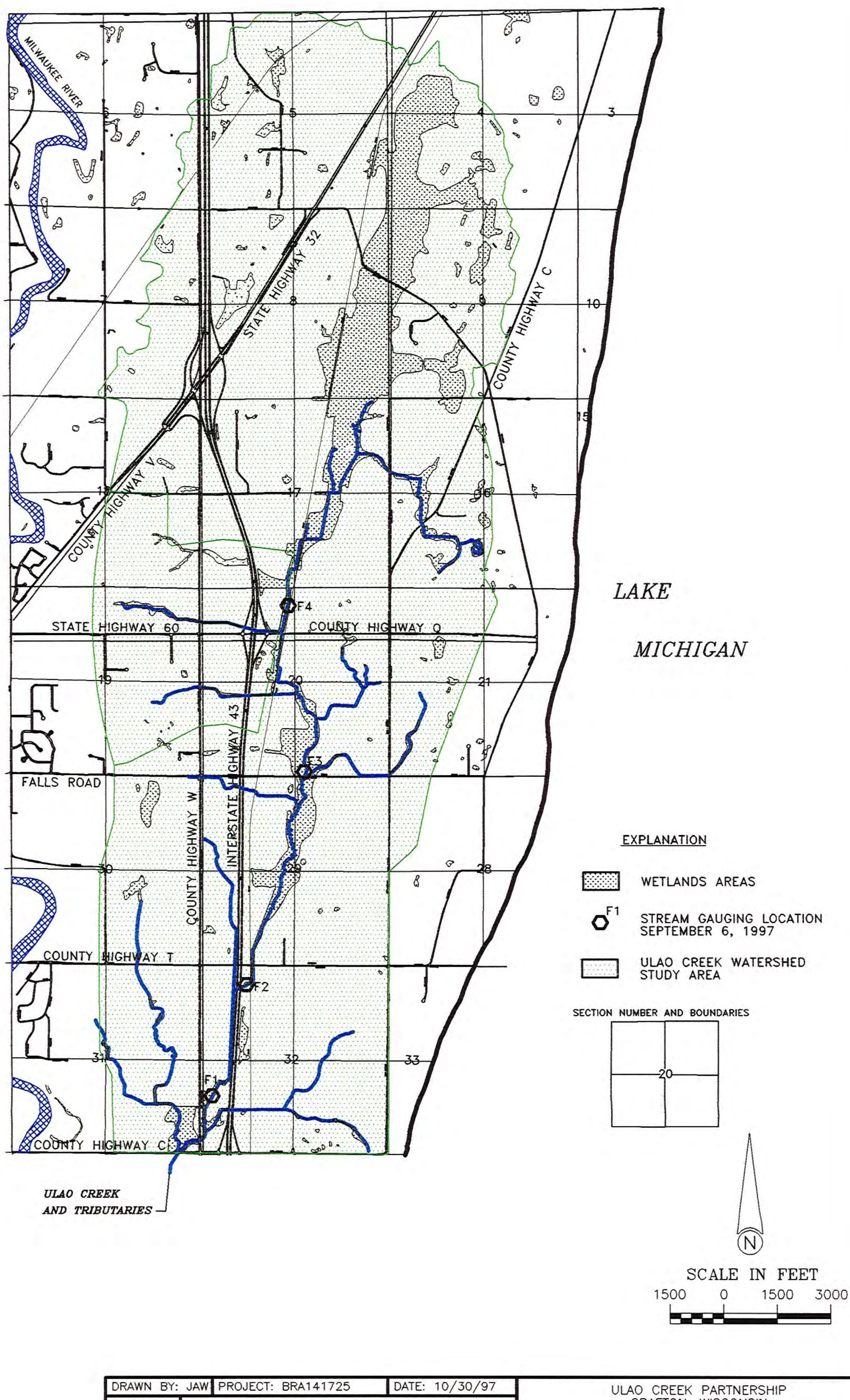

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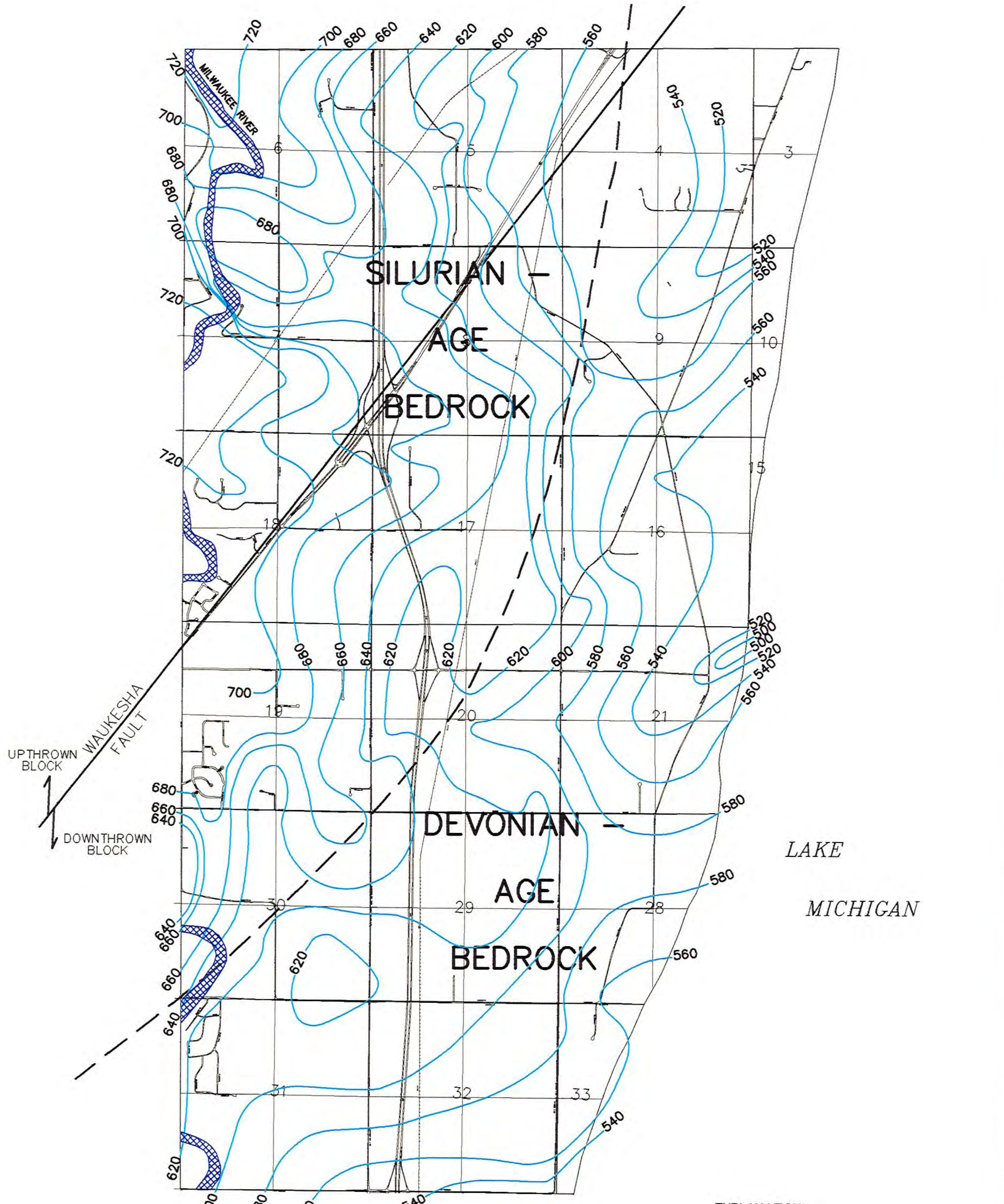
FIGURE 2



EXPLANATION:

20 — SECTION NUMBER AND BOUNDARIES

600 — BEDROCK ELEVATION CONTOUR, FEET ABOVE MEAN SEA LEVEL.

— — — APPROXIMATE EXTENT OF DEVONIAN–AGE ROCKS. LOCAL STRUCTURE WILL INFLUENCE THE ACTUAL EXTENT

NOTE:
1. LOCATIONS OF HIGHWAYS ARE ILLUSTRATED FOR REFERENCE ONLY.
2. LOCATION OF WAUKESHA FAULT AND DEVONIAN/SILURIAN DEMARCATION ADAPTED FROM ROVEY, 1990.
3. THE DEPICTED LOCATION OF THE FAULT AND EXTENT OF SURFICIAL ROCK TYPES ARE BASED UPON REGIONAL STUDIES. ACTUAL LOCATIONS WILL VARY.

N

SCALE IN FEET

1500 0 1500 3000

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FIGURE 3

Figure 4 Stratigraphy and Properties of the Niagara Aquifer, Ozaukee County, Wisconsin

Age	Formation Name	Lithology	Documented Thickness in Southern Ozaukee County	Extent	Hydrostratigraphic Unit	Hydraulic Properties	Aquifer Name
Devonian (365 to 415 million years before present)	Antrim	Shale	0	Very limited areal distribution. Only known to be present under a very small portion of east central Milwaukee County. May be present offshore under Lake Michigan.	Antrim	Aquitard K < 10^{-7} cm/sec	Not an aquifer
	Milwaukee North Point Member	Shale with Dolomite Interlayers	0	Underlies northeastern Milwaukee County and extreme southeastern Ozaukee County. Generally confined to areas east of the Milwaukee River except at Estabrook Park.	Lindwurm	Aquitard K < 10^{-7} cm/sec	Niagara Aquifer
	Lindwurm Member	Shale	0				
	Berthelet Member	Dolomite and Shaly Dolomite	0-?		Berthelet	Aquitard K = 10^{-4} to 10^{-5} cm/sec	
	Thiensville	Porous Dolomite	0-80	Underlies small areas in extreme southeastern Ozaukee County. Also isolated occurrence near Thiensville.	Thiensville	Aquifer K = 5 x 10^{-3} cm/sec	
	Lake Church Ozaukee Member	Nonporous Dolomite	0-40	Underlies a narrow (1-5 mile-wide) band along the Lake Michigan shoreline. Wider in southern Ozaukee County.	Lake Church-Racine	Aquifer paralleling fault (width 5 to 10 miles wide, mostly to north of fault) (K = 10^{-3} cm/sec) Aquitard north and south of Waukesha Fault (K = 1 x 10^{-5} cm/sec) Note: Analysis of data from wells within the Watershed yields the following values: weathered Lake Church/Racine: 2x10^{-3} cm/sec Racine Packstone-Grainstone Facies (Near Fault): 1x10^{-4} cm/sec Racine Mudstone Facies (Distant from Fault): 2x10^{-4} cm/sec	
	Belgium Member						
Silurian (415 to 465 million years before present)	Waubakee	Nonporous Dolomite	0-25	Underlies portions of central and northern Ozaukee County.			
	Racine Undifferentiated	Dolomite. Nonporous south of Waukesha Fault. Porous north of Waukesha Fault.	180-375	Underlies all of Ozaukee County. Undergoes facies change and thickens along Waukesha Fault.			
	Romeo Member	Porous Dolomite	0-20	Underlies southern Ozaukee County. Thickens near Waukesha Fault, pinches out north of fault.	Romeo	Aquifer K = 1 x 10^{-4} cm/sec, except basal portion which	
	Manistique Waukesha Member	Dolomite. Nonporous south of Waukesha Fault. Porous north of Waukesha Fault.	10-50	Underlies all of Ozaukee County. Undergoes facies change north of Waukesha Fault.	Waukesha - Byron	Aquitard south of Waukesha Fault. K = 5 x 10^{-6} cm/sec Aquifer north of fault (Manistique only) K = 1 x 10^{-4} cm/sec	
	Brandon Bridge Member						
	Franklin Quarry Member						
	Byron	Dolomite. Nonporous south of Waukesha Fault. Porous north of Waukesha Fault.	15-55	Underlies all of Ozaukee County. Thickens to the northwest.			
	Mayville	Porous Dolomite	95-120	Underlies all of Ozaukee County. Thickens to the northwest.	Mayville	Aquifer K = 3 x 10^{-4} cm/sec	
Ordovician (465 to 510 million years before present)	Maquoketa	Dolomitic Shale	195-205	Underlies all of Ozaukee County.	Maquoketa	Not an aquifer	Not an aquifer

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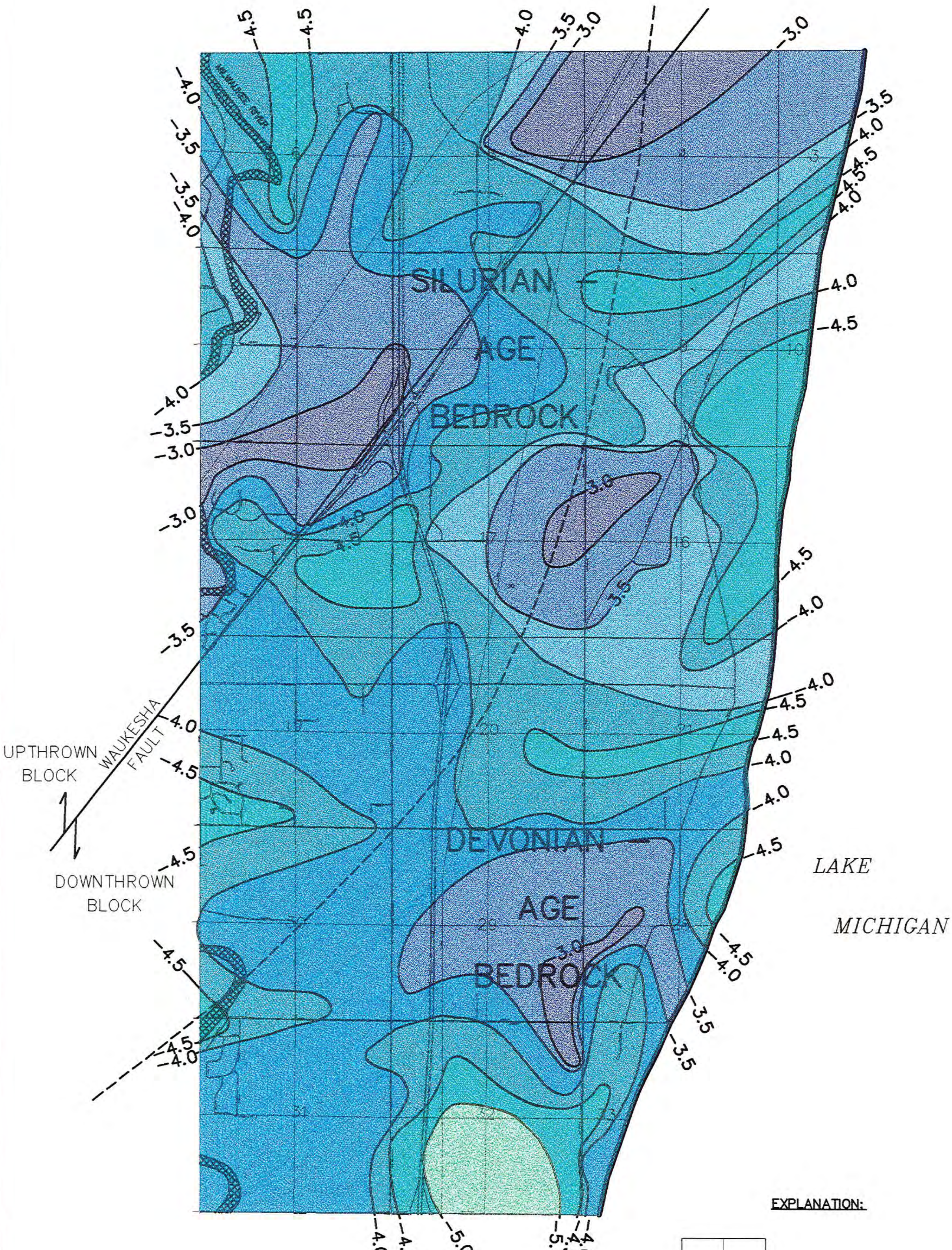

EXPLANATION:

20 SECTION NUMBER AND BOUNDARIES

-4.0 BEDROCK HYDRAULIC CONDUCTIVITY CONTOUR. VALUES EXPRESSED AS LOG BASE 10, CENTIMETERS PER SECOND.

APPROXIMATE EXTENT OF DEVONIAN-AGE ROCKS. LOCAL STRUCTURE WILL INFLUENCE THE ACTUAL EXTENT.

NOTE:
1. LOCATION OF HIGHWAYS ARE ILLUSTRATED FOR REFERENCE ONLY.
2. LOCATION OF WAUKESHA FAULT AND DEVONIAN/SILURIAN DEMARCATION ADAPTED FROM ROVEY, 1990.
3. THE DEPICTED LOCATION OF THE FAULT AND EXTENT OF SURFICIAL ROCK TYPES ARE BASED UPON REGIONAL STUDIES. ACTUAL LOCATIONS WILL VARY.

N

SCALE IN FEET
1500 0 1500 3000

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FIGURE 5

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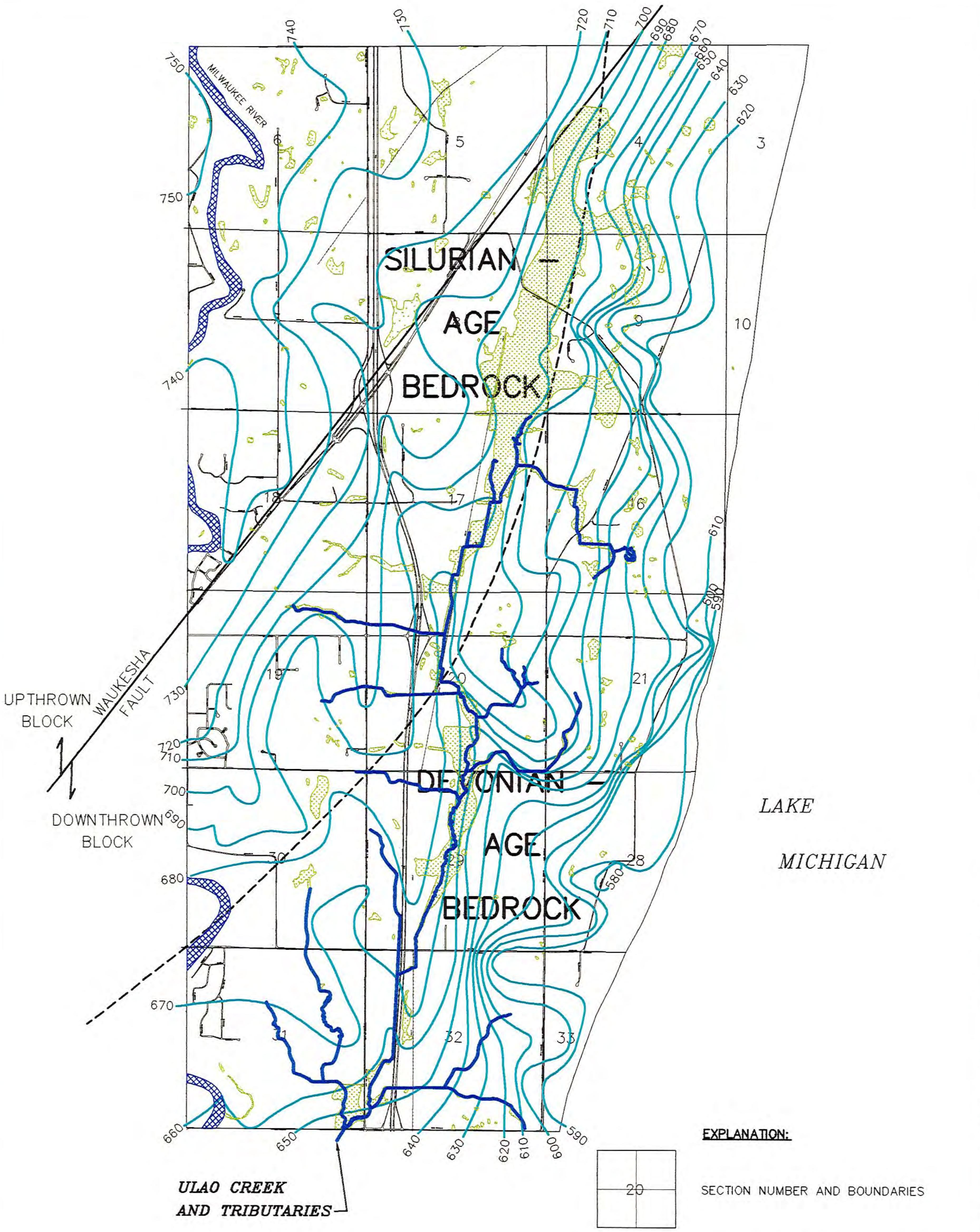

EXPLANATION:

20 SECTION NUMBER AND BOUNDARIES

600 GROUND–WATER ELEVATION CONTOUR FEET ABOVE MEAN SEA LEVEL

APPROXIMATE EXTENT OF DEVONIAN–AGE ROCKS. LOCAL STRUCTURE WILL INFLUENCE THE ACTUAL EXTENT.

WETLAND AREAS

NOTE:
1. LOCATION OF HIGHWAYS ARE ILLUSTRATED FOR REFERENCE ONLY.
2. LOCATION OF WAUKESHA FAULT AND DEVONIAN/SILURIAN DEMARCATION ADAPTED FROM ROVEY, 1990.
3. THE DEPICTED LOCATION OF THE FAULT AND EXTENT OF SURFICIAL ROCK TYPES ARE BASED UPON REGIONAL STUDIES. ACTUAL LOCATIONS WILL VARY.

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ULAO CREEK PARTNERSHIP
GRAFTON, WISCONSIN

GROUND–WATER ELEVATION CONTOURS DOLOMITE AQUIFER AND INTERCONNECTED PORTIONS OF THE SAND AND GRAVEL AQUIFER

FIGURE 6

TABLES

Table 1 Stream Gaging Data, September 6, 1997

Station	Location	Time	Throat Width (inches)	Gage Height (foot)	Flow CFS	Flow GPM	Comments
F1	Section 29: Approximately 500 feet north of Port Washington Road Bridge	1315	4	0.00	0.000	0	Installed Flume
		1415	4	0.33	0.227	101	
		1550	4	0.42	0.367	164	
		1610	4	0.43	0.385	172	Blocked Discharge
		1642	4	0.47	0.459	206	Opened Discharge
		1705	4	0.46	0.440	197	
		1729	4	0.45	0.421	189	
F2	Section 29: Approximately 50 feet west of Chicago-Northwester Railroad Bridge	1400	4	0.00	0.000	0	Installed Flume
		1403	4	0.42	0.367	164	
		1405	4	0.42	0.367	164	
		1407	4	0.41	0.350	157	
		1435	4	0.41	0.350	157	
F3	Section 20: Approximately 70 feet north of Falls Road Bridge	1530	4	0.00	0.000	0	Installed Flume
		1558	4	0.30	0.300	83.9	
		1615	4	0.36	0.360	121	
		1631	4	0.38	0.380	135	
		1637	4	0.38	0.380	135	
		1652	4	0.39	0.390	142	
		1655	4	0.39	0.390	142	
		1713	4	0.40	0.333	149	Blocked Discharge
		1740	4	0.41	0.350	157	Opened Discharge
		1747	4	0.40	0.333	149	
F4	Section 20: Approximately 1000 feet north of Ulao Road Bridge	1530	8	0.00	0.000	0	Began Constructing Dam
		1832	8	0.29	0.355	160	Installed Flume
		1834	8	0.29	0.355	160	
		1837	8	0.28	0.331	149	
		1855	8	0.24	0.243	109	
		1901	8	0.23	0.223	101	
		1939	8	0.22	0.204	92	

Note:

CFS = cubic feet per second
GPM = gallons per minute

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October 30, 1997

Table 2 Important Ground-Water/Surface Water Interactions in the Ulao Creek Watershed

SURFACE-WATER BODIES WHICH LOSE FLOW TO GROUND WATER			
Name of Feature Losing Water	**Location**	**Description**	**Probable Discharge Area for Infiltrated Water**
Milwaukee River	Section 6 and northern Section 7	Water infiltrates the riverbed, entering a thick sand-and-gravel layer and permeable bedrock. Cultural modifications are not believed to have significantly affected interaction.	Water flows east from the Milwaukee River discharging to Ulao Swamp or Lake Michigan, or flows south re-entering the Milwaukee River.
Milwaukee River	Southern Section 7, Section 18, and northern Section 19	Water infiltrates the riverbed, entering bedrock. Sand-and-gravel layers may also transmit water. The backwaters created by the Grafton Woolen Mill and Chair Factory Dam millponds accentuate infiltration into the riverbed.	Most water flows south, re-entering the Milwaukee River south of each dam. Some water may move east and southeast discharging to Ulao Creek and Lake Michigan. Dam construction probably increased the volume of water flowing east toward Lake Michigan.
Milwaukee River	Southern Section 30	Water infiltrates the river bed, entering a thick sand-and-gravel layer and bedrock. Bedrock forms the river channel in many nearby areas. The backwater created by the Lime Kiln Park Dam millpond may accentuate infiltration into the riverbed.	Most water flows south, re-entering the Milwaukee River downstream of the dam, and south of the river's confluence with Cedar Creek. Some water flows east, discharging to Lake Michigan. A small amount of water may also discharge through small gravel windows to the lower reaches of Ulao Creek (i.e., in southern Sections 31 and 32).
Ulao Creek	Southern Section 20	Water infiltrates the creek bed, entering a thick sand-and-gravel layer and possibly bedrock. This sand-and-gravel layer receives water from the Milwaukee River, and only has a limited capacity to carry water from Ulao Creek. Consequently, the losing stretch of the creek is likely longer during dry periods. Conversely, this layer may not be able to accept much of Ulao Creek's water during wet periods. Erosion and redeposition of fine-grained sediments in the Ulao Creek floodplain has likely decreased interaction.	Water flows southeast, discharging to Lake Michigan. Particularly strong discharge likely occurs along the shoreline of souther Section 28 and northern Section 33.
Ulao Swamp, northern areas	Northeastern quarter of Section 4	Ground water migrating through sand-and-gravel lenses hydraulically connected to the Milwaukee River formerly discharged to the Ulao Swamp. Water is now diverted north, out of the Watershed. Construction of drainage ditches lowered the water table at the watershed divide, promoting relatively more ground water to enter the Mineral Springs Creek watershed. Gravel quarrying/pond construction also likely promotes relatively more ground water to flow north, out of the Watershed.	Mineral Springs Creek watershed
Ulao Swamp, eastern areas	Southwestern Section 4, western Sections 9 and 16, limited portion of eastern Sections 8 and 17	Water which accumulates in Ulao Swamp infiltrates into the underlying clayey soils. Although the clayey soils are relatively impermeable, they cover large areas. Water moves downward to coarser-grained sediments, then east to Lake Michigan.	Lake Michigan
SURFACE-WATER BODIES WHICH RECEIVE GROUND WATER			
Name of Feature Gaining Water	**Location**	**Description**	**Probable Source of Water Discharging to Feature**
Milwaukee River	Immediately downstream of the three Grafton Dams and the Grafton Dells area	Incised river channel rests upon bedrock, allowing ground water to enter the river. Much of the inflow is a direct result of dam construction causing river water to infiltrate into sand and gravel and bedrock underlying the millponds, which re-appears as ground-water discharge downstream of the dams.	Milwaukee River, with small contributions from regional bedrock aquifer system.
Milwaukee River	Section 31	Riverbed rests upon complexly interlayered glacial sediments. Most water likely flows through bedrock. Grafton dams likely increase discharge a small amount.	Milwaukee River with contributions from regional bedrock aquifers.
Ulao Swamp/Ulao Creek	Western Section 4, eastern Section 8	Water infiltrates through sand-and-gravel layer underlying the Milwaukee River. This sand-and-gravel lenses extend east, and outcrop under the western flank of the Ulao Swamp. This water is supplemented by discharge from the Niagara Aquifer. Bedrock aquifer discharge is promoted by facies changes near the Waukesha Fault. Agricultural drainage and gravel mining probably have caused some ground water to be diverted to the Mineral Springs Creek Watershed, reducing discharge to the Ulao Creek Watershed.	Regional bedrock aquifer and the Milwaukee River
Ulao Swamp/Headwater of Ulao Creek	Section 17	Water infiltrates into sand-and-gravel layers and bedrock underlying the Milwaukee River. These strata are hydraulically connected to the lowlands in Section 17, and rise to the surface in the Valley occupied by Interstate 43. Some water diffusely discharges to the surface, while most migrates east to Lake Michigan. In many areas, the permeable strata are overlain by clay, and water is found under artesian conditions. Natural discharge has likely been reduced by filling completed during construction of I-43, and redeposition of fine-grained soils eroded from adjacent uplands.	Milwaukee River with smaller contributions from regional bedrock aquifer systems.
Ulao Creek	Northwestern Section 32, Southeastern Section 31	Cross-sectional area of granular sediments paralleling the creek reduces, forcing ground water into the creek channel. Also, a sand-and-gravel layer may hydraulically connect the Milwaukee River to Ulao Creek in limited areas. Cultural modifications are not believed to have significantly affected this interaction.	Surface infiltration along Ulao Creek, the Milwaukee River, and regional bedrock aquifers.

APPENDIX A

GLOSSARY

GLOSSARY

Alluvium. Sediments eroded, transported, and deposited by streams.

Anthropogenic. Induced by or resultant from human activity.

Aquifer. A permeable strata capable of yielding appreciable quantities of water to wells and springs.

Aquitard. A low permeability strata hindering flow of ground water.

Argillaceous. Rocks or sediments composed predominantly of clay-size particles.

Attenuating. Lessening the density of; weakening or reducing as in strength or value.

Concordant. Harmonious, accordant, in agreement.

Contiguous. Sharing a boundary or edge; nearby; adjacent.

Dendritic. Having a tree-like branching structure.

Devonian. A portion of the Paleozoic Era from approximately 415 million to 365 million years before present.

Diamicton. A non-lithified poorly-sorted or unsorted assemblage of many particle sizes, without consideration of the mode of deposition.

Dolomite. A whitish carbonate mineral similar in appearance to limestone, but in which calcium is partially substituted by magnesium.

Drumlin. A streamlined hill formed by glacial action shaped like an inverted spoon, with its long axis paralleling the direction of ice movement.

Embayment. Indentation in a shoreline forming a bay.

Empirical. Relying on experiments or observations rather than theory.

End Moraine. Typically, a pronounced hill formed from glacially-derived sediments which accumulate at the terminus of a glacier, or at a point where glacial movement paused.

Escarpment. A cliff or steep slope separating two levels of gently sloping areas.

Evapotranspiration. Loss of water from the Earth's surface by direct evaporation from water bodies or soil, coupled with losses induced by growth of plant life.

Facies. Any observable attribute(s) of a rock or stratigraphic unit (such as appearance or composition) which can be used to distinguish one part of a rock or unit from another part.

Fissile. Capable of being split along the line of the grain or cleavage plane.

Fluvial. Belonging to or produced by streams or rivers.

Flux. A continued flow of liquid or gas.

Geomembrane. An impermeable sheet buried in soil to prevent movement of liquids or gas.

Geotextile. A cloth designed to be buried in soil to alter the soil's structure or material properties.

Grainstone. A sedimentary carbonate rock composed largely of a self-supporting framework of granular material, without a mud matrix.

Ground Moraine. Sediments carried and deposited directly by glaciers under glaciers. Typically moraines exhibit gentle topography.

Hydraulic Conductivity. A measure of a sediment's ability to transmit a liquid, typically water.

Hydrostratigraphic Unit. Groups of geologic units segregated by their water-bearing characteristics.

Isotropic. Having material properties which are the same, regardless of the direction of measurement.

Lacustrine. Belonging to or produced by lakes.

Lithology. The physical characteristics of a rock or stratigraphic unit based on visual observation of structure, mineralogy, texture, odor, etc.

Matrix. The fine-grained body of a sediment or rock in which large grains are embedded.

Misfit Stream. A stream which is either too large or too small to have formed the valley in which it flows.

Mudstone. A blocky or massive sedimentary rock composed of equal proportions of silt and clay. Generally lacks the fine laminations of shale.

Ordovician. A portion of the Paleozoic Era from approximately 510 million to 465 million years before present.

Outcrop. Exposure of a geologic stratum at the Earth's surface.

Outlier. An isolated occurrence of rock or sediment separated from the main mass by older rocks or sediments.

Outwash. Sand and gravel deposited by glacial meltwater.

Packstone. A sedimentary carbonate rock composed largely of a self-supporting framework of granular material, but also containing calcareous mend.

Paleozoic. An era of geologic time 600 million years before present to 225 million years before present.

Petroliferous. Containing petroleum.

Potentiometric Surface. An imaginary surface representing the static head to which water would rise. Pressure surface.

Precambrian. All geologic time before 600 million years before present.

Primary Porosity. The void space in a rock or unconsolidated sediment resulting from the original depositional environment and material deposited.

Secondary Porosity. Interstices appearing after a sediment or rock is deposited. Typically resultant from fracturing or weathering.

Shale. A laminated or fissile sedimentary rock composed of silt and/or clay-sized particles.

Silurian. A portion of the Paleozoic Era from approximately 465 million to 415 million years before present.

Strata. A distinct layer of rock or sediment spread out on the Earth's surface.

Stratigraphy. The form, arrangement, distribution, correlation, etc. of rock strata.

Surficial. Of, relating to, or taking place on the Earth's surface.

Till. An unsorted mixture of various sized particles deposited directly by glacial ice.

Unconformable. A lack of continuity between two adjacent geologic units.

Unconsolidated. Sediments which are not bound by a cementing agent (e.g., calcium carbonate).

Undifferentiated. Concerning grouping together of a collection of potentially separable items.

Vernal. Relating to, appearing, or occurring in the Spring season.

APPENDIX B

WELL CONSTRUCTOR
REPORT SUMMARY

Appendix B Well Constructor Report Summary, Ulao Creek Watershed

Section	Reference	Address	Year Completed	Distance to Building	Depth to Bedrock (feet)	Completion Interval Top	Completion Interval Bottom	Completion Interval Length	Depth to Water Static	Depth to Water During Pumping	Pumping Rate (gpm)	Aquifer Thickness (feet)	Calculated Hydraulic Conductivity (cm/sec)	Surface Elevation Average	Surface Elevation Low	Surface Elevation High	Bedrock Elevation Average	Bedrock Elevation Low	Bedrock Elevation High	Sand & Gravel in Contact with Bedrock Top	Sand & Gravel in Contact with Bedrock Bottom	Sand & Gravel in Contact with Bedrock Thickness	Isolated Sand & Gravel Lenses Number	Isolated Sand & Gravel Lenses Total Thickness	Water Elevation Average	Water Elevation Low	Water Elevation High	Vertical Gradient
4	4-1	Hoppe, Fred	1955	18	> 40.5 (g)	40.5	41	0.5	1	10	27	1	7E-02	ERR			-41	-41	-41	30	"e" 160	130	0	0	-1	-1	-1	-0.02
4	4-2	2331 Lakeshore Rd (Schanen)	1958	24	197	196.5	215	19	79	80	20	19	2E-02	711	710	712	516	514	516	-	-	0	0	0	632	631	633	-0.38
4	4-3	Pioneer Rd & Stonecroft Rd	1973	50	180	180	400	220	80	120	165	220	2E-04	721	718	724	541	538	544	100	178	78	1	10	641	638	644	-0.28
4	4-4	Stonecroft Rd	1982	15	178	178	220	42	90	105	18	42	3E-04	721	718	724	543	540	546	150	178	28	0	0	631	628	634	-0.45
5	5-1	Powers, Dale	1956	10	> 154 (g)	153.5	154	0.5	54	61	21	1	7E-02	ERR			-154	-154	-154	81	> 154	> 73	0	0	-54	-54	-54	-0.35
5	5-1	2396 Marak	1991	35	> 127 (g)	127	127	0	47	95	10	1	2E-03	781	780	782	< 654	< 653	< 655	65	"e" 159	"e" 94	1	3	734	733	735	-0.37
5	5-1	2149 Port Wash. Road	1977	10	138	139	164	25	21	50	12	25	2E-04	737	736	738	599	598	600	-	-	0	0	0	716	715	717	-0.14
5	5-1	2188 Port Wash. Road	1990	6	148	148	235	87	3	25	8	87	5E-05	720	718	722	572	570	574	-	-	0	1	11	717	715	719	-0.02
5	5-1	2228 Port Wash. Road	1984	30	157	158	204	46	15	40	10	46	1E-04	ERR			-157	-157	-157	-	-	0	0	0	-15	-15	-15	-0.08
5	5-1	2149 Ridgewood Road	1970	12	152	152	201	49	40	65	10	49	9E-05	764	762	766	612	610	614	-	-	0	0	0	724	722	726	-0.23
5	5-1	2170 Ridgewood Road	1968	11	144	144	180	36	33	55	15	36	2E-04	759	758	760	615	614	616	-	-	0	0	0	726	725	727	-0.20
5	5-1	2206 Ridgewood Road	1971	12	148	148	200	52	29	50	15	52	2E-04	ERR			-148	-148	-148	85	148	63	0	0	-29	-29	-29	-0.17
5	5-1	2235 Ridgewood Road	1971	15	146	146	213	67	38	50	20	67	3E-04	763	762	764	617	616	618	70	146	76	0	0	725	724	726	-0.21
5	5-1	2238 Ridgewood Road	1971	13	159	159	172	13	29	45	30	13	2E-03	760	760	760	601	601	601	95	159	64	0	0	731	731	731	-0.18
5	5-1	2268 Ridgewood Road	1984	15	173	174	220	46	43	75	12	46	9E-05	758	750	766	585	577	593	-	-	0	0	0	715	707	723	-0.22
5	5-1	2259 Ridgewood Road	1987	24	155	165	260	105	40	70	15	105	5E-05	765	760	770	610	605	615	145	155	10	0	0	725	720	730	-0.19
5	5-1	2312 Ridgewood Road	1990	12	> 130 (g)	130	131	1	42	47	15	1	3E-02	766	768	764	< 636	< 638	< 634	130	"e" 151	"e" 21	0	0	724	726	722	-0.32
5	5-1	2314 Ridgewood Road	1993	8	129	131	146	15	26	41	12	15	6E-04	763	762	764	634	633	635	-	-	0	0	0	737	736	738	-0.19
5	5-1	2320 Ridgewood Road	1990	11	147	148	206	58	35	65	12	58	8E-05	764	762	766	617	615	619	-	-	0	0	0	729	727	731	-0.20
5	5-1	2328 Ridgewood Road	1991	16	147	148	206	58	19	60	12	58	6E-05	766	764	768	619	617	621	-	-	0	0	0	747	745	749	-0.11
5	5-1	2350 Ridgewood Road	1983	15	175	176	220	44	49	80	10	44	8E-05	778	776	780	603	601	605	95	175	80	0	0	729	727	731	-0.25
5	5-1	797 East Sauk Road (Zeusch)	1957	15	210	210	275	65	60	135	400	65	9E-04	776	772	779	566	562	569	75	190	115	1	28	716	712	719	-0.25
5	5-1	1100 Ulao Parkway	1992	18	136	136	140	4	60	70	15	4	4E-03	779	778	779	643	642	643	30	136	106	0	0	719	718	719	-0.43
5	5-1	989 Woodview Drive	1991	42	164	165	235	70	23	60	12	70	7E-05	745	742	748	581	578	584	-	-	0	1	21	722	719	725	-0.12
5	5-1	991 Woodview Drive	1979	20	161	161	256	95	27	65	15	95	5E-05	749	744	754	588	583	593	-	-	0	2	17	722	717	727	-0.13
5	5-1	995 Woodview Drive	1978	15	152	152	183	31	20	80	20	31	1E-04	750	750	750	598	598	598	-	-	0	1	20	730	730	730	-0.12
5	5-1	996 Woodview Drive	1970	15	164	164	215	51	35	80	15	51	7E-05	760	748	772	596	584	608	135	162	27	1	13	725	713	737	-0.18
5	5-1	1057 Woodview Drive	1993	14	145	148	220	72	47	95	12	72	4E-05	768	770	766	623	625	621	-	-	0	0	0	721	723	719	-0.26
5	5-1	1060 Woodview Drive	1991	14	133	133	205	72	34	65	20	72	1E-04	761	762	760	628	629	627	-	-	0	0	0	727	728	726	-0.20
6	6-1	2217 Highway O	1984	18	81	81	102	21	4	20	15	21	5E-04	759	758	760	678	677	679	0	81	81	0	0	755	754	756	-0.04
6	6-2	Highway W (Well. Golf)	1993	-	128	134	642	508	46	270	412	508	4E-05	803	802	804	675	674	676	96	126	30	1	53	757	756	758	-0.12
6	6-3	Highway W (Well. Golf)	1993	30	116	118	134	16	76	128	68	16	8E-04	803	802	804	687	686	688	-	-	0	1	55	727	726	728	-0.60
6	6-4	2133 Highway W	1989	34	118	119	205	86	70	85	12	86	1E-04	795	792	798	677	674	680	-	-	0	0	0	725	722	728	-0.43
6	6-5	2133 Highway W	1980	15	121	122	205	83	69	85	12	83	1E-04	795	792	798	674	671	677	-	-	0	0	0	726	723	729	-0.42
6	6-6	2335 N Port Wash. Rd (Hwy W)	1992	10	138	140	176	36	37	49	10	36	3E-04	777	776	778	639	638	640	-	-	0	0	0	740	739	741	-0.23
6	6-7	2109 Edgewater Rd	1992	15	82	84	220	136	28	60	12	136	3E-05	ERR			-82	-82	-82	70	82	12	1	27	-28	-28	-28	-0.18
6	6-8	2196 Edgewater Rd	1988	15	> 55 (g)	55	55	0	14	20	12	1	2E-02	763	762	764	708	> 707	> 709	35	"e" 73	"e" 38	1	16	749	748	750	-0.25
6	6-9	2256 Edgewater Rd	1986	20	87	87	98	11	14	20	12	11	2E-03	769	768	770	682	681	683	45	87	42	1	35	755	754	756	-0.15
6	6-10	2160 Green Bay Road	1977	10	> 88 (g)	87	88	1	12	55	10	1	3E-03	ERR			-88	-88	-88	87		-87			-12	-12	-12	-0.14
6	6-11	2266 Green Bay Road	1991	21	34	60	130	70	9	30	12	70	9E-05	753	752	754	719	718	720	0	34	34	0	0	744	743	745	-0.09
6	6-12	2286 Green Bay Road	1991	12	53	56	160	104	12	30	12	104	7E-05	755	754	756	702	701	703	-	-	0	1	22	743	742	744	-0.11
6	6-13	2320 Green Bay Road	1986	12	36	62	145	93	7	30	12	93	6E-05	756	754	756	719	718	720	-	-	0	0	0	748	747	749	-0.07
6	6-14	2336 Green Bay Road	1989	14	39	56	160	104	11	30	12	104	7E-05	755	754	756	716	715	717	-	-	0	0	0	744	743	745	-0.10
6	6-15	2148 East River Rd	1986	21	80	80	146	66	20	36	15	66	2E-04	757	756	758	677	676	678	-	-	0	1	24	737	736	738	-0.18
6	6-16	2151 East River Rd	1990	10	78	79	190	111	11	70	10	111	2E-05	754	752	756	676	674	678	-	-	0	1	30	743	741	745	-0.08
6	6-17	1307 East Sauk Road	1979	20	68	68	198	130	23	40	18	130	8E-05	762	760	764	694	692	696	-	-	0	1	18	739	737	741	-0.17
6	6-18	1381 East Sauk Road	1993	12	73	78	205	127	22	60	12	127	3E-05	763	762	764	690	689	691	38	73	35	0	0	741	740	742	-0.16
6	6-19	1280 Trailway Court	1989	14	89	89	208	119	32	60	10	119	5E-05	775	774	776	686	686	687	-	-	0	0	0	743	742	744	-0.22
6	6-20	1310 Trailway Court	1984	15	106	106	200	94	29	60	10	94	4E-05	772	770	774	666	664	668	75	96	21	1	31	743	741	745	-0.19
6	6-21	1336 Trailway Court	1985	31	80	80	220	140	24	40	11	140	6E-05	ERR			-80	-80	-80	56	80	24	1	21	-24	-24	-24	-0.16
6	6-22	1206 Trailway Drive	1991	18	130	132	190	58	36	70	12	58	7E-05	774	772	776	644	642	646	-	-	0	1	18	738	736	740	-0.22
6	6-23	1227 Trailway Drive	1992	22	> 118 (g)	115	118	3	33	60	25	3	4E-03	779	778	780	< 441	< 660	< 662	64	"e" 137	"e" 83	0	0	746	745	747	-0.28
6	6-24	1235 Trailway Drive	1990	12	134	135	161	26	42	55	12	26	4E-04	779	778	780	645	644	646	-	-	0	0	0	737	736	738	-0.28
6	6-25	1247 Trailway Drive	1992	18	139	139	180	41	46	60	12	41	2E-04	787	786	788	648	647	649	95	139	44	0	0	741	740	742	-0.29
6	6-26	1254 Trailway Drive	1979	18	135	137	182	45	52	70	12	45	2E-04	790	788	792	655	653	657	134	135	1	1	13	738	736	740	-0.33
6	6-27	1259 Trailway Drive	1979	12	148	149	205	56	49	70	12	56	1E-04	791	790	792	643	642	644	-	-	0	0	0	742	741	743	-0.28
6	6-28	1270 Trailway Drive	1989	18	130	130	205	75	46	70	10	75	6E-05	788	786	790	658	656	660	100	130	30	0	0	742	740	744	-0.27
6	6-29	1302 Trailway Drive	1989	15	103	118	250	132	47	120	10	132	1E-06	778	776	780	675	673	677	-	-	0	0	0	731	729	733	-0.26
6	6-30	1310 Trailway Drive	1984	15	116	117	175	58	39	65	12	58	9E-05	780	778	782	664	662	666			0			741	739	743	-0.27
7	7-1	Blank, Frederick	1962	11	87	87	148	61	43	60	20	61	5E-04	ERR			-87	-87	-87	-	-	0	1	12	-43	-43	-43	-0.37
7	7-2	Freitag, George	1978	10	96	96	152	56	64	70	15	56	5E-04	ERR			-96	-96	-96	-	-	0	0	0	-64	-64	-64	-0.52
7	7-3	Matton, Scott (KnollWood Farm)		100	125	125	180	55	52	60	20	55	5E-04	ERR			-125	-125	-125	100	125	25	0	0	-52	-52	-52	-0.34
7	7-4	Olson Transportation Company		5	97.5	97.5	172	74.5	33	38	18	75	5E-04	ERR			-98	-98	-98	-	-	0	0	0	-33	-33	-33	-0.24
7	7-5	2065 Edgewater Drive	1992	6	58	59	145	86	23	45	12	86	7E-05	763	762	764	705	704	706	-	-	0	1	30	740	739	741	-0.23
7	7-6	1959 Mary Glade Drive	1983	13	104	105	144	39	12	35	12	39	2E-04	763	762	764	659	658	660	-	-	0	1	11	751	750	752	-0.10
7	7-7	1976 Mary Glade Drive	1989	15	105	106	131	25	19	40	12	25	3E-04	752	750	754	647	645	649	-	-	0	1	5	733	731	735	-0.16
7	7-8	1911 Mary Glade Road	1974	11	33	44	132	132	15	30	20	132	1E-04	759	758	760	726	725	727	-	-	0	0	0	744	743	745	-0.23
7	7-9	1931 Mary Glade Road	1989	10	47	47	163	116	31	46	20	116	1E-04	757	756	758	710	709	711	-	-	0	0	0	726	725	727	-0.30
7	7-10	1947 Mary Glade Road	1965	12	45	45	115	70	19	30	15	70	2E-04	759	758	760	714	713	715	-	-	0	1	10	740	739	741	-0.24
7	7-11	1689 Port Wash. Road	1978	20	73	73	112	39	35	40	15	39	9E-04	ERR			-73	-73	-73	72	73	1	0	0	-35	-36	-35	-0.38
7	7-12	1927 Port Wash. Road	1978	20	121	121	160	39	56	65	20	39	6E-04	777	774	780	656	653	659	120	121	1	1	69	721	718	724	-0.40
7	7-13	1810 East River Road	1973	14	53	53	117	64	32	37	18	64	6E-04	774	772	776	721	719	723	-	-	0	0	0	742	740	744	-0.38
7	7-14	2019 East River Road	1971	11	65	65	119	54	15	22	20	54	6E-04	759	758	760	694	693	695	-	-	0	1	50	744	743	745	-0.16
7	7-15	1341 Terminal Road	1978	20	89	89	170	81	75	80	16	81	4E-04	804	802	806	715	713	717	-	-	0	1	25	729	727	731	-0.58
7	7-16	1361 Terminal Road	1968	12	81	81	162	81	52	75	18	81	1E-04	774	772	776	693	691	695	-	-	0	1	11	722	720	724	-0.43

Appendix B Well Constructor Report Summary, Ulao Creek Watershed

Section	Reference	Address	Year Completed	Distance to Building	Depth to Bedrock (feet)	Completion Interval Top	Completion Interval Bottom	Completion Interval Length	Depth to Water Static	Depth to Water During Pumping	Pumping Rate (gpm)	Aquifer Thickness (feet)	Calculated Hydraulic Conductivity (cm/sec)	Surface Elevation Average	Surface Elevation Low	Surface Elevation High	Bedrock Elevation Average	Bedrock Elevation Low	Bedrock Elevation High	Sand & Gravel in Contact with Bedrock Top	Sand & Gravel in Contact with Bedrock Bottom	Sand & Gravel in Contact with Bedrock Thickness	Isolated Sand & Gravel Lenses Number	Isolated Sand & Gravel Lenses Total Thickness	Water Elevation Average	Water Elevation Low	Water Elevation High	Vertical Gradient
8	8-7	Buch	1952	5	106	106	250	144	23	36	18	144	1E-04	760	760	760	654	654	654	-	-	0	0	0	737	737	737	-0.13
8	8-1	Buch, Arnold	1964	12	90	90	109	19	46	52	12	19	1E-03	ERR			-90	-90	-90	-	-	0	0	0	-46	-46	-46	-0.46
8	8-2	Disch, Milton	1950	15	> 107 (g)	107	107.5	1	27	35	10	1	3E-02	ERR			-107	-107	-107	80	130	50	0	0	-27	-27	-27	-0.25
8	8-3	Rau, Gilbert	1949	15	> 90 (g)	89.5	90	1	25	52	7	1	6E-03	ERR			-90	-90	-90	90	"e" 130	40	1	3	-25	-25	-25	-0.28
8	8-4	Syparko, Herman	1960	15	145	145	167	12	36	44	12	12	1E-03	ERR			-145	-145	-145	-	-	0	0	0	-36	-36	-36	-0.24
8	8-5	Veloon, Melvin	1964	15	123	123	138	15	30	32	12	15	5E-03	ERR			-123	-123	-123	-	-	0	0	0	-30	-30	-30	-0.23
8	8-6	State Hwy 32 WEPCO Ash Landfill	1979	-	107	107	260	143	45	115	500	143	6E-04	755	754	756	648	647	649	-	-	0			710	709	711	-0.25
8	8-8	2018 Port Wash. Road	1979	15	132	132	184	52	40	60	20	52	2E-04	750	746	754	618	614	622	-	-	0	1	40	710	706	714	-0.25
8	8-9	2057 Port Wash. Road	1978	20	152	152	250	98	49	65	20	98	1E-04	762	760	764	610	608	612	123	152	29	0	0	713	711	715	-0.24
8	8-10	2069 Port Wash. Road	1980	5	144	145	230	85	41	63	10	85	6E-05	755	754	756	611	610	612	132	144	12	0	0	714	713	715	-0.22
9	9-1	1817 Highway C	1994	15	150	150	165	15	76	100	26	15	8E-04	711	710	712	561	560	562	-	-	0	0	0	635	634	636	-0.48
9	9-2	2050 Highway C	1977	20	175	175	285	110	73	75	20	110	1E-03	ERR			-175	-175	-175	-	-	0	0	0	-73	-73	-73	-0.32
9	9-3	2058 Highway C	1978	20	158	158	231	73	63	73	20	73	3E-04	ERR			-158	-158	-158	-	-	0	1	14	-63	-63	-63	-0.32
9	9-4	2064 Highway C	1974	15	172	172	265	93	57	65	15	93	2E-04	ERR			-172	-172	-172	-	-	0	1	34	-57	-57	-57	-0.26
9	9-5	679 Kara Drive	1993	21	161	161	166	5	31	60	20	5	2E-03	712	710	714	651	649	653	-	-	0	1	16	681	679	683	-0.19
9	9-6	176 Lake Shore Road	1972	12	170	170	231	61	115	120	17	61	6E-04	ERR			-170	-170	-170	-	-	0	0	0	-115	-115	-115	-0.57
9	9-7	1740 Lake Shore Road	1982	30	154	155	244	89	97	150	10	89	2E-06	711	708	714	557	554	560	-	-	0	0	0	614	611	617	-0.49
9	9-8	1776 Lake Shore Road	1984	11	165	165	252	87	97	120	20	87	1E-04	ERR			-165	-165	-165	-	-	0	0	0	-97	-97	-97	-0.47
9	9-9	1863 Lake Shore Road	1975	-	170	170	247	77	99	126	15	77	9E-05	717	714	720	547	544	550	-	-	0	2	50	618	615	621	-0.47
9	9-10	1966 Lake Shore Road	1984	18	150	150	220	70	74	95	12	70	9E-05	707	706	708	557	556	558	-	-	0	1	12	633	632	634	-0.40
9	9-11	1972 Lake Shore Road	1964	16	151	150.6	212	62	81	83	20	62	2E-03	709	706	712	559	556	562	138	151	13	1	8	628	626	631	-0.45
9	9-12	2087 Lake Shore Road	1983	13	189	190	288	98	76	130	10	98	2E-05	698	694	702	509	505	513	-	-	0	0	0	622	618	626	-0.32
9	9-13	716 Lancaster Court	1992	13	154	154	264	110	52	85	20	110	6E-05	713	712	714	559	558	560	-	-	0	1	12	661	660	662	-0.25
9	9-14	727 Lancaster Court	1992	20	153	155	221	66	31	40	12	66	2E-04	712	710	714	559	557	561	-	-	0	0	0	681	679	683	-0.16
9	9-15	751 Lancaster Court	1992	13	> 164 (g)	61	64	3	19	40	20	3	4E-03	705	704	706	< 431	< 650	< 642	56	"e" 120	"e" 64	0	0	686	685	687	-0.30
9	9-16	765 Lancaster Court	1991	13	118	119	220	101	23	50	12	101	5E-05	705	704	706	587	586	588	-	-	0	1	20	682	681	683	-0.14
9	9-17	783 Lancaster Court	1993	12	110	113	116	3	18	25	12	3	6E-03	704	702	706	594	592	596	-	-	0	1	5	686	684	688	-0.16
9	9-18	790 Lancaster Court	1992	16	> 55 (g)	60	61	1	21	40	30	1	2E-02	704	702	706	649	647	651	55	"e" 120	65	0	0	683	681	685	-0.35
9	9-19	614 Ulao Parkway South	1986	16	158	158	200	42	50	60	12	42	3E-04	714	710	718	556	552	560	-	-	0	1	30	664	660	668	-0.28
9	9-20	720 Ulao Parkway South	1985	14	141	142	220	78	40	80	12	78	4E-05	711	708	714	570	567	573	-	-	0	0	0	671	668	674	-0.22
9	9-21	1926 Ulao Parkway	1988	14	> 101 (g)	126	126	0	79	100	25	1	1E-02	709	708	710	608	607	609	101	"e" 159	"e" 58	0	0	630	629	631	-0.63
16	16-1	Knellsville Canning Company	1944	6	59	59	266	207	47	120	80	207	6E-05	ERR			-59	-59	-59	-	-	0	0	0	-47	-47	-47	-0.29
16	16-2	Uihlein, Erwin C.	1968	-	175	175	670	495	87	250	66	495	9E-06	702			-175	-175	-175	140	175	35	4	70	-87	-87	-87	-0.21
16	16-3	535 High Bluff Road	1991	15	171	171	225	54	80	100	20	54	2E-04	ERR			-171	-171	-171	-	-	0	0	0	-80	-80	-80	-0.40
16	16-4	Lake Shore Drive (Stock)	1948	5	139	139	229	90	58	68	15	90	2E-04	723	722	724	584	583	585	-	-	0	1	119	665	664	666	-0.32
16	16-5	Lake Shore Drive (Bienlaine)	1951	4	178	178	182	4	51	60	10	4	3E-03	731	730	732	553	552	554	-	-	0	1	8	680	679	681	-0.28
16	16-6	176 Lake Shore Drive	1972	12	170	170	231	61	115	120	17	61	6E-04	ERR			-170	-170	-170	-	-	0	0	0	-115	-115	-115	-0.57
16	16-7	1407 Lake Shore Drive	1980	20	216	216	322	106	108	150	12	106	3E-05	727	726	728	511	510	512	180	216	0	1	10	619	618	620	-0.40
16	16-8	1491 Lake Shore Drive	1966	12	206	206	305	99	89	120	20	99	7E-06	ERR			-206	-206	-206	-	-	0	0	0	-89	-89	-89	-0.35
16	16-9	1492 Lake Shore Drive	1975	-	173	174	373	199	100	130	10	199	2E-05	722	720	724	549	547	551	-	-	0	0	0	622	620	624	-0.37
16	16-10	1494 Lake Shore Drive	1971	16	166	166	300	134	90	115	26	134	8E-05	ERR			-166	-166	-166	-	-	0	0	0	-90	-90	-90	-0.39
16	16-11	1502 Lake Shore Drive	1978	48	185	186	296	110	89	140	10	110	2E-05	ERR			-185	-185	-185			0			-89	-89	-89	-0.37
16	16-12	1531 Lake Shore Drive	1991	18	184	184	290	106	82	92	15	106	2E-04	729	728	730	545	544	546	-	-	0	0	0	647	646	648	-0.35
16	16-13	1589 Lake Shore Drive	1991	11	184	184	260	76	73	95	15	76	1E-04	723	722	724	539	538	540	-	-	0	0	0	650	649	651	-0.33
16	16-14	1605 Lake Shore Drive	1990	16	176	176	233	57	75	80	20	57	8E-04	717	716	718	541	540	642	160	176	16	0	0	642	641	643	-0.37
16	16-15	1340 Pioneer Road (Cty Hwy C)	1978	20	122	122	200	78	55	65	20	78	3E-04	734	732	736	612	610	614	-	-	0	1	35	679	677	681	-0.34
16	16-16	1446 Pioneer Road (Cty Hwy C)	1978	20	154	154	213	59	50	60	15	59	3E-04	711	710	712	557	556	558	-	-	0	0	0	661	660	662	-0.27
16	16-17	1480 Pioneer Road (Cty Hwy C)	1978	20	161	163	183	20	60	70	12	20	7E-04	713	712	714	552	551	553	156	161	5	0	0	653	652	654	-0.35
16	16-18	1498 Pioneer Road (Cty Hwy C)	1965	15	171	171	225	54	70	80	15	54	3E-04	723	722	724	552	551	553	169	171	2	1	25	653	652	654	-0.35
16	16-19	1589 Pioneer Road (Cty Hwy C)	1979	12	175	175	185	10	55	56	10	10	1E-02	730	728	732	555	553	557	-	-	0	0	0	675	673	677	-0.31
16	16-20	1394 Ulao Parkway South	1977	15	> 129 (g)	129	129	0	60	70	10	1	1E-02	729	728	730	< 600	< 599	< 601	126	"e" 151	"e" 26	1	10	669	668	670	-0.47
17	17-1	1055 Arrowhead Road	1983	8	136	136	202	66	38	75	15	66	7E-05	719	716	722	583	580	586	-	-	0	0	0	681	678	684	-0.22
17	17-2	1055 Arrowhead Road	1975	12	98	98	141	43	35	60	16	43	3E-04	719	716	722	621	618	624	-	-	0	0	0	684	681	687	-0.29
17	17-3	1062 Arrowhead Road	1967	15	137	137	192	55	49	69	15	55	2E-04	740	738	742	603	601	605	-	-	0	0	0	691	689	693	-0.30
17	17-4	1076 Arrowhead Road	1980	20	102	102	190	88	62	70	10	88	2E-04	748	747	749	646	645	647	95	102	7	0	0	686	685	687	-0.42
17	17-5	1085 Arrowhead Road	1956	16	101	101	174	73	32	55	18	73	1E-04	734	732	736	633	631	635	98	101	3	0	0	702	700	704	-0.23
17	17-6	1614 Indian Hill Road	1989	15	86	104	255	151	36	80	10	151	2E-06	752	750	753	666	664	667	-	-	0	0	0	716	714	717	-0.20
17	17-7	1626 Indian Hill Road	1979	15	84	84	203	119	40	60	20	119	1E-04	751	750	752	667	666	668	-	-	0	0	0	711	710	712	-0.28
17	17-8	1654 Indian Hill Road	1970	14	97	84	162	58	33	48	12	58	2E-04	747	746	748	650	649	651	66	84	18	0	0	714	713	716	-0.27
17	17-9	1672 Indian Hill Road	1971	15	90	90	158	68	30	50	15	68	1E-04	745	744	745	655	654	655	-	-	0	0	0	715	714	715	-0.24
17	17-10	1680 Indian Hill Road	1989	18	84	102	150	48	27	60	12	48	5E-05	743	742	743	659	658	659	70	84	14	0	0	716	716	716	-0.18
17	17-11	1570 Port Wash. Road (Cty Hwy W)	1986	17	51	52	175	123	15	50	12	123	3E-05	728	727	729	677	676	678	40	51	11	0	0	713	712	714	-0.13
17	17-12	1615 Ulao Parkway South (Fred Kaul)	1962	4	131	131	169	38	43	48	20	38	1E-03	721	720	722	590	589	591	130	131	1	1	17	678	677	679	-0.29
17	17-13	1669 Ulao Parkway South	1989	18	109	110	130	20	22	35	12	20	5E-04	701	700	702	592	591	593	-	-	0	0	0	679	678	680	-0.18

Appendix B Well Constructor Report Summary, Ulao Creek Watershed

Section	Reference	Address	Year Completed	Distance to Building	Depth to Bedrock (feet)	Completion Interval Top	Completion Interval Bottom	Completion Interval Length	Depth to Water Static	Depth to Water During Pumping	Pumping Rate (gpm)	Aquifer Thickness (feet)	Calculated Hydraulic Conductivity (cm/sec)	Surface Elevation Average	Surface Elevation Low	Surface Elevation High	Bedrock Elevation Average	Bedrock Elevation Low	Bedrock Elevation High	Sand & Gravel in Contact with Bedrock Top	Sand & Gravel in Contact with Bedrock Bottom	Sand & Gravel in Contact with Bedrock Thickness	Isolated Sand & Gravel Lenses Number	Isolated Sand & Gravel Lenses Total Thickness	Water Elevation Average	Water Elevation Low	Water Elevation High	Vertical Gradient
29	29-1	10512 Bridge Street	1990	100	57	57	340	283	55	80	50	283	8E-05	ERR			-57	-57	-57	-	-	0	0	0	-55	-55	-55	-0.28
29	29-2	Messdig, Hannah	1948	6	61	61	161	100	7	12	15	100	3E-04	ERR			-61	-61	-61	-	-	0	1	8	-7	-7	-7	-0.06
29	29-3	Millikin, Ray	1968	14	113	113	265	152	110	130	15	152	6E-05	ERR			-113	-113	-113	-	-	0	0	0	-110	-110	-110	-0.58
29	29-4	Weiland, Norbert	1953	4	82	82	120	38	28	38	20	38	6E-04	ERR			-82	-82	-82	-	-	0	1	4	-28	-28	-28	-0.28
29	29-5	Corner of Lakefield and Highway C	1947	4	149	149	181	32	147	147.5	20	32	1E-02	725	724	726	576	575	577	-	-	0	1	17	578	577	579	-0.89
29	29-6	1/4 mile north of Hwy 141 & Lakefield Rd	1933	-	86	-	105	105	24	38	8	105	6E-05	700	700		264	614	-86	-	-	0	1	7	326	676	-24	-0.46
29	29-7	Apartments - Lakefield Rd	1957	25	61	61	188	127	12	20	20	127	2E-04	678	677	678	617	616	617	-	-	0	0	0	666	665	666	-0.10
29	29-8	Apartments - Lakefield Rd	1968	26	71	71	178	107	12	20	20	107	3E-04	680	679	680	609	608	609	-	-	0	0	0	668	667	668	-0.10
29	29-9	Apartments - Lakefield Rd	1958	-	74	74	176	102	14	15	20	102	2E-03	680	679	680	606	605	606	-	-	0	0	0	666	665	666	-0.11
29	29-10	1142 Lakefield Rd	1987	16	72	73	160	87	6	15	12	87	2E-04	683	682	683	611	610	611	63	72	9	1	5	677	676	677	-0.05
29	29-11	1193 Lakefield Rd	1965	30	82	82	187	105	27	35	30	105	4E-04	701	700	702	619	618	620	80	82	2	1	6	674	673	675	-0.20
29	29-12	588 Port Washington Rd	1986	10	80	80	130	50	20	30	15	50	3E-04	693	690	696	613	610	616	-	-	0	0	0	673	670	676	-0.19
29	29-13	628 Port Washington Rd (Cty Hwy W)	1971	11	100	100	145	45	47	60	15	45	3E-04	711	710	711	611	610	611	-	-	0	0	0	664	663	664	-0.38
29	29-14	678 Port Washington Rd (Cty Hwy W)	1963	15	97	97	143	46	40	40	15	46	ERR	713	710	716	616	613	618	94	97	3	1	25	673	670	676	-0.33
30	30-1	Village of Grafton Well #7	1992	-	97	120	580	460	51	214	400	460	6E-05	ERR			-97	-97	-97	15	97	82	0	0	-51	-51	-51	-0.15
30	30-2	1481 Falls Rd	1986	13	75	76	205	129	29	47	12	129	6E-05	761	760	761	686	685	686	8	75	67	0	0	732	731	732	-0.21
30	30-3	1623 Manchester Drive	1972	12	53	53	203	150	15	25	15	150	1E-04	688	687	688	635	634	635	40	53	13	0	0	673	672	673	-0.12
30	30-4	809 Port Washington Rd	1984	16	85	86	145	59	59	70	10	59	2E-04	739	738	739	654	653	654	-	-	0	0	0	680	679	680	-0.51
30	30-5	River Bend Rd (Soccer Field)	1989	-	114	115	205	90	57	65	12	90	2E-04	734	734	734	620	620	620	-	-	0	0	0	677	677	677	-0.36
30	30-6	525 River Bend Rd	1991	12	106	106	197	91	50	72	10	91	6E-05	723	722	723	617	616	617	-	-	0	1	12	673	672	673	-0.33
30	30-7	656 River Bend Rd	1989	10	120	121	160	39	54	70	12	39	2E-04	733	730	736	613	610	616	-	-	0	0	0	679	676	682	-0.38
30	30-8	769 River Bend Rd	1971	14	143	143	242	99	50	60	15	99	2E-04	ERR			-143	-143	-143	56	143	87	0	0	-50	-50	-50	-0.26
30	30-9	1414 River Bend Rd	1977	-	87	87	147	60	38	50	15	60	2E-04	721	720	721	634	633	634	-	-	0	1	5	683	682	683	-0.32
30	30-10	1435 River Bend Rd	1968	11	91	91	197	106	56	64	10	106	1E-04	722	720	723	631	629	632	-	-	0	0	0	666	664	667	-0.39
30	30-11	1501 River Bend Rd	1987	16	80	81	160	79	45	60	15	79	1E-04	730	729	730	650	649	650	-	-	0	1	75	685	684	685	-0.37
30	30-12	1555 River Bend Rd	1988	30	54	54	120	66	42	50	16	66	3E-04	732	730	733	678	676	679	-	-	0	0	0	690	688	691	-0.48
30	30-13	1559 River Bend Rd	1972	15	50	50	145	95	30	40	20	95	2E-04	716	715	716	666	665	666	38	50	12	0	0	686	685	686	-0.31
31	30-1	Rossman, Fred (Garage)	1956	4	86	86	179	93	35	35	20	93	ERR	ERR			-86	-86	-86	-	-	0	0	0	-35	-35	-35	-0.26
31	31-2	488 Armin Road	1969	13	88	88	184	96	40	55	15	96	1E-04	ERR			-88	-88	-88	-	-	0	0	0	-40	-40	-40	-0.29
31	31-3	1538 Cardinal Road	1979	15	64	64	204	140	10	20	15	140	1E-04	681	680	681	617	616	617	5	64	59	0	0	671	670	671	-0.07
31	31-4	469 Hillcrest Drive	1973	21	80	81	155	74	30	80	10	74	3E-05	711	710	711	631	630	631	-	-	0	1	33	681	680	681	-0.25
31	31-5	1207 Lakefield Road	1989	13	82	82	149	67	33	42	10	67	2E-04	701	700	702	619	618	620	-	-	0	0	0	668	667	669	-0.29
31	31-6	1237 Lakefield Road	1966	11	86	86	184	98	42	52	20	98	2E-04	712	712	712	626	626	626	-	-	0	0	0	670	670	670	-0.31
31	31-7	385 Pheasant Lane	1973	14	93	94	156	62	49	60	20	62	3E-04	723	722	723	630	629	630	-	-	0	1	19	674	673	674	-0.39
31	31-8	394 Pheasant Lane	1973	18	110	111	171	60	56	63	10	60	3E-04	716	716	716	606	606	606	-	-	0	1	15	660	660	660	-0.40
31	31-9	1372 Pioneer Rd (Cty Hwy W)	1968	10	108	108	132	24	25	35	20	24	9E-04	671	670	671	663	662	663	-	-	0	1	11	646	645	646	-0.21
31	31-10	Warehouse Port Washington Rd (Cty Hwy W)	1975	15	88	90	173	83	32	65	17	83	7E-05	ERR			615	615		-	-	0	0	0	-32	-32	-32	-0.24
31	31-11	295 Port Washington Rd	1978	16	84	84	304	220	25	100	16	220	1E-05	ERR			-84	-84	-84	-	-	0	0	0	-25	-25	-25	-0.13
31	31-12	331 Port Washington Rd (Cty Hwy W)	1953	15	88	88	115	27	24	30	10	27	7E-04	694	690	698	606	602	610	-	-	0	0	0	670	666	674	-0.24
31	31-13	441 Port Washington Rd (Cty Hwy W)	1974	16	90	90	287	197	35	55	15	197	4E-05	703	702	703	613	612	613	78	90	14	0	0	668	667	668	-0.19
31	31-14	329 Valley View Drive	1974	15	77	77	100	23	35	40	20	23	2E-03	691	690	691	614	613	614	56	77	21	0	0	656	655	656	-0.40
31	31-15	336 Valley View Drive	1992	13	83	83	144	61	34	65	20	61	1E-04	691	690	691	608	607	608	-	-	0	0	0	657	656	657	-0.30
32	32-1	Hovener, Henry	1947	4	85	85	181	96	12	28	10	96	7E-05	ERR			-85	-85	-85	-	-	0	2	14	-12	-12	-12	-0.09
32	32-2	Rethke, Robert	1965	16	79	79	155	76	28	33	15	76	4E-04	ERR			-79	-79	-79	-	-	0	0	0	-28	-28	-28	-0.24
32	32-3	Sievers, Erwin	1950	15	118	118	152	34	117	126	7	34	3E-04	ERR			-118	-118	-118	-	-	0	1	6	-117	-117	-117	-0.87
32	32-4	Sievers, Erwin	1967	12	101	101	179	78	52	62	15	78	2E-04	ERR			-101	-101	-101	-	-	0	0	0	-52	-52	-52	-0.37
32	32-5	143 Lake Shore Rd	1981	14	160	160	254	94	117	147	10	94	4E-05	710	708	712	550	548	552	-	-	0	1"M"	125	593	591	595	-0.57
32	32-6	197 Lake Shore Rd	1975	14	151	151	268	117	124	160	10	117	4E-05	718	716	720	567	565	569	-	-	0	1	11	594	592	596	-0.59
32	32-7	393 Lake Shore Rd	1985	12	142	142	235	93	135	137	15	93	9E-04	724	722	726	582	580	584	-	-	0	0	0	589	587	591	-0.72
32	32-8	3/4 mile east of Hwy 41 on Lakefield Rd (Barn)	1942	-	82	82	115	33	30	44	8	33	2E-04	ERR			580	580		-	-	0	0	0	-30	-30	-30	-0.30
32	32-9	1103 Lakefield Rd	1993	9	70	73	160	87	11	30	12	87	8E-05	683	682	684	613	612	614	-	-	0	1	12	672	671	673	-0.09
32	32-10	822 Pioneer Rd (Cty Hwy C)	1971	15	176	176	255	79	85	115	10	79	5E-05	705	704	706	529	528	530	160	176	16	0	0	620	619	621	-0.39
32	32-11	866 Pioneer Rd (Cty Hwy C)	1969	10	179	179	310	131	106	200	10	131	9E-06	708	706	710	529	527	531	160	179	19	1"M"	115	602	600	604	-0.43
32	32-12	878 Pioneer Rd	1969	10	165	165	280	115	110	120	20	115	2E-04	ERR			-165	-165	-165	-	-	0	0	0	-110	-110	-110	-0.49
32	32-13	252 Port Washington Rd	1983	13	96	96	177	81	12	25	20	81	2E-04	ERR			-96	-96	-96	-	-	0	1	32	-12	-12	-12	-0.09
32	32-14	270 Port Washington Rd	1986	11	89	89	177	88	8	76	15	88	3E-05	671	670	672	582	581	583	-	-	0	1	20	663	662	664	-0.08
32	32-15	St. John's Lutheran Church - Lakefield Rd	1965	30	82	82	187	105	27	35	30	105	4E-04	699	697	701	617	615	619	80	82	2	1	6	672	670	674	-0.20
33	33-1	416 Lake Bluff Lane	1987	11	146	146	268	122	124	145	15	122	7E-05	ERR			-146	-146	-146	-	-	0	0	0	-124	-124	-124	-0.60
33	33-2	454 Lake Bluff Lane	1990	18	152	153	280	127	128	160	12	127	3E-05	717	717	717	565	565	565	-	-	0	0	0	589	589	589	-0.59
33	33-3	474 Lake Bluff Lane	1992	14	147	149	295	146	133	165	15	146	4E-05	718	718	718	571	571	571	-	-	0	0	0	585	585	585	-0.60
33	33-4	142 Lake Shore Rd	1984	28	170	170	247	77	118	125	10	77	2E-04	709	707	710	539	537	540	-	-	0	0	0	591	589	592	-0.57
33	33-5	214 Lake Shore Rd	1969	15	160	160	220	60	140	150	15	60	3E-04	722	720	724	562	560	564	-	-	0	1"M"	80	582	580	584	-0.74
33	33-6	300 Lake Shore Rd	1973	16	163	164	290	126	120	160	10	126	2E-05	726	725	726	563	562	563	161	163	2	1	15	606	605	606	-0.53
33	33-7	384 Lake Shore Rd	1979	48	146	147	265	118	120	135	12	118	8E-05	711	710	712	565	564	566	-	-	0	0	0	591	590	592	-0.56
33	33-8	671 Lakefield Rd	1973	13	153	153	286	133	125	135	15	133	1E-04	710	710	710	557	557	557	-	-	0	0	0	585	585	585	-0.57
33	33-9	715 Lakefield Rd	1982	13	153	154	219	65	126	145	10	65	9E-05	713	712	713	560	559	560	-	-	0	1	16	587	586	587	-0.68

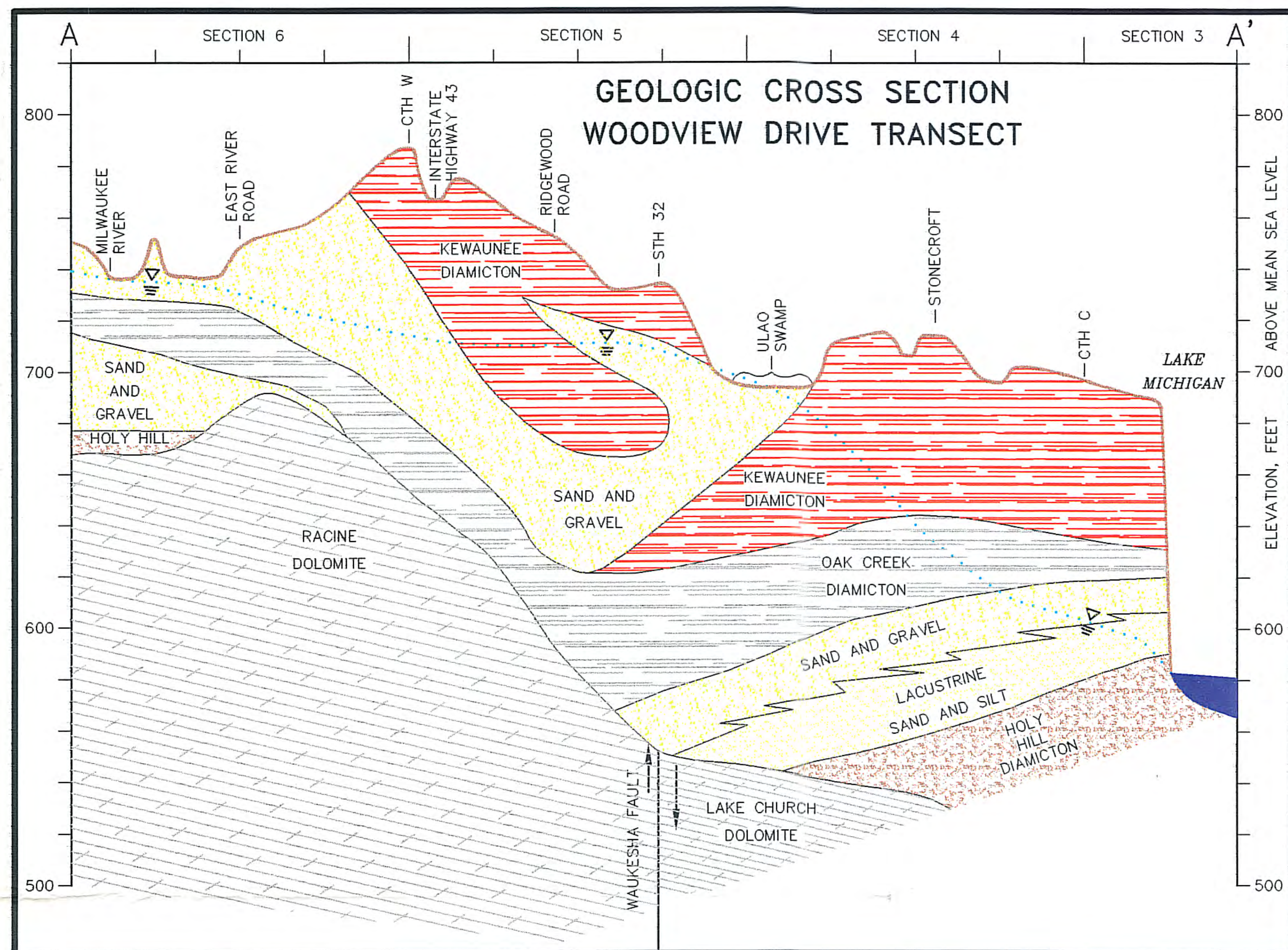
Note:
(g) = gravel
gpm = gallons per minute
"e" = estimated thickness
"M" = multiple interbedded layers
Vertical gradient: Vertical hydraulic gradient between the land surface and the potentiometric surface of the aquifer

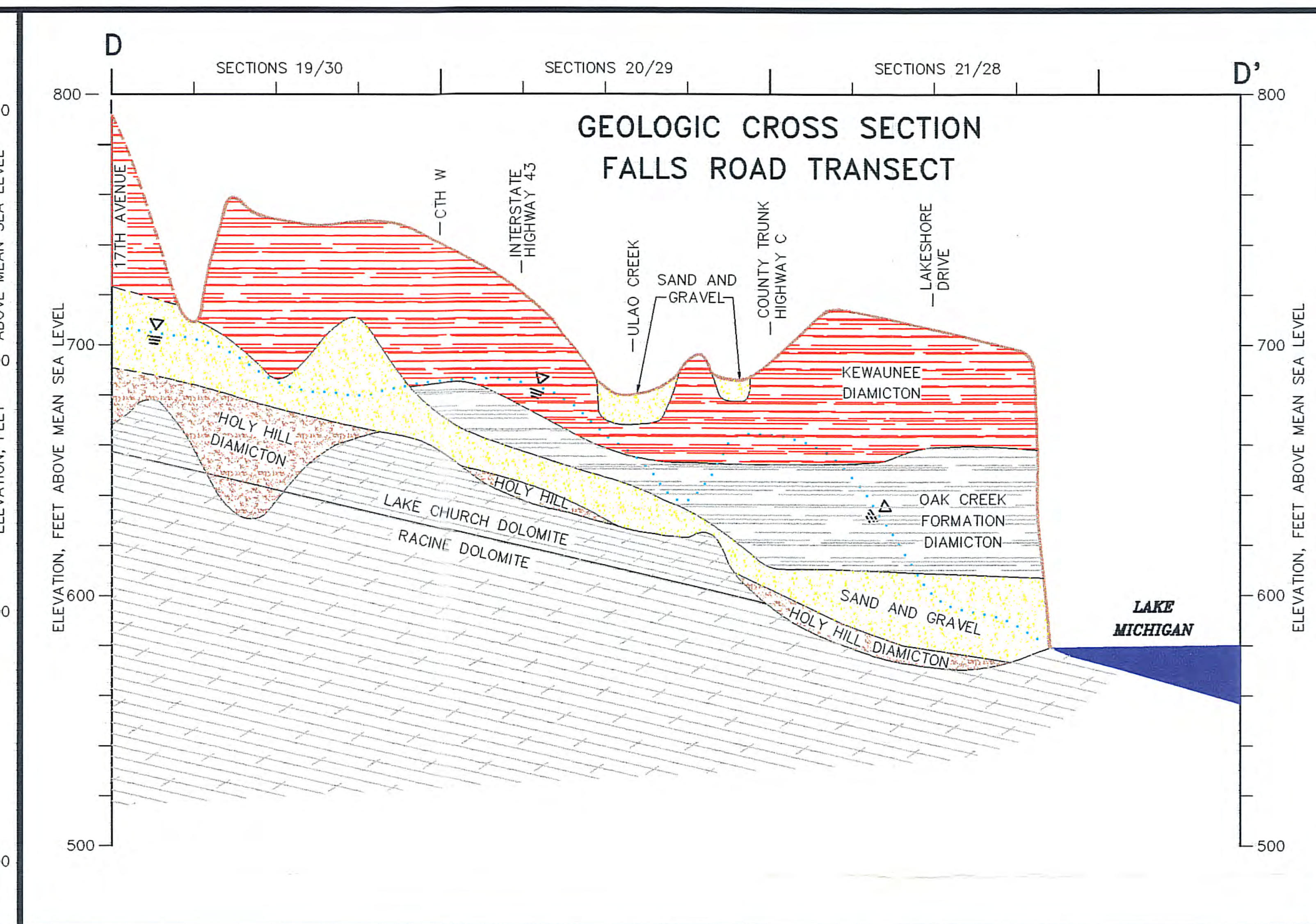
October 30, 1997

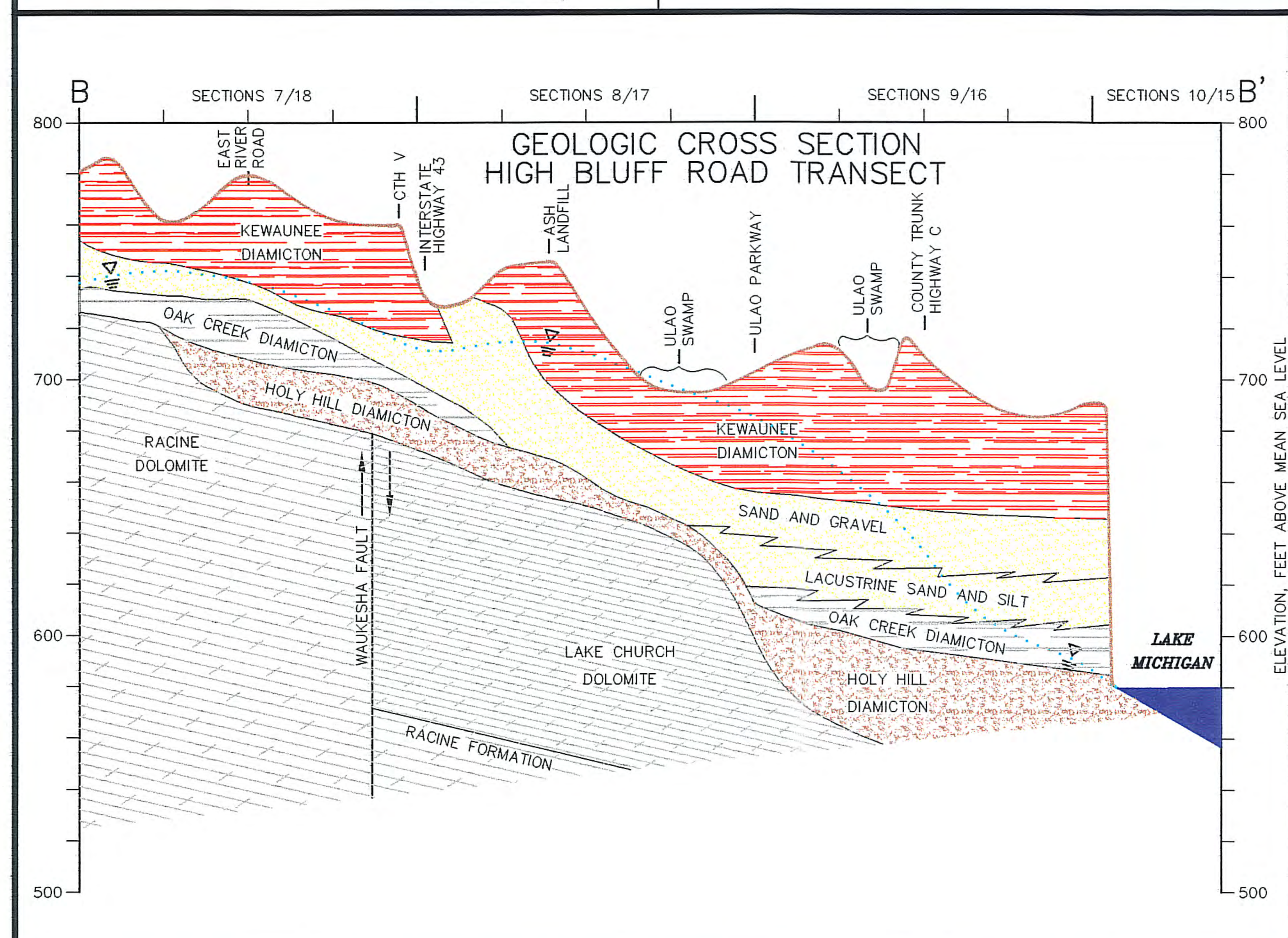
Appendix B Well Constructor Report Summary, Ulao Creek Watershed

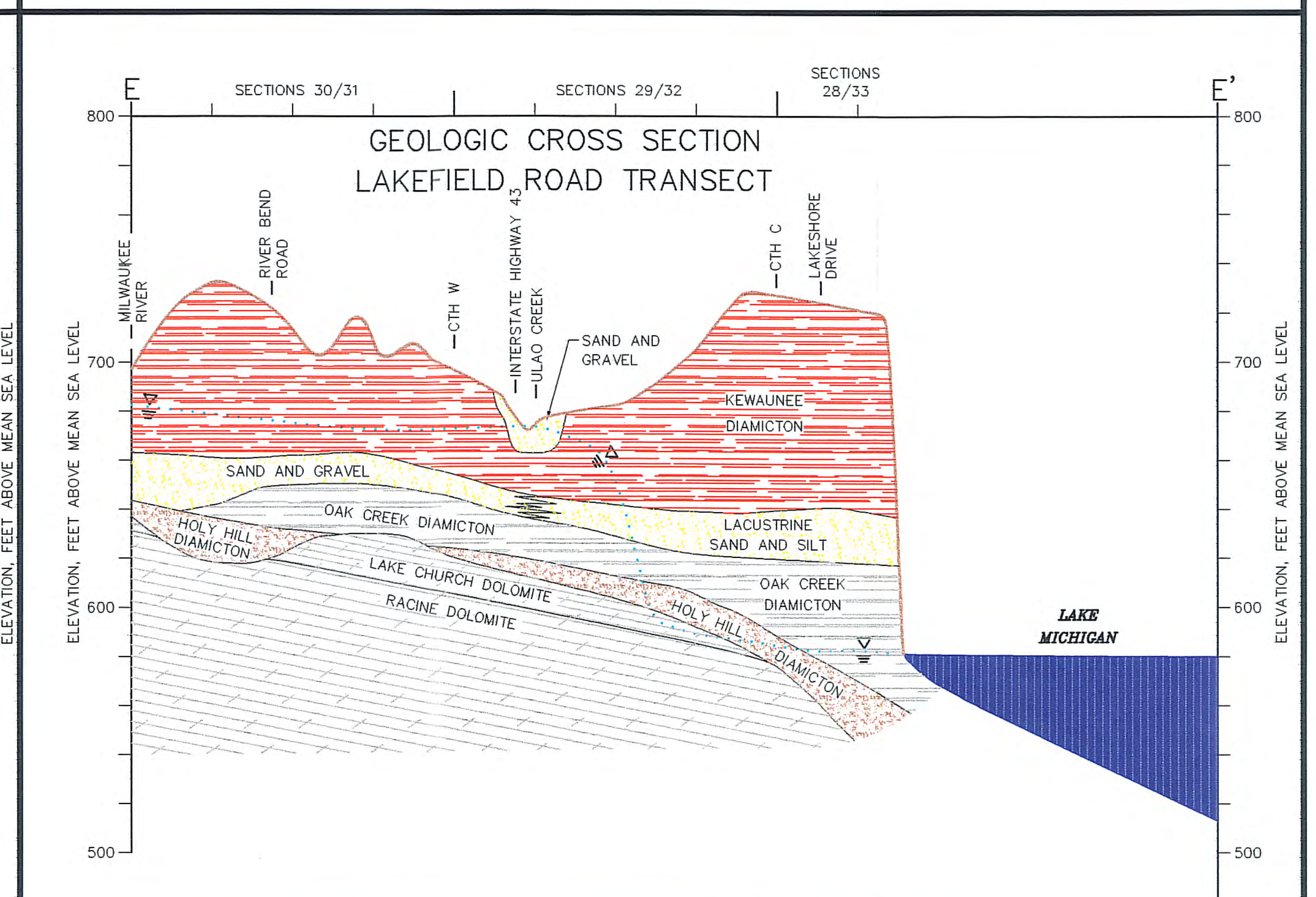
Section	Reference	Address	Year Completed	Distance to Building	Depth to Bedrock (feet)	Completion Interval Top	Completion Interval Bottom	Completion Interval Length	Depth to Water Static	Depth to Water During Pumping	Pumping Rate (gpm)	Aquifer Thickness (feet)	Calculated Hydraulic Conductivity (cm/sec)	Surface Elevation Average	Surface Elevation Low	Surface Elevation High	Bedrock Elevation Average	Bedrock Elevation Low	Bedrock Elevation High	Sand & Gravel in Contact with Bedrock Top	Sand & Gravel in Contact with Bedrock Bottom	Sand & Gravel in Contact with Bedrock Thickness	Isolated Sand & Gravel Lenses Number	Isolated Sand & Gravel Lenses Total Thickness	Water Elevation Average	Water Elevation Low	Water Elevation High	Vertical Gradient
18	18-1	U.S. Hwy 41 & Port Wash. Road	1950	-	> 48 (g)	48	48.5	1	20	29	25	1	3E-02	ERR			0	0	0	45	"e" 100	"e" 55			-20	-20	-20	-0.41
18	18-2	Vocke, William	1964	6	104	104	130	26	55	60	30	26	3E-03	ERR			-104	-104	-104	65	104	39	0	0	-55	-55	-55	-0.47
18	18-3	1332 Arrowhead Road	1989	150	98	98	218	120	58	115	25	120	4E-05	786	784	788	688	686	690	-	-	0	0	0	728	726	730	-0.37
18	18-4	1332 Arrowhead Road	1970	13	76	76	169	93	32	55	15	93	8E-05	783	782	784	706	704	708	-	-	0	1	12	751	750	752	-0.26
18	18-5	1332 Arrowhead Road	1967	18	80	85	158	73	45	75	15	73	8E-05	784	782	786	704	702	706	80	85	5	1	12	739	737	741	-0.37
18	18-6	1625 Bridge Street	1966	14	44	44	140	96	30	45	15	96	1E-04	ERR			-44	-44	-44	-	-	0	0	0	-30	-30	-30	-0.33
18	18-7	1064 Crestview Drive	1967	15	60	60	177	117	34	48	15	117	1E-04	ERR			-60	-60	-60	-	-	0	0	0	-34	-34	-34	-0.29
18	18-8	1591 Crestview Drive	1965	18	55	55	164	109	65	74	11	109	1E-04	779	778	780	724	723	725	-	-	0	0	0	714	713	715	-0.59
18	18-9	1374 Grafton Avenue (State Hwy 57)	1976	16	65	66	110	44	46	63	12	44	4E-04	ERR			-65	-65	-65	-	-	0	0	0	-46	-46	-46	-0.52
18	18-10	1388 Grafton Avenue (State Hwy 57)	1987	17	78	79	116	37	51	65	15	37	3E-04	ERR			-78	-78	-78	-	-	0	0	0	-51	-51	-51	-0.52
18	18-11	1439 Hickory Court	1989	12	68	69	190	121	53	80	12	121	4E-05	791	790	792	723	722	724	-	-	0	0	0	738	737	739	-0.41
18	18-12	1504 JoDee Lane	1966	15	74	74	151	77	41	51	15	77	2E-04	783	782	784	709	708	710	72	74	2	0	0	742	741	743	-0.36
18	18-13	1599 Port Wash. Road (Cty Hwy W)	1969	-	66	66	132	66	30	35	20	66	7E-04	757	756	758	691	690	692	60	66	6	0	0	727	726	728	-0.30
18	18-14	1544 East River Road	1985	18	93	93	155	62	70	80	20	62	4E-04	811	810	812	718	717	719	-	-	0	0	0	741	740	742	-0.56
18	18-15	1694 East River Road	1979	12	90	91	100	9	36	41	10	9	3E-03	775	774	776	685	684	686	-	-	0	0	0	739	738	740	-0.38
18	18-16	1496 Woodland Drive	1971	10	43	43	150	107	17	45	15	107	6E-05	759	758	760	716	715	717	-	-	0	0	0	742	741	743	-0.18
18	18-17	1532 Woodland Drive	1974	14	46	46	200	154	24	40	15	154	7E-05	761	760	762	715	714	716	19	46	27	0	0	737	736	738	-0.20
18	18-18	1550 Woodland Drive	1974	14	54	54	212	158	27	38	15	158	1E-04	763	762	764	709	708	710	-	-	0	1	23	736	735	737	-0.20
18	18-19	1569 Woodland Drive	1975	11	26	42	166	124	18	30	15	124	1E-04	751	746	756	725	720	730	-	-	0	0	0	733	728	738	-0.17
18	18-20	1571 Woodland Drive	1972	14	26	42	175	133	18	20	15	133	6E-04	751	750	752	725	724	726	0	26	26	0	0	733	732	734	-0.17
18	18-21	1580 Woodland Drive	1973	11	62	63	172	109	22	30	12	109	2E-04	761	760	762	699	698	700	0	0	0	1	19	739	738	740	-0.19
18	18-22	1597 Woodland Drive	1969	10	48	48	142	94	24	25	20	94	2E-03	758	756	760	710	708	712	6	48	42	0	0	734	732	736	-0.25
18	18-23	1698 Woodland Drive	1978	20	54	54	170	116	60	66	20	116	4E-04	778	776	780	724	722	726	-	-	0	0	0	718	716	720	-0.64
19	19-1	Paulus, Richard	1965	12	104	104	191	87	61	65	20	87	7E-04	ERR			-104	-104	-104	103	104	1	1	7	-61	-61	-61	-0.41
19	19-2	Village Well #3	1958	-	75			0				0	ERR	ERR			-75	-75	-75	70	75	5	0	0	0	0	0	ERR
19	19-3	1220 Falls Road	1989	12	94	95	160	65	59	75	12	65	1E-04	ERR			-94	-94	-94	-	-	0	0	0	-59	-59	-59	-0.46
19	19-4	1230 Falls Road	1989	12	94	95	160	65	59	75	12	65	1E-04	742	742	742	648	648	648			0			683	683	683	-0.46
19	19-5	1232 Falls Road	1980	20	79	80	145	65	55	75	12	65	1E-04	740	740	740	661	661	661	-	-	0	0	0	685	685	685	-0.49
19	19-6	1282 Falls Road	1954	16	92	92	175	83	75	90	15	83	1E-04	761	760	762	669	668	670	-	-	0	0	0	686	685	687	-0.56
19	19-7	1468 Falls Road	1964	15	123	123	155	32	100	105	10	32	7E-04	757	756	759	634	633	635	18	123	105	0	0	657	656	658	-0.72
19	19-8	1406 Fox Lane	1994	12	138	140	250	110	75	100	12	110	5E-05	762	762	762	624	624	624	-	-	0	1	10	687	687	687	-0.36
19	19-9	1427 Fox Lane	1978	20	118	118	226	108	60	104	12	108	3E-05	751	750	752	633	632	634	-	-	0	0	0	691	690	692	-0.35
19	19-10	1345 Ulao Road	1979	14	83	84	160	76	58	80	12	76	8E-05	751	750	751	668	667	668	-	-	0	0	0	693	692	693	-0.48
19	19-11	1435 Washington Ave	1966	13	85	85	189	104	79	80	15	104	2E-03	765	762	768	680	677	683	-	-	0	0	0	686	683	689	-0.58
19	19-12	1241 Westwood Drive	1965	20	102	102	187	85	60	75	20	85	2E-04	748	746	750	646	644	648	101	102	1	1	7	688	686	690	-0.42
19	19-13	1252 Westwood Drive	1965	11	107	107	189	82	65	75	18	82	2E-04	756	754	757	649	647	650	-	-	0	1	8	691	689	692	-0.44
20	20-1	862 Falls Road	1978	15	64	66	131	65	21	33	16	65	2E-04	687	686	687	623	622	623	-	-	0	0	0	666	665	666	-0.21
20	20-2	890 Falls Road	1974	15	80	80	205	125	65	70	15	125	3E-04	699	698	699	619	618	619	76	80	4	0	0	634	633	634	-0.46
20	20-3	1024 Falls Road	1982	12	76	76	160	84	18	35	10	84	8E-05	697	696	698	621	620	622	61	76	15	1	24	679	678	680	-0.15
20	20-4	1100 Falls Road	1976	12	91	91	152	61	38	43	15	61	6E-04	718	710	726	627	619	635	76	91	15	1	19	680	672	688	-0.31
20	20-5	1100 Falls Road	1989	9	88	90	127	37	24	40	12	37	2E-04	719	712	726	631	624	638	-	-	0	0	0	695	688	702	-0.22
20	20-6	955 Pioneer Road (Cty Hwy C)	1979	20	104	104	176	72	37	70	15	72	7E-05	710	709	711	606	605	607	98	104	6	0	0	673	672	674	-0.26
20	20-7	955 Pioneer Road (Cty Hwy C)	1966	13	75	75	388	313	26	71	12	313	9E-06	710	709	711	635	634	636	-	-	0	0	0	685	684	686	-0.11
20	20-8	1057 Pioneer Road (Cty Hwy C)	1989	18	> 118 (g)	118	118	0	43	55	15	1	1E-02	732	731	732	<614	<613	<61	81	"e" 147	"e" 66	0	0	689	688	689	-0.36
20	20-9	1115 Pioneer Road (Cty Hwy C)	1988	65	139	139	293	154	52	65	20	154	4E-05	729	724	733	590	586	594	-	-	0	0	0	677	672	681	-0.24
20	20-10	980 Port Wash. Road (Cty Hwy W)	1990	12	90	91	176	85	39	55	55	85	5E-04	736	735	736	646	645	646	-	-	0	1	28	697	696	697	-0.29
20	20-11	970 Ulao Road	1988	67	117	118	213	95	35	75	15	95	4E-05	733	732	734	616	615	617	-	-	0	0	0	698	697	699	-0.21
20	20-12	988 Ulao Road	1985	50	94	95	189	94	28	56	10	94	4E-05	719	718	720	625	624	626	-	-	0	0	0	691	690	692	-0.20
20	20-13	989 Ulao Road (Tews Company)	1991		77	77	312	235	11	66	60	235	4E-05	700	699	700	623	622	623	-	-	0	0	0	689	688	689	-0.06
20	20-14	994 Ulao Road	1987	6	76	76	240	164	20	70	15	164	2E-05	699	698	700	623	622	624	36	76	40	0	0	679	678	680	-0.13
20	20-15	1121 Ulao Road (Mr. Z's Pizza)	1983	8	82	82	157	75	4	25	25	75	2E-04	691	690	692	609	608	610	-	-	0	1	60	687	686	688	-0.03
20	20-16	1138 Ulao Road	1970	15	99	99	172	73	20	40	20	73	2E-04	714	710	718	615	611	619	97	99	2	1	7	694	690	698	-0.15
21	21-1	921 Lake Shore Drive	1969	15	145	145	220	75	110	120	15	75	2E-04	708	706	710	563	561	565	-	-	0	1	42	598	596	600	-0.60
21	21-2	989 Lake Shore Drive	1977	15	160	160	230	70	90	110	15	70	1E-04	715	712	718	555	552	558	-	-	0	1	37	625	622	628	-0.46
21	21-3	1030 Lake Shore Drive	1978	12	146	147	160	13	101	105	10	13	2E-03	705	704	706	559	558	560	-	-	0	0	0	604	603	605	-0.68
21	21-4	1108 Lake Shore Drive	1978	18	162	163	295	132	102	135	10	132	3E-05	704	702	706	542	540	544	-	-	0	0	0	602	600	604	-0.45
21	21-5	1130 Lake Shore Drive	1992	8	163	163	283	120	95	150	20	120	3E-05	704	702	706	541	539	543	-	-	0	2	26	609	607	611	-0.43
21	21-6	1135 Lake Shore Drive	1979	16	200	200	203	3	98	140	25	3	2E-03	729	728	730	529	528	530	-	-	0	1	30	631	630	632	-0.49
21	21-7	1206 Lake Shore Drive	1973	11	208	208	312	104	83	95	20	104	2E-04	710	708	712	502	500	504	-	-	0	1	45	627	625	629	-0.32
21	21-8	1220 Lake Shore Drive	1970	15	216	216	280	64	100	120	20	64	2E-04	706	704	708	490	488	492	-	-	0	1	60	606	604	608	-0.40
21	21-9	1270 Lake Shore Drive	1977	12	179	180	298	118	95	120	12	118	5E-05	709	708	710	530	529	531	-	-	0	0	0	614	613	615	-0.40
21	21-10	806 Ulao Road	1970	17	181	183	203	20	75	120	11	20	1E-04	725	724	726	544	543	545	-	-	0	0	0	650	649	651	-0.39
28	28-1	Metzger	1955		137	137	240	103	120	162	9	103	3E-05	711	710	712	574	573	575	-	-	0	0	0	591	590	592	-0.64
28	28-2	Totzlaff, H.	1965	12	125	125	285	160	82	107	8	160	2E-05	ERR			-125	-125	-125	-	-	0	0	0	-82	-82	-82	-0.40
28	28-3	692 Highway C	1967	11	131	131	282	151	128	130	15	151	6E-04	731	730	732	600	599	601	-	-	0	0	0	603	602	604	-0.62
28	28-4	686 Lakefield Rd	1978	20	165	165	280	115	120	135	20	115	1E-04	707	706	707	542	541	542	-	-	0	1	51	587	586	587	-0.54
28	28-5	694 Lakefield Rd	1986	16	166	166	295	129	119	150	16	129	4E-05	710	710	710	545	545	545	-	-	0	1"M"	28	591	591	591	-0.52
28	28-6	510 Lake Shore Drive	1970	15	151	152	248	96	135	180	15	96	4E-05	714	712	716	563	561	565	-	-	0	0	0	579	577	581	-0.68
28	28-7	520 Lake Shore Drive	1987	24	158	158	300	142	126	134	16	142	1E-04	715	714	716	557	556	557	-	-	0	0	0	589	588	589	-0.55
28	28-8	558 Lake Shore Drive	1965	-	150	150	231	81	130	131	15	81	2E-03	705	704	706	555	554	556	144	150	6	0	0	575	574	576	-0.68
28	28-9	573 Lake Shore Drive	1986	31	143	144	265	121	110	136	12	121	5E-05	717	714	720	574	571	577	-	-	0	1"M"	10	607	604	610	-0.54
28	28-10	583 Lake Shore Drive	1989	15	138	138	205	67	111	140	15	67	9E-05	715	714	716	577	576	578	-	-	0	0	0	604	603	605	-0.65
28	28-11	655 Lake Shore Drive	1992	11	143	143	287	144	145	160	15	144	2E-04	717	716	718	574	573	575	-	-	0	0	0	572	571	573	-0.67
28	28-12	700 Lake Shore Drive	1990	12	136	163	355	192	118	130	20	192	1E-04	710	710	710	574	574	574	-	-	0	1	45	592	592	592	-0.46
28	28-13	701 Lake Shore Drive	1973	15	140	140	191	51	129	132	16	51	1E-03	721	718	724	581	578	584	-	-	0	0	0	592	589	595	-0.78
28	28-14	703 Lake Shore Drive (Fromm Labs)	1971	-	130	132	402	270	145	280	125	270	4E-05	717	716	718	587	586	588	115	130	15	70	70	572	571	573	-0.54
28	28-15	790 Lake Shore Drive	1988	17	123	123	247	124	118	165	18	124	4E-05	704	702	706	581	579	583	-	-	0	0	0	586	584	588	-0.84

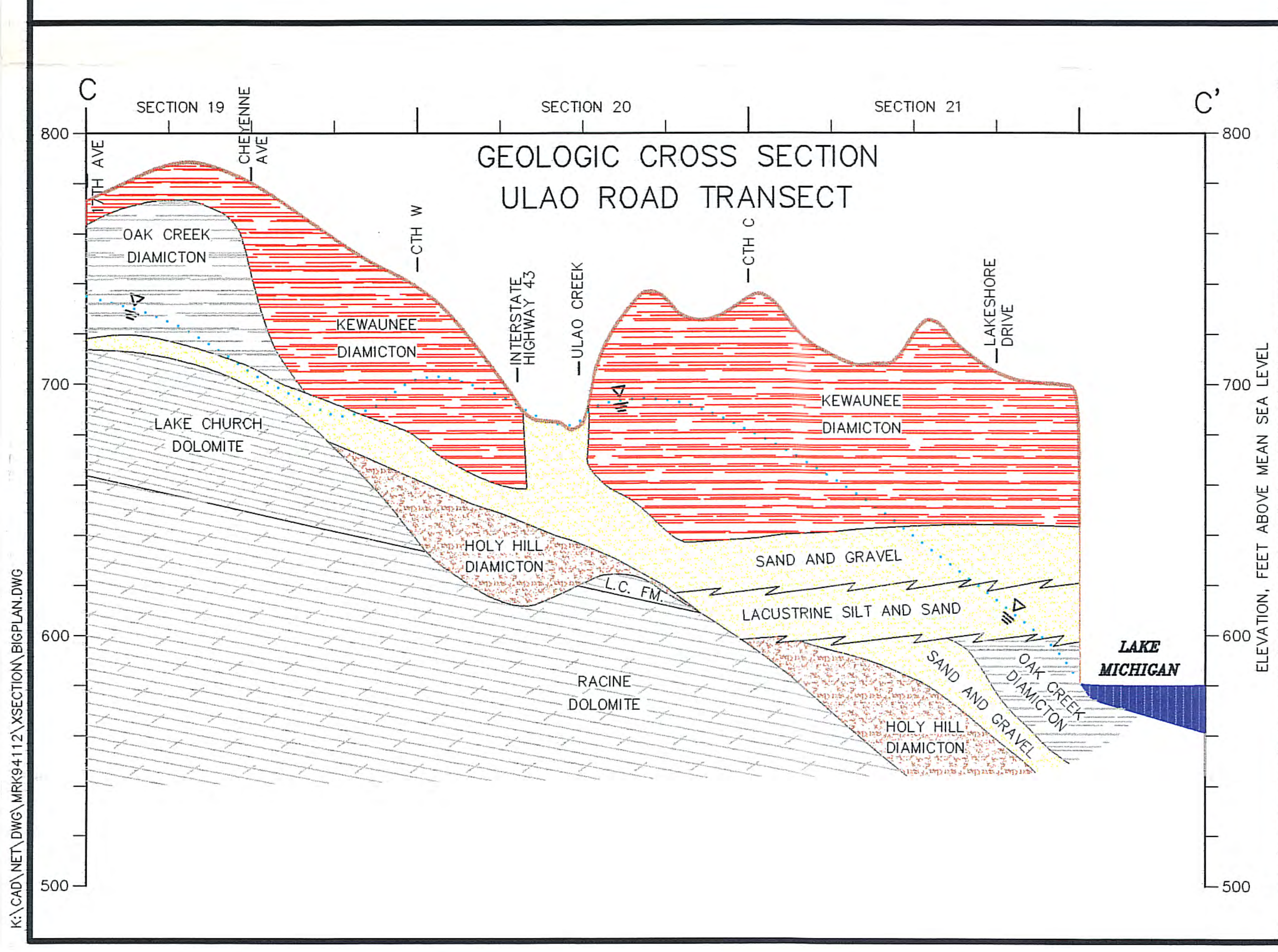
PLATES



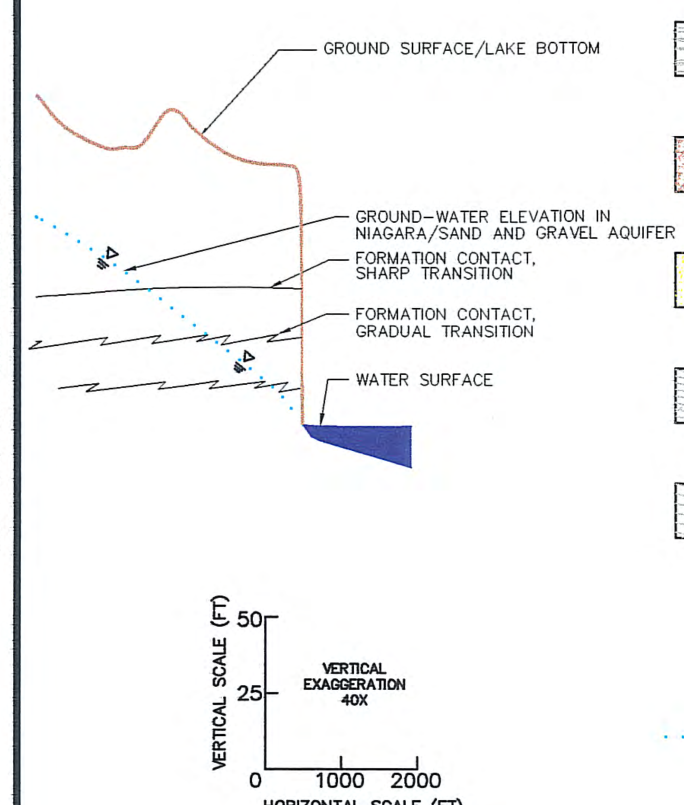








EXPLANATION:



KEWAUNEE FORMATION DIAMICTON
PREDOMINANTLY REDDISH BROWN TO PINKISH GRAY TO LIGHT GRAY CLAYEY SILT TILL WITH A LITTLE SAND. RELATIVELY SMALL AMOUNTS OF FLUVIOLACUSTRINE SAND AND SILT MAY BE INTERLAYERED WITH THE TILL.

OAK CREEK FORMATION DIAMICTON
PINKISH GRAY SILTY CLAY TILL. THICK LAYERS OF LAKE SEDIMENT ARE INCLUDED IN THIS UNIT, PARTICULARLY SILTY SAND LAYERS IN THE UPPER LAYERS NEAR LAKE MICHIGAN.

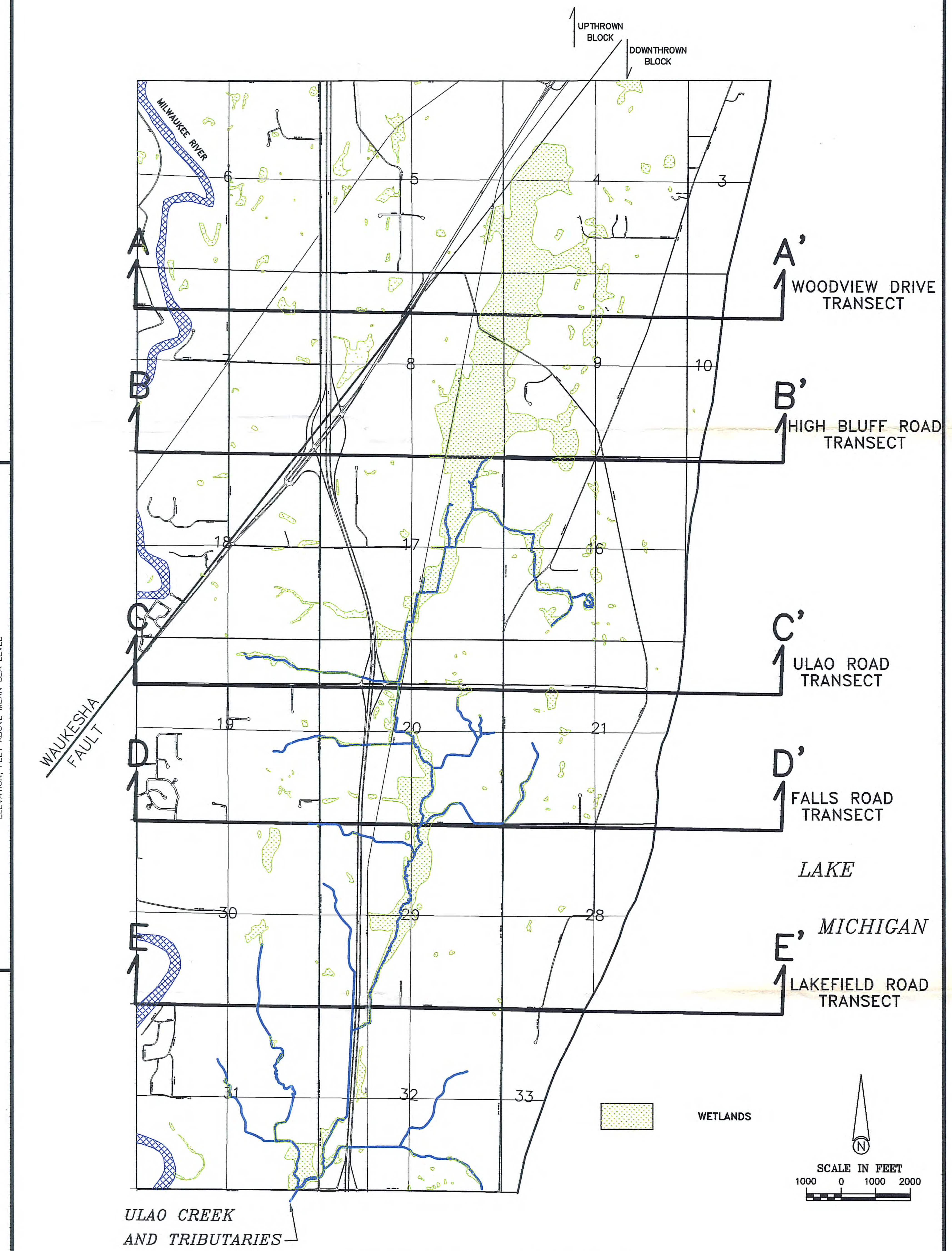
HOLY HILL FORMATION DIAMICTON
GRAY TO BROWN COARSE GRAVELLY TILL AND FLUVIAL DEPOSITS. THE DEPTH OF BURIAL AND COARSE TEXTURE MAKE IT DIFFICULT TO DIFFERENTIATE THE FLUVIAL DEPOSITS.

LACUSTRINE AND FLUVIAL DEPOSITS
FLUVIAL SAND AND GRAVEL AND LACUSTRINE SAND AND SILT DEPOSITS. INCLUDES SEDIMENTS OF THE KEWAUNEE, OAK CREEK, AND HOLY HILL FORMATIONS AS WELL AS POST- AND PRE-GLACIAL DEPOSITS.

LAKE CHURCH FORMATION DOLOMITE
BROWN TO GRAY DOLOMITE WITH SCATTERED SHALE LAMINAE. THE UPPER 20 FEET ARE MORE WEATHERED AND MORE PERMEABLE. AREAS NEAR THE WAUKESHA FAULT ARE COARSER TEXTURED AND MORE PERMEABLE.

RACINE FORMATION DOLOMITE
GRAY DOLOMITE. BEDROCK LESS THAN 20 FEET BELOW GLACIAL DEPOSITS IS MORE WEATHERED AND MORE PERMEABLE. AREAS NEAR THE WAUKESHA FAULT ARE COARSER TEXTURED AND MORE PERMEABLE.

GROUND-WATER ELEVATION



CROSS SECTION LOCATIONS

DRAWN BY: JAW	PROJECT: BRA141725	DATE: 10/30/97
REV. DATE 2/2/98	THIS DRAWING AND ALL INFORMATION CONTAINED THEREON IS THE PROPERTY OF NORTHERN ENVIRONMENTAL INCORPORATED AND SHALL NOT BE COPIED OR USED EXCEPT FOR THE PURPOSE FOR WHICH IT IS EXPRESSLY FURNISHED.	

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ULAO CREEK PARTNERSHIP
GRAFTON, WISCONSIN

GEOLOGIC CROSS SECTIONS

PLATE 1

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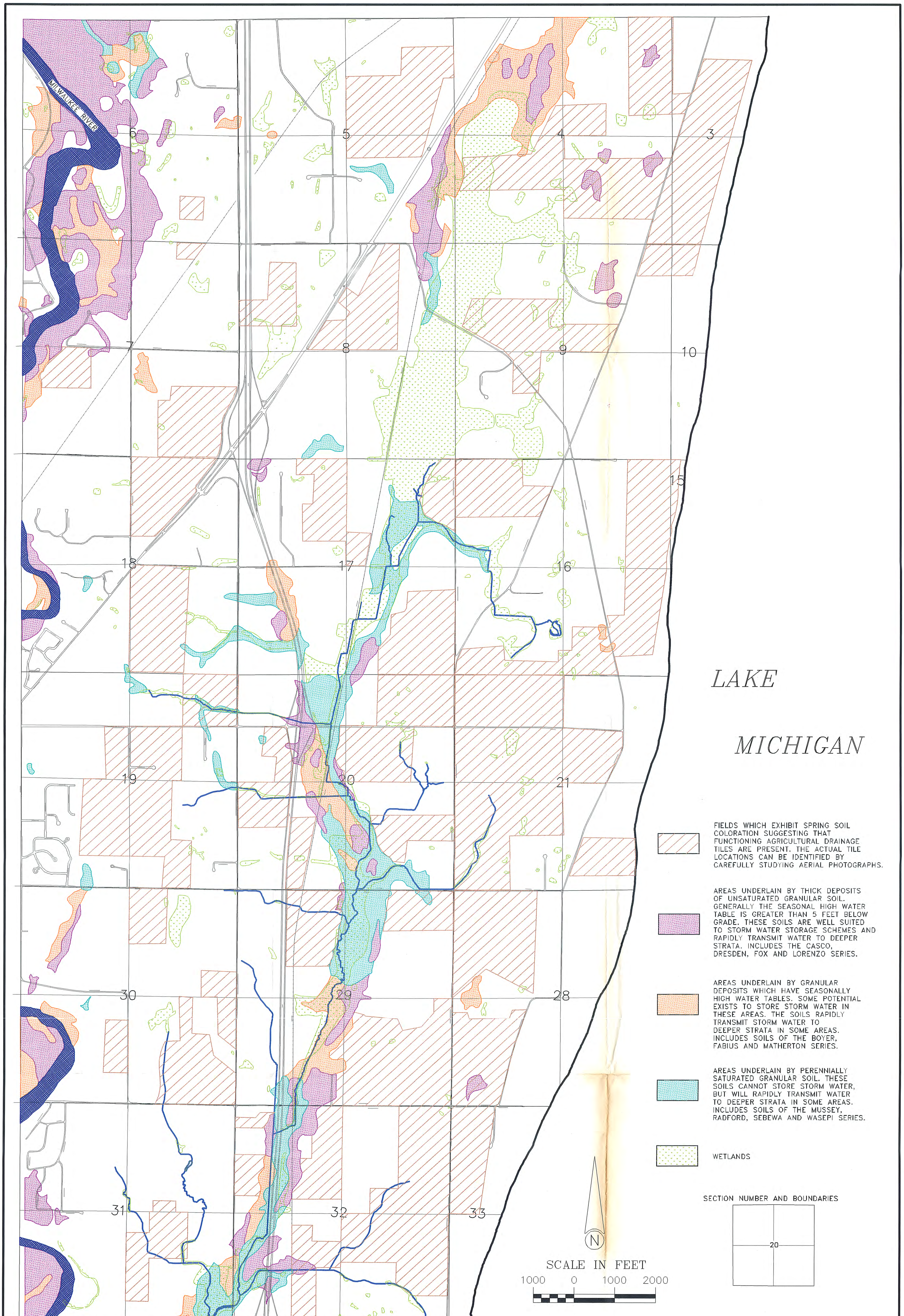


DRAWN BY: JAW	PROJECT: BRA141725	DATE: 10/30/97	ULAO CREEK PARTNERSHIP GRAFTON, WISCONSIN
REV. DATE 2/2/98	THIS DRAWING AND ALL INFORMATION CONTAINED THEREON IS THE PROPERTY OF NORTHERN ENVIRONMENTAL INCORPORATED AND SHALL NOT BE COPIED OR USED EXCEPT FOR THE PURPOSE FOR WHICH IT IS EXPRESSLY FURNISHED.		DISTRIBUTION OF SURFICIAL GRANULAR SEDIMENTS AND POSSIBLE DRAIN TILE LOCATIONS
	Northern Environmental℠ Hydrologists · Engineers · Geologists		

PLATE 2

APPENDIX D

VILLAGE OF GRAFTON - NORTHEAST DRAINAGE STUDY
EXECUTIVE SUMMARY

BACKGROUND

The northeast section of the Village of Grafton has seen increased development over the last five years, resulting in an increase in stormwater generated. In most instances, the systems in place to handle stormwater are rural controls working with a delicate balance of ecological factors. Increased stormwater flows exceed the capacity of rural controls and subsequently have been shown to disrupt the downstream ecological system, the Ulao Creek Watershed.

The limits of the study encompass an area whose stormwater is tributary to the Ulao Creek. The Village is taking an active role in the management of stormwater runoff and its effects on the Ulao Creek watershed. This management consists of evaluating future developments for stormwater control. This study was provided to aid the Village of Grafton in making educated decisions concerning the effects of development on the current drainage patterns.

Initial concern of drainage patterns arose from a proposed development at the intersection of HWY 60 and Port Washington Road. The development was designed with a stormwater detention facility to accommodate the stormwater generated on-site. Midway through the study of the regional stormwater pond, the study limits were expanded to include a greater area tributary to the Ulao Creek. The DNR is currently funding a multi-community effort to explore water quantity and quality problems present in the Ulao Creek from the Town of Grafton to the City of Mequon.

Increasing future development also prompted this study. The majority of the current study area consists of agricultural and open lands. The Village realized that without careful planning now, the ability and effectiveness of controlling stormwater would be difficult. This plan will be used as a guide for any future development and will ensure that if recommendations are implemented, the downstream effects to property owners and the Ulao Creek are minimized.

OBJECTIVES

In February and March 1997 an inventory of the existing conditions in the study area for the Village of Grafton was completed. The study area encompasses areas in the Village of Grafton, recently annexed lands, and those lands part of the Ulao Creek Watershed as most probable candidates for annexation. The study area itself is approximately 561.66 acres in size. A total of 17 structures in the study area critical for modeling water quantity were identified and measured. Drainage boundaries were identified based on topography and existing roads dictating surface flows. A total of 20 subcatchments were delineated for the 561.66 acre study area. The primary objectives and general intent of the stormwater management plan evolved from evaluating the existing and proposed conditions throughout the watershed.

The summarized objectives of this plan are:

1. Reduce flood risks and damages
2. Preserve and improve water quality
3. Reduce erosion, sedimentation and pollution from surface runoff flows
4. Assess existing and future pollutant loadings
5. Serve as a blueprint for municipal staff to incorporate best management practices for new development
6. Protect and enhance wildlife habitat
7. Provide guidance for preventative measures and for retrofitting of existing drainage channels for improved water quality and reduced flooding
8. Protect the natural beauty of the watershed and the quality of the primary and secondary environmental corridors including floodplains, woodlands, and wetlands.

PLAN RECOMMENDATIONS

The Northeast Drainage Study accomplished these goals through the inventory of the watershed and stormwater conveyance system, water quality and quantity modeling, analyzing management alternatives, and providing recommendations to achieve the project objectives.

Water Quantity

The stormwater management plan reduces flood risks and damages by recommending structural water quantity Best Management Practices (BMPs) projects that will store the 100-year future development runoff and release it at the 10-year pre-settlement runoff rate. This will assure that in the future, when the this area is fully developed, that flooding and flood damage will be significantly reduced. The costs associates with the projects in each subwatershed are as follows:

Table 7
Recommended Improvement Costs

Subwatershed	Improvement	Area at HWL (Acre)	Cost
1	2 ponds	4.45	$356,000
3	1 pond	3.50	$280,000
4	1 pond	1.93	$154,400
5	1 pond	1.20	$96,000
6	1 pond	1.20	$96,000
8	1 pond	1.00	$80,000
11	1 pond	1.00	$80,000
15	1 pond	1.00	$80,000
21	1 pond	1.00	80,000
22	1 pond	1.00	$80,000
23	1 pond	1.10	$88,000
Total			**$1,470,400**

Water Quality
The plan preserves and improves water quality, including the reduction of erosion, sedimentation, and pollution of surface runoff. The land use intensity will dictate the type of water quality BMPs to be implemented. Structural BMPs, like wet detention ponds, for commercial and industrial land uses, and less intensive structural BMPs, like grassed buffer strips and channel improvements. The implementation of these recommendations will preserve the water quality of the Ulao Creek by providing measure to filter pollutants in stormwater to an acceptable level regardless of land use.

The plan estimates the annual existing loading of 204,904 pounds of sediment, 343 pounds of phosphorous, and 289 pounds of lead in the watershed. Future land use changes will increase the quantity of pollutants entering Ulao Creek. The recommendations detailed in the plan will reduce the levels of pollutant loading to less then existing loading, thus enhancing water quality.

Condition	Sediment	Phosphorus	Lead
Existing	204,904 *	343	289
Proposed	347,588	346	1047
With Proposed Recommendations	69,518	139	210

*All values in pounds/year

Channel Enhancement
The two major existing channels in the study area (channel #1,& #2, per inventory) should be preserved and enhanced. This will allow them to continue to provide, and with enhancement improve, water quantity and quality benefits. Natural channels with vegetated buffers slow flows, allow infiltration, keep water temperature low, trap sediments, and use up nutrients. There are three recommendations for preserving and enhancing the channels. First, establish a 30 foot minimum permanent drainage easement buffer adjacent to the channel. Second, re-vegetate the buffers with native trees, shrubs, and grass-sedge mixes. Finally, create an overflow channel with a secured biodegradable erosion mat on exposed soils. Costs for channel enhancement work are as follows:

Channel #1
- Approximately 1300' to enhance per cross section detail
- $25/linear foot

$27,500 for construction
$ 5,000 for design
Total -$32,500

Channel #2
- Approximately 1200' to relocate, restore per cross section detail
- $75/linear foot

$100,000 for construction
$10,000 for design
Total - $110,000

FLOODPLAIN STUDY

This study was prepared to investigate the possibility of flooding along a portion of the Ulao Creek located in the Town of Grafton and adjacent to the eastern limits of the Village of Grafton. The focus of the study involves two areas where the stormwater flows from the Village enter the Ulao Creek and the effects on the surrounding properties.

This study was prepared under the direction of the Village of Grafton and coordination with the Town of Grafton, Wisconsin Department of Resources, and the Ulao Creek Partnership.

The Flood Insurance Rate Map for the area (Map # 55089C0066 D, Number 550310, Panel 0066, Suffix D) illustrates an area along the creek inundated by the 100-year flood, but does not contain any base flood elevations for these areas. This study is intended to provide base flood elevations during the 100-year storm event for the Ulao Creek watershed.

The study area is located within Ozaukee County and close proximity to Lake Michigan. The Ulao Creek drainage basin is located between Lake Michigan and the Milwaukee River watershed basin. This study included the analysis of approximately 12 square miles of the Town of Grafton and a 560 acre area of the Village of Grafton draining to the Ulao Creek. The existing land use in the study area consists primarily of agricultural lands with low density residential, commercial, and light industrial spread throughout.

This area of Ozaukee County has been classified as an "rapidly urbanizing watershed" by the WDNR. This classification requires analyzing the Ulao Creek watershed under future land use conditions in the Town and Village. In 1996, the Town of Grafton adopted a future land use plan which serves as the basis for hydrological modeling for the area. The Village of Grafton also provided a breakdown of future land use conditions in the tributary areas. Future stormwater flows used in hydraulic modeling are calculated for the built-out conditions in each area.

A hydrology analysis performed for the water quantity section of the Ulao Creek Stormwater Management Plan prepared to determine flows for the floodplain study for the Village of Grafton. Visual HEC-1 version 1.0 was used to run the model. The hydrologic analysis were executed to establish the peak discharge-frequency relationships for each subwatershed and pond location.

The flows calculated in the HEC-1 model for the Stormwater Management Plan are used to run a floodplain analysis for the portion of the Ulao Creek abutting the Village of Grafton. This analysis was run using HEC-RAS version 2.1. Cross sections for the study were surveyed in the field and locations are presented on the Ulao Creek Floodplain Map.

The DNR and the Southeast Wisconsin Regional Planning Commission is currently reviewing the technical results of the hydrology and hydraulic calculations. Approval of the modeling will result in an update to the floodplain maps in the area.

CONCLUSIONS

The Stormwater Management Plan outlines steps that need to be taken to accomplish the project objectives. The implementation of proper stormwater management in the Northeast Drainage Study can be broken down into a series of tasks which need to be completed. The Village of Grafton should adhere to the following prioritized tasks:

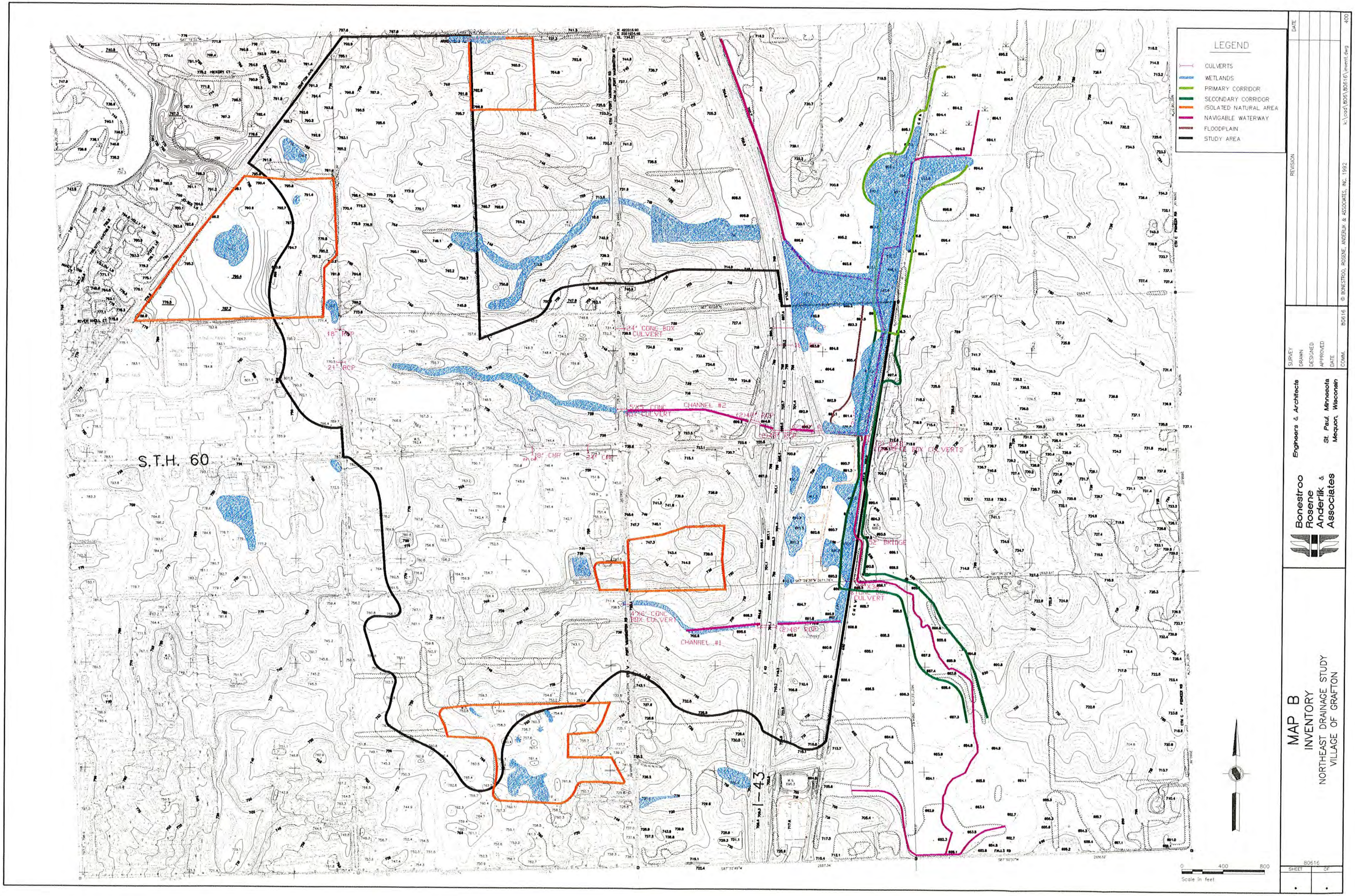
1. **Adopt the Northeast Drainage Study as a stormwater planning document**

2. **Develop Stormwater Zoning Ordinance (per NR 216 stormwater permit requirements)**

3. **Construct, as development and drainage problems arise, the structural water quantity BMP projects**

4. **Pursue 60' drainage easement for channels #1 and #2**

5. **Update floodplain maps for properties along the Ulao Creek within the Village of Grafton limits with approval from DNR and SEWRPC**



LEGEND
CULVERTS
WETLANDS
PRIMARY CORRIDOR
SECONDARY CORRIDOR
ISOLATED NATURAL AREA
NAVIGABLE WATERWAY
FLOODPLAIN
STUDY AREA
S.T.H. 60
I-43
CHANNEL #2
CHANNEL #1
18" RCP
21" RCP
24" CONC BOX CULVERT
18" CMP
0 400 800
Scale in feet
MAP B
INVENTORY
NORTHEAST DRAINAGE STUDY
VILLAGE OF GRAFTON
Bonestroo Rosene Anderlik & Associates
Engineers & Architects
St. Paul, Minnesota
Mequon, Wisconsin
SURVEY
DRAWN
DESIGNED
APPROVED
DATE
COMM. 80616
REVISION
DATE
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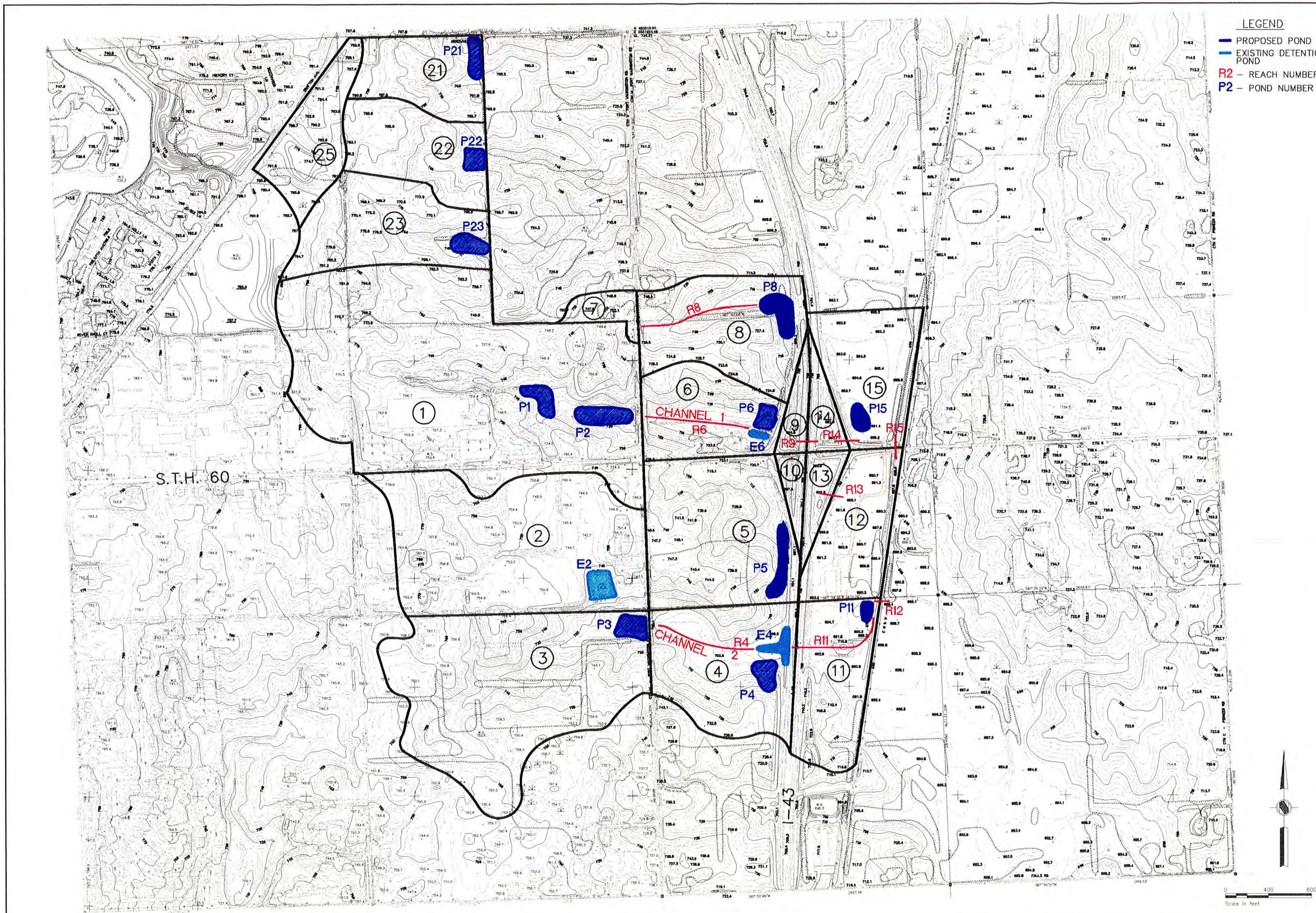

MAP E

PROPOSED STORMWATER PONDS

NORTHEAST DRAINAGE STUDY
VILLAGE OF GRAFTON

Bonestroo Rosene Anderlik & Associates
Engineers & Architects
St. Paul, Minnesota
Mequon, Wisconsin

COMM. 80616

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FIGURE #1
CHANNEL #1

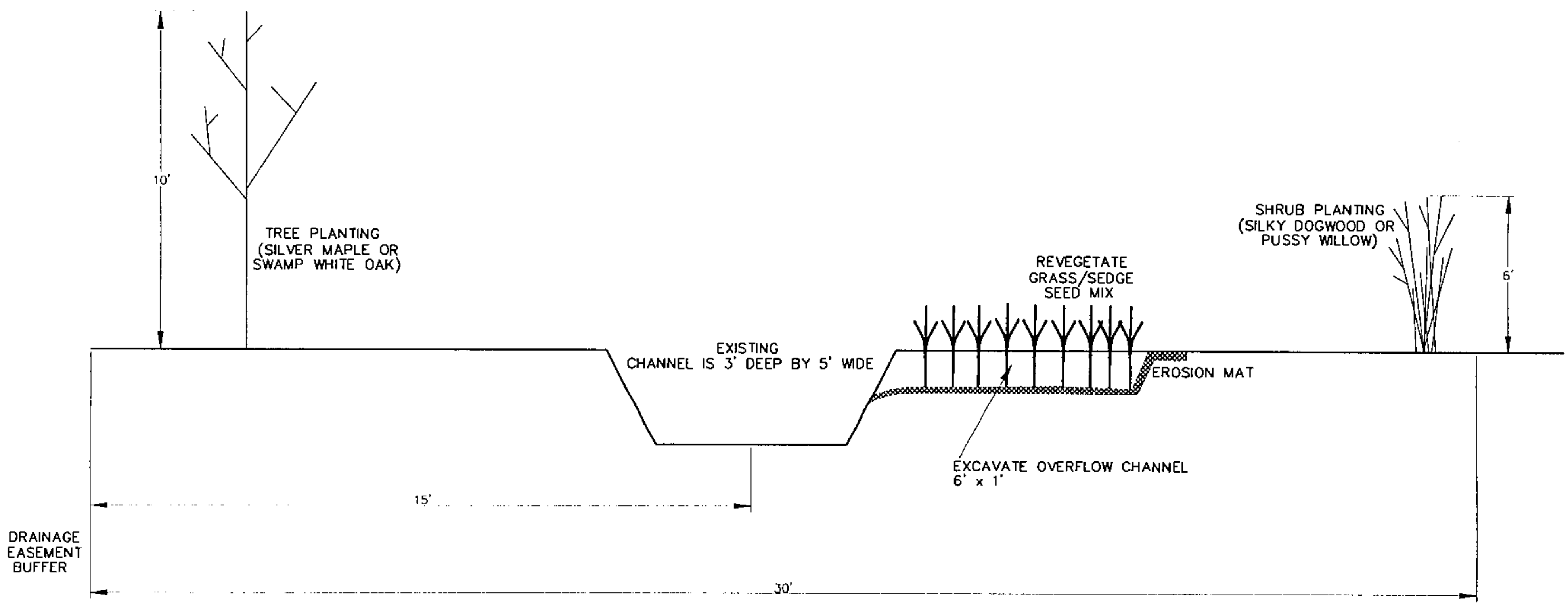
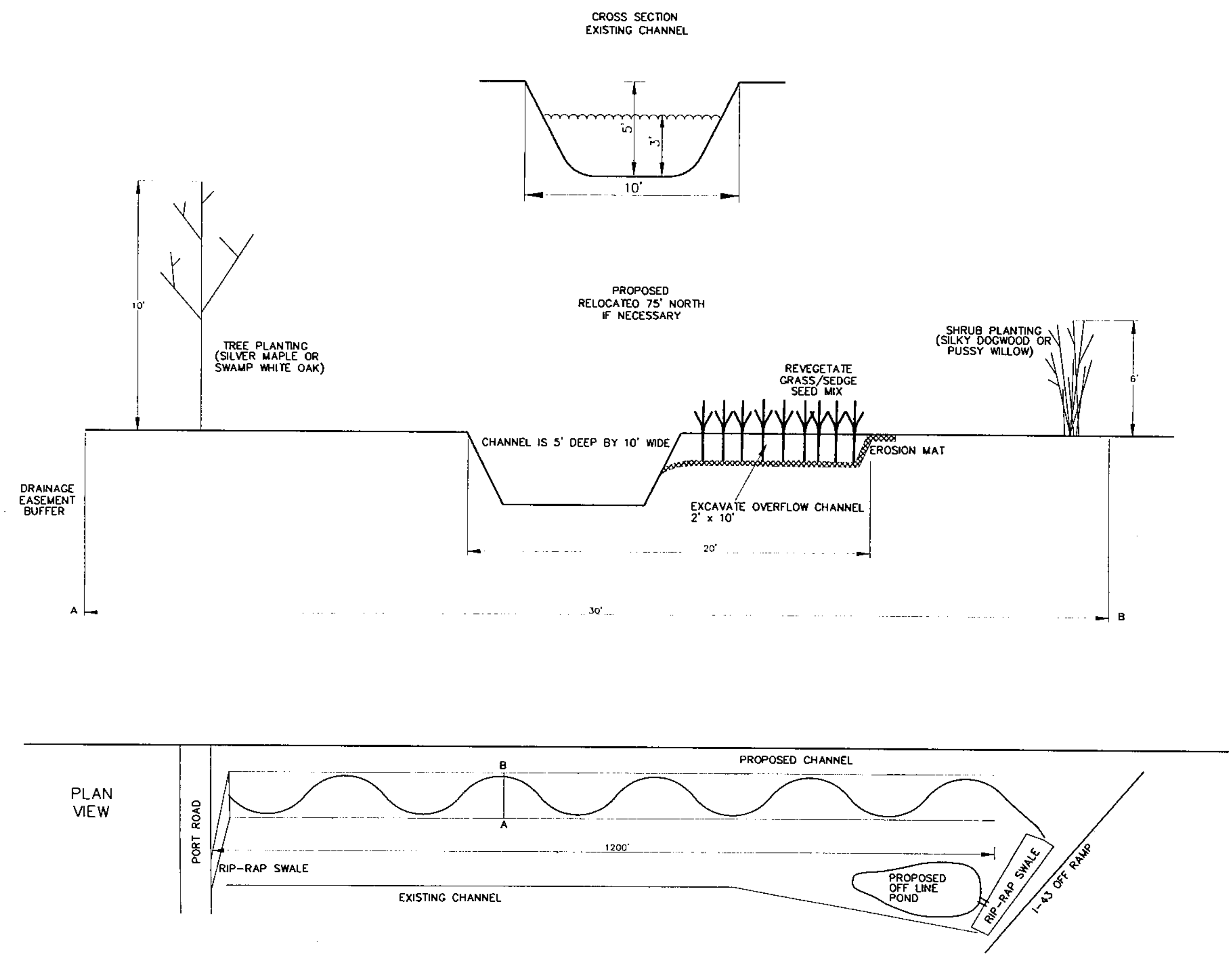


FIGURE #2
CHANNEL #2



APPENDIX E (MISSING)

APPENDIX F

Model Stormwater Management Zoning Ordinance

Table of Contents

List of Tables

List of Figures

PART 1. INTRODUCTION

This model storm water management zoning ordinance is being prepared pursuant to s. 144.266 Wis. Stats. This section of the state law requires the Wisconsin Department of Natural Resources to develop a model storm water management zoning ordinance, and to make the ordinance available to local municipalities for voluntary local adoption. This ordinance is only one of several storm water management tools that the Department is responsible for developing. Other items include an identification of cost-effective storm water management practices, storm water technical standards (in association with WDOT), and a state storm water management plan (in association with DILHR). Eventually, some of these tools will be promulgated as administrative rules, as required by s. 144.266 Wis. Stats.

This model ordinance is meant to be complementary to the model construction site erosion control ordinance prepared in 1987 by the Department, in conjunction with the Wisconsin League of Municipalities(1.). That ordinance is supported by a technical handbook (2.). Likewise the model storm water management zoning ordinance will also be supported by a technical handbook, the Wisconsin Storm Water Manual. Part One of this manual has been published and is available for distribution through the DOA Division of Document Sales(3.). It is an overview of storm water science, legal and planning information, and a brief synopsis of management practices. Part Two is the technical design manual, and is being developed for distribution beginning in 1996 (4.).

It is the Department's intent to present this draft as a basis for discussion at the state and local level. It is hoped that these discussions will lead to suggestions to modify this ordinance as needed to make it as understandable, practical, and usable as possible. Following these discussions, the Department intends to publish this model ordinance for general distribution.

Any questions or comments about this proposed model ordinance should be directed to:

John Pfender
Wisconsin Department of Natural Resources
PO Box 7921, Madison, Wisconsin 53707-7921
Telephone: 608-266-9266 FAX: 608-267-2800

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1. Construction Site Erosion Control Model Ordinance. 1987. Wisconsin Department of Natural Resources and League of Wisconsin Municipalities. DNR Publication WR-231-87. 11 pages.

2. Wisconsin Construction Site Best Management Practice Handbook. 1989. Wisconsin Department of Natural Resources. DNR Publication WR-222-89.

3. Wisconsin Stormwater Manual, Part One: Overview. 1994. Wisconsin Department of Natural Resources. DNR Publication WR-349-94.

4. Wisconsin Stormwater Manual, Part Two: Technical Design Guidelines for Stormwater Best Management Practices. Wisconsin Department of Natural Resources (In Preparation).

PART 2. MODEL ORDINANCE

Note: This model ordinance includes the use of brackets [ ] around phrases that are to be filled in by the local municipality. For example, the phrase [administering authority] is frequently used. Where the municipality chooses to have the ordinance administered by the City Engineer, the phrase [administering authority] should be replaced by "City Engineer". In a few places, the model ordinance includes phrases in brackets that are underlined [______]. In these cases, one of the underlined phrases must be selected verbatim. For example, if the phrase includes statutory citations, several underlined choices will be given such as [59.974, 60.627, 61.354, or 62.234). A county would replace the phrase in brackets with "59.974", since that is the appropriate citation.

AN ORDINANCE TO CREATE [CHAPTER, SECTION] OF THE MUNICIPAL CODE OF THE [LOCAL MUNICIPALITY] RELATING TO THE CONTROL OF POST-CONSTRUCTION STORM WATER RUNOFF

The [governing body] of the [local municipality] does hereby ordain that [Chapter, Section] of the Municipal Code of the [local municipality] is created to read as follows:

[CHAPTER, SECTION]
STORM WATER RUNOFF

S. .01 AUTHORITY

(1) This ordinance is adopted by the [governing body] under the authority granted by s. [59.974, 60.627, 61.354, or 62.234] Wis. Stats. This ordinance supersedes all conflicting and contradictory storm water management regulations previously enacted under s. [59.97, 60.62, 61.35, or 62.23], Wis. Stats. Except as specifically provided for in s. [59.974, 60.627, 61.354, or 62.234] Wis. Stats., s. [59.97 and 59.99, 60.62, 61.35, or 62.23], Wis. Stats. applies to this ordinance and to any amendments to this ordinance.

(2) The provisions of this ordinance are deemed not to limit any other lawful regulatory powers of the same governing body.

(3) The [governing body] hereby designates the [administering authority] to administer and enforce the provisions of this ordinance.

(4) The requirements of this ordinance do not pre-empt more stringent storm water management requirements that may be imposed by WPDES Storm Water Permits issued by the Department of Natural Resources under s. 147.021 Wis. Stats.

S. 02. FINDINGS OF FACT

The [governing body] finds that uncontrolled storm water runoff from land development activity has a significant impact upon water resources and the health, safety, general welfare of the community and diminishes the public enjoyment and use of natural resources. Specifically, uncontrolled storm water runoff can:

(1) degrade physical stream habitat by increasing stream bank erosion, increasing stream bed scour, diminishing groundwater recharge, and diminishing stream base flows;

(2) diminish the capacity of lakes and streams to support fish, aquatic life, recreational, and water supply uses by increasing loadings of nutrients and other urban pollutants;

(3) alter wetland communities by changing wetland hydrology and by increasing pollutant loads;

(4) reduce the quality of groundwater by increasing pollutant loading;

(5) threaten public health, safety, property, and general welfare by overtaxing storm sewers, drainage ways, and other minor drainage facilities;

(6) threaten public health, safety, property, and general welfare by increasing major flood peaks and volumes;

(7) undermine floodplain management efforts by increasing the incidence and levels of flooding.

S. 03. PURPOSE AND INTENT

(1) PURPOSE. The general purpose of this ordinance is to set forth storm water requirements and criteria which will diminish the threats to public health, safety, welfare, and the aquatic environment due to runoff of storm water from land development activity. Specific purposes are to:

(a) further the maintenance of safe and healthful conditions;

(b) prevent and control the adverse effects of storm water, prevent and control soil erosion, prevent and control water pollution, protect spawning grounds, fish, and aquatic life;

(c) control exceedance of the safe capacity of existing drainage facilities and receiving water bodies; prevent undue channel erosion; control increases in the scouring and transportation of particulate matter; prevent conditions that endanger downstream property;

(d) control building sites, placement of structures, and land uses, and promote sound economic growth.

(2) INTENT. It is the intent of the [governing body] that this ordinance manage the long-term, post-construction storm water discharges from land development activities. The [governing body] recognizes that the preferred method of addressing storm water management problems and needs is through the preparation of comprehensive storm water management system plans for subwatershed areas which are designed to meet the purpose and intent of this ordinance. Where such system plans have been developed and approved by the [governing body], it is the intent that all land development activities will include storm water management measures that meet performance standards set forth in those approved plans. Where such stormwater management system plans have not been developed or approved by the [governing body], it is the intent of the [governing body] that the generic storm water management standards set forth in S.07(1) and S.07(2) of this ordinance be applied unless otherwise excepted by the [administering authority].

S. 04. DEFINITIONS

(1) "Administering authority" means the governmental employee, or a regional planning commission empowered under s. [59.974; 60.627; 61.354; 62.234] Wis. Stats., designated by the [governing body] to administer this ordinance.

(2) "Agricultural activity" means the planting, growing, cultivating, and harvesting of crops; growing and tending of gardens, and trees; harvesting of trees.

(3) "Business day" means a day which both the offices of the [administering authority] of the permit holder are routinely and customarily open for business.

(4) "Cease and desist order" means a court issued order to halt land developing activity that is being conducted without the required permit.

(5) "Common plan of development or sale" means all lands included within the boundary of a certified survey or subdivision plat created for the purpose of development or sale of property where multiple separate and distinct land developing activity may take place at different times and on different schedules.

(6) "Design storm" means a hypothetical discrete rainstorm characterized by a specific duration, temporal distribution, rainfall intensity, return frequency, and total rainfall depth.

(7) "Discharge volume" means the quantity of runoff discharged from the land surface as the result of a rainfall event.

(8) ["Division of land" means the creation from one parcel of [number] or more parcels or building sites of [number] or fewer acres each in area where such creation occurs at one time or through the successive partition within a 5 year period.]

(9) ["Extra-territorial" means the unincorporated area within 3 miles of the corporate limits of a first, second, or third class city, or within 1 1/2 miles of a fourth class city or village.]

(10) "Fee in lieu" means a payment of money to the [governing body] in place of meeting all or part of the storm water performance standards required by the ordinance.

(11) "Financial guarantee" means a performance bond, maintenance bond, surety bond, irrevocable letter of credit, or similar guarantees submitted to the [administering authority] by the permit holder to assure that requirements of the ordinance are carried out in compliance with the storm water management plan.

(12) "Governing body" means town board of supervisors, county board of supervisors, city council, village board of trustees, or village council.

(13) "Gross aggregate area" means the total area, in acres, of all land located within the property boundary containing the land development activity.

(14) "Groundwater enforcement standard" means a numerical value expressing the concentration of a substance in groundwater which is adopted under s. 160.07 Wis. Stats., and s. NR 140.10 or s.160.09 Wis. Stats, and s. NR 140.12.

(15) "Groundwater preventive action limit" means a numerical value expressing the concentration of a substance in groundwater which is adopted under s. 160.15 Wis. Stats., and s. NR 140.10, 140.12, or 140.20.

(16) "Impervious surface" means a surface that releases the rainfall as surface runoff during a large portion of the design rainfall event. Rooftops, sidewalks, parking lots, and street surfaces are examples of impervious surfaces.

(17) "Infiltration" means the process by which rainfall or surface runoff percolates or penetrates into the underlying soil.

(18) "Land development activity" means any construction or re-development of buildings, roads, parking lots, paved and unpaved storage areas, and similar facilities, but not including agricultural activity.

(19) "Local municipality" means a town, county, village, or city.

(20) "Maintenance agreement" means a legal document that is filed with the County Register of Deeds as a property deed restriction, and which provides for long-term maintenance of storm water management practices.

(21) "Wetlands" means an area where water is at, near, or above the land surface long enough to be capable of supporting aquatic or hydrophytic vegetation and which has soils indicative of wet conditions. These wetlands include natural, mitigation, and restored wetlands.

(22) "Non-storm discharge" means a discharge to the storm sewer system created by some process other than stormwater runoff.

(23) "Non-structural measure" means a practice, technique, or measure to reduce the volume, peak flow rate, or pollutants in storm water that does not require the design or installation of fixed storm water management facilities.

(24) "Off-site" means located outside the property boundary described in the permit application for land development activity.

(25) "Other than residential development" means development of the following land uses: commercial; industrial; government and institutional; recreation; transportation, communication, and utilities.

(26) "On-Site" means located within the property boundary described in the permit application for the land development activity.

(27) "Peak flow discharge rate" means the maximum rate at which a unit volume of storm water is discharged.

(28) "Permit" means a written authorization made by the [administering authority] to the applicant to conduct land development activities.

(29) "Permit administration fee" means a sum of money paid to the [administering authority] by the permit applicant for the purpose of recouping the expenses incurred by the authority in administering the permit.

(30) "Pervious surface" means a surface that infiltrates rainfall during a large portion of the design rainfall event. Well managed lawns, fields and woodlands are examples of pervious surfaces.

(31) "Post-construction storm water discharge" means any storm water discharged from a site following the completion of land disturbing construction activity and final site stabilization.

(32) "Post-development condition" means the extent and distribution of land cover types, anticipated to occur under conditions of full development, that will influence stormwater runoff and infiltration.

(33) "Pre-development condition" means the extent and distribution of land cover types present before the initiation of land development activity, assuming that all land uses prior to development activity are managed in an environmentally sound manner.

(34) "Pre-treatment" means the treatment of storm water prior to its discharge to the primary storm water treatment practice in order to reduce pollutant loads to a level compatible with the capability of the primary practice.

(35) "Residential development" means that which is created to house people, including the residential dwellings as well as all attendant portions of the development including lawns, driveways, sidewalks, garages, and access streets. This type of development includes single family, multi-family, apartments, and trailer parks.

(36) "Site restriction" means any physical characteristic which limits the use of a storm water best management practice as prescribed in the Wisconsin Storm Water Manual.

(37) "Stop work order" means an order issued by the [administering authority] which requires that all construction activity on the site be stopped.

(38) "Storm water management plan" means a document that identifies what actions will be taken to reduce storm water quantity and pollutant loads from land development activity to levels meeting the purpose and intent of this ordinance.

(39) "Stormwater management system plan" is a comprehensive plan developed to address storm water drainage and nonpoint source pollution control problems on a watershed or sub-watershed basis, and which meets the purpose and intent of this ordinance."

(40) "Storm water runoff" means that portion of the precipitation falling during a rainfall event, or that portion of snow-melt, that runs off the surface of the land and into the natural or artificial conveyance or drainage network.

(41) "Structural measure" means source area practices, conveyance measures, and end-of-pipe treatment that are designed to control storm water runoff pollutant loads, discharge volumes, and peak flow discharge rates.

(42) "Waters of the state" means those portions of Lake Michigan and Lake Superior within the boundaries of Wisconsin, and all lakes, bays, rivers, streams, springs, ponds, wells, impounding reservoirs, marshes, watercourses, drainage systems and other surface water or groundwater, natural or artificial, public or private, within the state or its jurisdiction.

(43) "Wetland functional value" means the type, quality, and significance of the ecological and cultural benefits provided by wetland resources, such as: flood storage, water quality protection, groundwater recharge and discharge, shoreline protection, fish and wildlife habitat, floral diversity, aesthetics, recreation, and education.

(44) "WPDES Storm Water Permit" means a permit issued by the Wisconsin Department of Natural Resources under s. 147.021 Wis. Stats. that authorizes the point source discharge of storm water to waters of the state.

S. 05. APPLICABILITY AND JURISDICTION

(1) APPLICABILITY. This ordinance applies to land development activities which meet the applicability criteria specified in this section. The ordinance also applies to land development activities that are smaller than the minimum applicability criteria if such activities are part of a larger common plan of development or sale that meets any of the following applicability criteria, even though multiple separate and distinct land development activities may take place at different times on different schedules:

(a) residential land development with a gross aggregate area of 5 acres or more;

(b) residential land development with a gross aggregate area of at least 3 acres, but less than 5 acres, if there are at least 1.5 acres of impervious surfaces;

(c) land development, other than a residential land development, with a gross aggregate area of 1.5 acres or more, or any nonresidential land development which creates an impervious area of .5 acres or more;

(d) land development activity of any size that, in the opinion of the [administering authority], is likely to result in storm water runoff which exceeds the safe capacity of the existing drainage facilities or receiving body of water, which causes undue channel erosion, which increases water pollution by scouring or the transportation of particulate matter or which endangers property or public safety.

(2) JURISDICTION. This ordinance applies to [land development activities within the boundaries of the [name of the local municipality]].

or

[land development activities within the boundaries of the [name of local municipality]. This ordinance applies to the division of land within the boundaries of the [name of the local municipality] and within its extraterritorial plat approval jurisdiction under Chapter 236 Wis. Stats.]

or

[land development activities within the boundaries of the [name of the local municipality]. This ordinance applies to all lands located within the extraterritorial plat approval jurisdiction of the [name of the local municipality], even if plat approval is not involved.]

(3) EXEMPTIONS. This ordinance does not apply to land development activities conducted or contracted for by any state agency, as defined under s. 227.01(1) Wis. Stats., but also including the office of district attorney.

S. 06. DESIGN CRITERIA, STANDARDS AND SPECIFICATIONS

Unless prior authorization is given by the [administering authority], the following methods shall be used in meeting the requirements of this ordinance:

(1) WATER QUALITY COMPONENTS. The following methods shall be used in designing components of storm water structures needed to meet the water quality standards of this ordinance:

(a) Practices shall be designed in accordance with the methods set forth in the latest edition of the "Wisconsin Storm water Manual, Part 2: Technical Design Guidelines for Storm Water BMP's" as published and amended from time-to-time by the State of Wisconsin Department of Natural Resources.

(b) Runoff volumes and peak flow rates used in designing the water quality components of storm water structures shall be calculated using the "Small Storm Hydrology" method set forth in the latest edition of the "Wisconsin Storm water Manual, Part 2: Technical Design Guidelines for Storm Water BMP's" as published and amended from time-to-time by the State of Wisconsin Department of Natural Resources.

(2) WATER QUANTITY COMPONENTS. The following methods shall be used in designing components of storm water structures needed to meet the water quantity standards of this ordinance:

(a) Peak flow shaving components of storm water structures shall be designed in accordance with standard engineering practice.

(b) Runoff volumes and peak flow rates used in designing the water quantity components of storm water structures shall be based on the principles of the document entitled "Urban Hydrology for Small Watersheds" (Technical Release 55: Engineering Division, Soil Conservation Service, United States Department of Agriculture, June 1992).

S. 07. STORM WATER MANAGEMENT STANDARDS

(1) STORM WATER DISCHARGE QUANTITY. Unless otherwise provided for in this ordinance, all land development activities subject to this ordinance shall establish on-site management practices to control the peak flow rates of storm water discharged from the site. Infiltration of storm water runoff from driveways, sidewalks, rooftops, and landscaped areas shall be incorporated to the maximum extent practical to provide volume control in addition to control of peak flows.
On-site management practices shall be used to meet the following minimum performance standards:

(a) The peak flow discharge rates of storm water runoff from the development shall not exceed those calculated for the series of design storms specified in S.07(1)(b) and pre-development conditions specified in S.07(1)(c). Discharge velocities must be non-erosive to discharge locations, outfall channels, and receiving streams.

(b) At a minimum, the 2-year/24 hour, the 10-year/24 hour, and 100-year/24 hour design storms shall be used in comparing peak flow discharge rates for pre-development and post-development conditions.

(c) Pre-development conditions for land developing activities shall assume a "good" level of land management. When the Soil Conservation Service TR-55 Method is used to calculate peak flow discharge rates and runoff volumes for the pre-development condition, NRCS curve numbers shall not exceed the following for the given soil hydrologic groups. When other methods for computing runoff are used, they shall assume a comparable pre-development condition.

Soil Hydrologic Group:	**A**	**B**	**C**	**D**
NRCS Curve Number for Meadow:	30	58	71	78
NRCS Curve Number for Woodland:	30	55	70	77
NRCS Curve Number for Grain:	55	68	77	80
NRCS Curve Number for Pasture:	39	61	74	80

NRCS Curve Number for Paved Roadways with Open Ditches*	83	89	92	93
NRCS Curve Number for Commercial/Business Districts*	89	92	94	95
NRCS Curve Number for Industrial Districts*	81	88	91	93

***For use with re-development projects only.**

(d) Increases or decreases in the hydrology of wetlands shall be minimized to the extent practical. Where such changes are proposed, the impact of the proposal on wetland functional values shall be assessed using a methodology acceptable to the [administering authority]. Significant degradation of wetland functional values shall be avoided.

(2) STORM WATER DISCHARGE QUALITY. Unless otherwise provided for in this ordinance, all land development activities subject to this ordinance shall establish on-site management practices to control the quality of storm water discharged from the site. On-site management practices shall be used to meet the following minimum standard:

(a) Storm water discharges shall be treated to remove, on an average annual basis, a minimum of 80% of the total suspended solids load. To achieve this level of control, storm water practices shall be designed to accommodate, at a minimum, the runoff volume resulting from 1.5 inches of rainfall.

(b) Discharge of urban storm water pollutants to wetlands shall be minimized to the extent practical. Where such discharges are proposed, the impact of the proposed discharge on wetland functional values shall be assessed using a method acceptable to the [administering authority].
At a minimum, storm water discharges shall be pre-treated prior to discharge to wetlands. Significant degradation of wetland functional values due to storm water pollutant loads shall be avoided.

(c) Storm water discharges shall be pre-treated prior to infiltration where necessary to prolong maintenance of the infiltration practice and to prevent discharge of storm water pollutants at concentrations that will result in exceedances of groundwater preventive action limits or enforcement standards established by the Department of Natural Resources in NR 140 Wisconsin Administrative Code. Storm water shall not be injected underground through excavations or openings that would violate NR 812.05 Wis. Admin. Code.

(d) Storm water ponds and infiltration devices shall not be located closer to water supply wells than indicated below without first notifying the [administering authority]:

(i) 100 feet from a well serving a private water system or a transient, non-community public water system;
(ii) 1,200 feet from a well serving a municipal public water system, an other-than municipal public water system, or a non-transient non-community public water system;
(iii) the boundary of a recharge area to a wellhead identified in a wellhead area protection plan.

(3) EXCEPTIONS. The [administering authority] may establish stormwater management requirements either more stringent or less stringent than those set forth in Sections S.07(1,2), provided that at least one of the following conditions applies.

(a) [the administering authority determines that an added level of protection is needed to protect sensitive resources,]

(b) the [administrating authority] determines that the land development activity is covered by an approved storm water management system plan that contains management requirements consistent with the purpose and intent of this ordinance.

(c) provisions are made to manage storm water by an off-site facility, provided that all of the following conditions for the off-site facility are met:

(i) the facility is in place,
(ii) the facility is designed and adequately sized to provide a level of storm water control equal to or greater than that which would be afforded by on-site practices meeting the requirements of this ordinance,
(iii) the facility has a legally obligated entity responsible for its long-term operation and maintenance.

(d) The [administering authority] finds that meeting the minimum on-site management requirements of this ordinance is infeasible due to space or site restrictions.

(4) FEE IN LIEU OF ON-SITE STORM WATER MANAGEMENT PRACTICES. Where the [administering authority] waives all or part of the minimum on-site storm water management requirements under S.07(3), the applicant may be required to pay a fee in an amount determined in negotiation with the [administering authority]. In setting the fee for land development projects, the [administering authority] shall consider an equitable distribution of the cost for land, engineering design, construction, and maintenance of stormwater management practices needed to serve the land development.

(5) GENERAL CONSIDERATIONS FOR ON-SITE AND OFF-SITE STORM WATER MANAGEMENT MEASURES. The following considerations shall be observed in managing storm water runoff:

(a) Natural topography and land cover features such as natural swales, natural depressions, native soil infiltrating capacity, and natural groundwater recharge areas shall be preserved and used, to the extent possible, to meet the requirements of this section.

(b) Emergency overland flow for all storm water facilities shall be provided to prevent exceeding the safe capacity of downstream drainage facilities and prevent endangerment of downstream property or public safety.

S. 08. PERMITTING REQUIREMENTS, PROCEDURES AND FEES

(1) PERMIT REQUIRED. No land owner or land operator may undertake a land development activity subject to this ordinance without receiving a permit from the [administering authority] prior to commencing the proposed activity.

(2) PERMIT APPLICATION AND FEE. Unless specifically excluded by this ordinance, any land owner or operator desiring a permit shall submit to the [administering authority] a permit application made on a form provided by the [administering authority] for that purpose.

(a) Unless otherwise excepted by this ordinance, a permit application must be accompanied by the following in order that the permit application be considered by the [administering authority]: a storm water management plan, a maintenance agreement, and a non-refundable permit administration fee.

(b) The storm water management plan shall be prepared to meet the requirements of S.09 of this ordinance, the maintenance agreement shall be prepared to meet the requirements of S.10 of this ordinance, the financial guarantee shall meet the intent of S.11 of this ordinance, and fees shall be those established by the [governing body] as set forth in S.12 of this ordinance.

(3) REVIEW AND APPROVAL OF PERMIT APPLICATION. The [administering authority] shall review any permit application that is submitted with a storm water management plan, maintenance agreement, and the required fee. The following approval procedure shall be used:

(a) Within [number] business days of the receipt of a complete permit application, including all items as required by S.08(2)(a), the [administering authority] shall inform the applicant whether the application, plan and maintenance agreement are approved or disapproved. The [administering authority] shall base the decision on requirements set forth in S.07, S.09, and S.10 of this ordinance.

(b) If the storm water permit application, plan and maintenance agreement are approved, or if an agreed upon payment of fees in lieu of stormwater management practices is made, the [administering authority] shall issue the permit.

(c) If the storm water permit application, plan or maintenance agreement are disapproved, the [governing body] shall detail in writing of the reasons for disapproval.

(d) If additional information is submitted, the [administering authority] shall have [number] business days from the date the additional information is received to inform the applicant that the plan and maintenance agreement are either approved or disapproved.

(e) Failure by the [administering authority] to inform the permit applicant of a decision within [number] business days of a required submittal shall be deemed to mean approval of the submittal and the applicant may proceed as if a permit had been issued.

(4) PERMIT CONDITIONS. All permits issued under this ordinance shall be subject to the following conditions, and holders of permits issued under this ordinance shall be deemed to have accepted these conditions. The [administering authority] may suspend or revoke a permit for violation of a permit condition, following written notification of the permittee. An action by the [administering authority] to suspend or revoke this permit may be appealed in accordance with S.14 of this ordinance.

(a) Compliance with this permit does not relieve the permit holder of the responsibility to comply with other applicable federal, state, and local laws and regulations.

(b) The permit holder shall design and install all structural and non-structural storm water management measures in accordance with the approved storm water management plan and this permit.

(c) The permit holder shall notify the [administering authority] at least [number] business days before commencing any work in conjunction with the storm water management plan, and within [number] business days upon completion of the storm water management practices. If required as a special condition, the permit holder shall make additional notification according to a schedule set forth by the [administering authority] so that practice installations can be inspected during construction.

(d) Practice installations required as part of this ordinance shall be certified "as built" by a licensed professional engineer. Completed storm water management practices must pass a final inspection to determine if they are in accordance with the approved storm water management plan and ordinance. The administering authority shall notify the permit holder in writing of any changes required in such practices to bring them into compliance with the conditions of this permit.

(e) The permit holder shall notify the [administering authority] of any significant modifications it intends to make to an approved storm water management plan. The [administering authority] may require that the proposed modifications be submitted for approval prior to incorporation into the storm water management plan and execution.

(f) The permit holder shall maintain all storm water management practices in accordance with the storm water management plan until the practices either become the responsibility of the [governing body], or are transferred to subsequent private owners as specified in the approved maintenance agreement.

(g) The permit holder authorizes the [administering authority] to perform any work or operations necessary to bring storm water management measures into conformance with the approved storm water management plan. and consents to a special assessment or charge against the property as authorized under s.

66.60(16) Wis. Stats., or to charging such costs against the financial guarantee posted under S.11 of this ordinance.

(h) If so directed by the [administering authority], the permit holder shall repair at the permit holder's own expense all damage to adjoining municipal facilities and drainage ways caused by storm water runoff, where such damage is caused by activities that are not in compliance with the approved storm water management plan.

(i) The permit holder shall permit property access to the [administering authority] for the purpose of inspecting the property for compliance with the approved storm water management plan and this permit.

(j) Where a storm water management plan involves changes in direction, increases in peak rate and/or total volume of runoff from a site, the [administering authority] may require the permittee to make appropriate legal arrangements with adjacent property owners concerning the prevention of endangerment to property or public safety.

(k) The permit holder is subject to the enforceable actions detailed in S.13 of the storm water management ordinance if the permit holders fails to comply with the terms of this permit.

(6) PERMIT DURATION. Permits issued under this section shall be valid from the date of issuance through the date the [administering authority] notifies the permit holder that all storm water management practices have passed the final inspection required under Permit Condition d.

S. 09. STORM WATER MANAGEMENT PLANS

(1) PLAN REQUIREMENTS. The storm water management plan required under S.08(2) of this ordinance shall contain any information the [administering authority] may need to evaluate the environmental characteristics of the area affected by land development activity, the potential impacts of the proposed development upon the quality and quantity of storm water discharges, the potential impacts upon water resources and drainage utilities, and the effectiveness and acceptability of proposed storm water management measures in meeting the performance standards set forth in this ordinance. Unless specified otherwise by this ordinance, storm water management plans shall contain at a minimum the following information:

(a) Name, address, and telephone number for the following or their designees: landowner; developer; project engineer for practice design and certification;

person(s) responsible for installation of storm water management practices; person(s) responsible for maintenance of storm water management practices prior to the transfer, if any, of maintenance responsibility to another party.

(b) A proper legal description of the property proposed to be developed referenced to the U.S. Public Land Survey system or to block and lot numbers within a recorded land subdivision plat.

(c) Pre-development site conditions, including:

(i) One or more site maps at a scale of not less than 1 inch equals [number] feet. The site maps shall show the following: site location and legal property description; predominant soil types and hydrologic soil groups; existing cover type and condition; topographic contours of the site at a scale not to exceed [number] feet; topography and drainage network including enough of the contiguous properties to show runoff patterns onto, through, and from the site; watercourses that may affect or be affected by runoff from the site; flow path and direction for all storm water conveyance sections, including time of travel and time of concentration applicable to each; watershed boundaries used in determinations of peak flow discharge rates and discharge volumes from the site; lakes, streams, wetlands, channels, ditches, and other watercourses on and immediately adjacent to the site; limits of the 100 year floodplain; location of wells located within 1,200 feet of storm water detention ponds, infiltration basins, or infiltration trenches; delineation of wellhead protection areas delineated pursuant to NR 811.16 Wis. Admin. Code.

(ii) Computations of peak flow discharge rates and discharge volumes for the 2-year/24 hour, 10-year/24 hour, and 100-year/24 hour storm events. All major assumptions used in developing input parameters shall be clearly stated. The computations shall be made for each discharge point in the development, and the geographic areas used in making the calculations shall be clearly cross-referenced to the required map(s).

(d) Post-development site conditions, including:

(i) Explanation of the provisions to preserve and use natural topography and land cover features to minimize changes in peak flow runoff rates and volumes to surface waters and wetlands.

(ii) Explanation of any restrictions on storm water management measures in the development area imposed by wellhead protection plans and ordinances.

(iii) One or more site maps at a scale of not less than 1 inch equals [number] feet showing: revised pervious land use including vegetative cover type and condition; impervious land use including all buildings, structures, and pavement; revised topographic contours of the site at a scale not to exceed [number] feet; revised drainage network including enough of the contiguous properties to show runoff patterns onto, through, and from the site; locations and dimensions of drainage easements; locations of maintenance easements specified in the maintenance agreement; flow path and direction for all storm water conveyance sections, including time of travel and time of concentration applicable to each; location and type of all storm water management conveyance and treatment practices, including the on-site and off-site tributary drainage area; location and type of conveyance system that will carry runoff from the drainage and treatment practices to the nearest adequate outlet such as a curbed street, storm drain, or natural drainage way; watershed boundaries used in determinations of peak flow discharge rates and discharge volumes; any changes to lakes, streams, wetlands, channels, ditches, and other watercourses on and immediately adjacent to the site.

(iv) Computation of the runoff volume resulting from the 1.5 inch rainfall, and computations of peak flow discharge rates and discharge volumes for the 2-year/24 hour, 10-year/24 hour, and 100-year/24 hour storm events. All major assumptions used in developing input parameters shall be clearly stated. The computations shall be made for each discharge point in the development, and the geographic areas used in making the calculations shall be clearly cross-referenced to the required map(s).

(v) Results of investigations of soils and groundwater required for the placement and design of storm water management measures.

(vi) Results of impact assessments on wetland functional values.

(vii) Design computations and all applicable assumptions for the storm water conveyance (open channel, closed pipe) system.

(viii) Design computations and all applicable assumptions for storm water quality practices (sedimentation type, filtration-type, infiltration-type) as needed to show that practices are appropriately sized to accommodate runoff from the 1.5 inch rainfall. For practice designs that depart from those specified in the "Wisconsin Storm Water Manual, Part 2," the results of continuous simulation modelling, conducted according to the guidelines established in this manual, shall be presented in such a way as to show the reduction in average annual total suspended solids loading from the developed site.

(ix) Detailed drawings including cross-sections and profiles of all permanent storm water conveyance and treatment practices.

(e) A storm water practice installation schedule.

(f) A maintenance plan developed for the life of each storm water management practice including the required maintenance activities and maintenance activity schedule.

(g) Cost estimates for the construction, operation, and maintenance of each storm water management practice.

(h) Other information as needed by the [administering authority] to determine compliance of the proposed storm water management measures with the provisions of this ordinance.

(i) All site investigations, plans, designs, computations, and drawings shall be certified by a [competent authority] to be prepared in accordance with accepted engineering practice and in accordance with The Wisconsin Storm Water Manual, Part Two: Technical Design Guidelines for Storm Water BMP's .

(2) EXCEPTIONS. The [administering authority] may prescribe alternative submittal requirements for applicants seeking an exemption to on-site storm water management performance standards under S.07(3) of this ordinance.

S. 10. MAINTENANCE AGREEMENT

(1) MAINTENANCE AGREEMENT REQUIRED. The maintenance agreement required for storm water management practices under S.08(2) of this ordinance shall be an agreement between the [administering authority] and the permittee to provide for maintenance of storm water practices beyond the duration period of this permit. The agreement or recordable document shall be recorded with the County Register of Deeds so that it is binding upon all subsequent owners of land served by the storm water management practices.

(2) AGREEMENT PROVISIONS. The maintenance agreement shall contain the following information and provisions:

(a) Identification of the storm water facilities and designation of the drainage area served by the facilities.

(b) A schedule for regular maintenance of each aspect of the storm water management system consistent with the storm water management plan.

(c) Identification of the landowner(s), organization or municipality responsible for long term maintenance of the storm water management practices.

(d) The landowner(s), organization, or municipality shall maintain storm water management practices in accordance with the schedule included in the agreement.

(e) The [administering authority] is authorized to access the property to conduct inspections of storm water practices as necessary to ascertain that the practices are being maintained and operated in accordance with the agreement.

(f) The [administering authority] shall maintain public records of the results of the site inspections, shall inform the landowner responsible for maintenance of the inspection results, and shall specifically indicate any corrective actions required to bring the storm water management practice into proper working condition.

(g) That if the [administering authority] notifies the party designated under the maintenance agreement of maintenance problems which require correction, the specified corrective actions shall be taken within a reasonable time frame as set by the [administering authority].

(h) The [administering authority] is authorized to perform the corrected actions identified in the inspection report if the landowner does not make the required corrections in the specified time period. The [administering authority] shall enter the amount due on the tax rolls and collect the money as a special charge against the property pursuant to s. 66.60(16) Wis. Stats.

S. 11. FINANCIAL GUARANTEE

(1) ESTABLISHMENT OF THE GUARANTEE. The [administering authority] may require the submittal of a financial guarantee, the form and type of which shall be acceptable to the [administering authority]. The financial guarantee shall be in an amount determined by the [administering authority] to be the estimated cost of construction and the estimated cost of maintenance during the period which the designated party in the maintenance agreement has maintenance responsibility. The financial guarantee shall give the [administering authority] the authorization to use the funds to complete the project if the landowner defaults or does not properly implement the approved storm water management plan.

(2) CONDITIONS FOR RELEASE. Conditions for the release of the financial guarantee are as follows:

(a) The [administering authority] shall release the portion of the financial guarantee established to assure installation of storm water practices, minus any costs incurred by the [administering authority] to complete installation of practices, upon submission of "as built plans" by a licensed professional engineer. The [administering authority] may make provisions for a partial pro-rata release of the financial guarantee based on the completion of various development stages.

(b) The [administering authority] shall release the portion of the financial security established to assure maintenance of storm water practices, minus any costs incurred by the [administering authority], at such time that the responsibility for practice maintenance is passed on to another entity via an approved maintenance agreement.

S. 12. FEE SCHEDULE

The fees referred to in other sections of this ordinance shall be established by the [administering authority] and may from time to time be modified by resolution. A schedule of the fees established by the [administering authority] shall be available for review in [location].

S. 13. ENFORCEMENT AND PENALTIES

(1) Any land development activity initiated after the effective date of this ordinance by any person, firm, association, or corporation subject to the ordinance provisions shall be deemed a violation unless conducted in accordance with said provisions.

(2) The [administering authority] shall notify the responsible owner or operator by certified mail of any non-complying land development activity. The notice shall describe the nature of the violation, remedial actions needed, a schedule for remedial action, and additional enforcement action which may be taken.

(3) Upon receipt of written notification from the [administering authority], the permit holder shall correct work which does not comply with the storm water management plan or other provisions of this permit. The permit holder shall make corrections as necessary to meet the specifications and schedule set forth by the [administering authority] in the notice.

(4) If the violations to this ordinance are likely to result in damage to properties, public facilities, or waters of the state, the [administering authority] may enter the land and take emergency actions necessary to prevent such damage. The costs incurred by the [administering authority] plus interest and legal costs shall be billed to the owner of title of the property.

(5) The [administering authority] is authorized to post a stop work order on all land development activity in violation of this ordinance, or to request the [municipal attorney, corporation counsel] to obtain a cease and desist order.

(6) The [administering authority] may revoke a permit issued under this ordinance for non-compliance with ordinance provisions.

(7) Any permit revocation, stop work order, or cease and desist order shall remain in effect unless retracted by the [administering authority] or by a court of competent jurisdiction.

(8) The [administering authority] is authorized to refer any violation of this ordinance, or of a stop work order or cease and desist order issued pursuant to this ordinance, to the [municipal attorney, corporation counsel] for the commencement of further legal proceedings.

(9) Any person, firm, association, or corporation who does not comply with the provisions of this ordinance shall be subject to a forfeiture of not less than [number] dollars nor more than [number] dollars per offense, together with the costs of prosecution. Each day that the violation exists shall constitute a separate offense.

(10) Every violation of this ordinance is a public nuisance. Compliance with this ordinance may be enforced by injunctional order at the suit of the [local municipality] pursuant to

s. [59.97(11), 60.74(4), or 62.23(8)] Wis. Stats. It shall not be necessary to prosecute for forfeiture before resorting to injunctional proceedings.

(11) When the [administering authority] determines that the holder of a permit issued pursuant to this ordinance has failed to follow practices set forth in the Storm Water Management Plan, or has failed to comply with schedules set forth in said Storm Water Management Plan, the [administering authority] or a party designated by the [administering authority] may enter upon the land and perform the work or other operations necessary to bring the condition of said lands into conformance with requirements of the approved plan. The [administering authority] shall keep a detailed accounting of the costs and expenses of performing this work. These costs and expenses shall be deducted from any financial security posted pursuant to S.11 of this ordinance. Where such a security has not been established, or where such a security is insufficient to cover these costs, the costs and expenses shall be entered on the tax roll as a special charge against the property and collected with any other taxes levied thereon for the year in which the work is completed.

S. 14. APPEALS

(1) BOARD OF [APPEALS or ADJUSTMENTS]. The board of [appeals or adjustments], created under section [number] of the [local municipality] zoning ordinance pursuant to s. [62.23(7)(e), or 59.99, or 60.75] Wis. Stats, shall hear and decide appeals where it is alleged that there is error in any order, decision or determination made by the [administering authority] in administering this ordinance. The Board shall also use the rules, procedures, duties, and powers authorized by statute in hearing and deciding appeals.

[Upon appeal, the Board may authorize variances from the provisions of this ordinance which are not contrary to the public interest, and where owing to special conditions a literal enforcement of the ordinance will result in unnecessary hardship.]

(2) WHO MAY APPEAL. Appeals to the board of [appeals or adjustments] may be taken by any aggrieved person or by an officer, department, board, or bureau of the [local municipality] affected by any decision of the [administering authority].

S. 15. SEVERABILITY

If any section, clause, provision or portion of this ordinance is judged unconstitutional or invalid by a court of competent jurisdiction, the remainder of the ordinance shall remain in force and not be affected by such judgement.

S. 16. EFFECTIVE DATE

This ordinance shall be in force and effect from and after its adoption and publication. The above and foregoing ordinance was duly adopted by the [governing body] of the [local municipality] on the [number] day of [month], [year].

Approved: ____________
Attested ___________
Published on [day, month, year].

ord.vs2

This draft model ordinance was prepared by Department of Natural Resources staff as a starting point for public discussion and input. The Department of Natural Resources is responsible for the development and promotion of this ordinance under section 144.266 Wis. Stats.

Department of Natural Resources
Internal Workgroup Members

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John Pfender, Chair and Principal Author	Nonpoint Source	Water Resources Management
Terry Donovan	Nonpoint Source	Water Resources Management
Roger Bannerman	Surface Water Standards	Water Resources Management
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Chuck Hammer		Legal Services
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Peg McBrien and Mary Anne Lowndes of the Nonpoint Source Section also provided review and comment on the draft model ordinance and commentary.

PART 3. COMMENTARY

The purpose of the commentary section is to provide background information explaining the reasoning behind various ordinance provisions. Each section of the commentary includes a statement of intent, or purpose. Where appropriate, additional discussion is presented to help potential users understand some of the legal, institutional, and technical considerations behind the ordinance provisions.

S.01: AUTHORITY

INTENT

The intent of this section is to state the legal authority under which the ordinance is being adopted and to specifically identify, if appropriate, municipal officers or employees invested to effectuate and administer the ordinance. This section should also identify any unique relationships between storm water regulations adopted in the ordinance and other pre-existing storm water regulations adopted by the municipality, or imposed by the state through WPDES permits.

DISCUSSION

Authority: Cities, counties, towns, and villages are given explicit authority by Wisconsin Statute to regulate storm water through a comprehensive storm water management zoning ordinance. This authority is found in ss. 62.234 (cities), 61.354 (villages), 59.974 (counties), and 60.627 (towns), Wis. Stats. Storm water ordinances adopted under these sections of the State Statutes may be enacted separately from ordinances enacted under general municipal zoning authority. Such an ordinance adopted by a county for application in unincorporated areas is not subject to town board approval or disapproval. However, a county ordinance enacted under s. 59.974 Wis. Stats. does not apply and has no effect in a town in which an ordinance enacted under s. 60.627 Wis. Stats. is in effect. An ordinance enacted by a county or town under ss 59.974 or 60.627 Wis. Stats. that is in effect in an area immediately before that area is annexed by a city or village continues in effect in the area after annexation unless the city or village enacts, maintains, and enforces an ordinance that complies with the minimum standards established by the Department of Natural Resources and that is at least as restrictive as the town or county ordinance.

A storm water ordinance enacted under this authority supersedes all provisions of an ordinance enacted under the general municipal zoning authority. However, such ordinances shall accord and be consistent with any comprehensive zoning plan or general zoning ordinance as far as is practical. All powers granted to a municipality under s. 236.45 Wis. Stats. may be exercised by it with respect to storm water management provided that the municipality has or provides a planning commission or agency. Finally, as long as the ordinance applies to all zoning districts in the municipality, there is no need for a separate zoning map to accompany the storm water ordinance.

The state Department of Natural Resources has the responsibility to regulate certain storm water discharges through the Wisconsin Pollutant Discharge Elimination System (WPDES) Program. WPDES permits will be issued by DNR to cover storm water discharges from new and existing industrial sites, new construction sites over 5 acres, and municipal storm sewers for selected municipalities as defined by NR 216 Wis. Admin. Code. In addition, DNR will issue WPDES storm water permits for other significant sources of water pollution as identified on a case-by-case basis. In some cases, storm water management requirements imposed by WPDES storm water discharge permits may be more stringent than those required by a local ordinance. When this occurs, the WPDES permit conditions must be met in addition to those conditions imposed by the local ordinance. The same holds true for other permits that may be issued by the DNR, such as Chapter 30 permits.

S.02: FINDINGS OF FACT

INTENT

This ordinance is an enactment of the local municipality's police power to regulate land use for the purpose of protecting and enhancing the health, safety, and general welfare of the community. This section specifically identifies the problems and threats that the ordinance is intended to remedy. Individuals regulated by this ordinance will look to this section to understand the reasons for imposition of the ordinance requirements.

DISCUSSION

All of these basic impacts are rooted in the fact that urbanization changes the way in which the landscape intercepts rainfall and releases runoff. Natural land cover typically allows a larger portion of rainfall to infiltrate, or soak into the ground. Under this condition, surface runoff is relatively slow and sustained. As an area is urbanized the natural perviousness is greatly reduced or destroyed, leading to larger volumes of rainfall discharged to surface waters in shorter periods of time. This is shown in *Figure 1*. In addition to these hydrologic changes, there are increases in pollutant loadings as well. This is because these urban surfaces (such as streets, sidewalks, driveways, parking lots, and rooftops) collect a wide array of pollutants generated in the urban environment. Rainfall and snowmelt runoff washes the pollutants from these urban source areas and carries them very efficiently through storm water conveyance systems to their points of discharge.

Extensive monitoring conducted both nationally (See *Table 1 and 2*) and within Wisconsin (See *Figures 2, 3, and 4*) shows that urban storm water runoff is highly contaminated with a wide array of pollutants (WEF/ASCE, 1992; Bannerman, R.T., 1990; Bannerman, et al., 1983;). These pollutants include suspended solids, nutrients (phosphorus & nitrogen), oxygen demand, bacteria and other pathogens, heavy metals (copper, zinc, lead, cadmium, chromium), pesticides, organic toxic compounds (polycyclic aromatic hydrocarbons, polychlorinated biphenyls), and increased temperature.

Figure 1. Changes in watershed hydrology as a result of urbanization.

Source: Urbanization and Water Quality. 1994. Terrene Institute, Washington, DC., 67 p.

Table 1. Urban runoff pollutants.	Table 2. Most frequently detected priority pollutants in National Urban Runoff Program samples.

Figure 2. Pollutants in Wisconsin urban runoff.

Source: Bannerman, R.T. 1990. "What to do with toxics in Wisconsin storm water." in *__Designing Storm Water Quality Management Practices, University of Wisconsin Extension Department of Engineering Profesional Development Course Manual.__* *University of Wisconsin.*

The impacts on the environment and public health, safety, and general welfare listed in the ordinance can be grouped into four basic categories for purposes of further discussion.

Physical Habitat Destruction: Hydrologic changes that occur as the result of decreased perviousness can significantly affect the suitability of physical habitat for fish and other aquatic life. One impact on physical habitat is the change in stream base flow. The base flow in streams originates from the slow release of groundwater. As less rainfall infiltrates into the ground, groundwater supplies are also reduced and can become insufficient to maintain adequate stream flow and temperature conditions during dry periods.

Another impact is on stream channel stability. Several aspects of this phenomenon are reviewed in a study of streamflow and channel morphology in the Pheasant Branch Basin near Middleton, Wisconsin (Krug, W.R., and G.L. Goddard, 1986). As peak discharges and discharge velocities increase, stream beds are scoured clean of habitat and aquatic life. In addition stream bank erosion increases as the equilibrium between stream flow, and the stream bank which contains that flow, is upset. Stream channels are normally of such size to carry the mean annual flood within their banks. This flood will generally occur once every 2.33 years . As the volume and peak discharge associated with the 2-year flood increases, the stream creates a new channel configuration through erosion. It has been shown that for stream channels free to adjust their shapes to a discharge at constant frequency, the channel width varies as the 0.5 power of the discharge and the depth varies as the 0.4 power of the discharge. A study of streamflow and channel morphology of Pheasant Branch Creek in Middleton, Wisconsin, predicts that an increase in the mean annual flood by a factor of 2.0 to 2.4 will cause a 40-50% increase in channel width and a 30-40% increase in channel depth. This can create a dish-like cross section, destroying stream bank habitat and depositing massive amounts of sediment on the stream bed.

Changes in ground and surface water flows into wetlands can lead to significant alterations in wetland habitat. Hydrologic conditions are a determining factor in the development of wetland communities. Changes in wetland hydrology are consequently some of the principal reasons why wetland habitat becomes unsuitable to support a healthy, diverse, and sometimes very unique wetland vegetation.

Ground and Surface Water Quality Degradation: As shown in *Table 3*, storm water pollutant concentrations measured in Wisconsin often exceed water quality criteria for fish, aquatic life and human health. Acute toxicity bioassay studies, where organisms are exposed to storm water, confirm that toxicity occurs, but at a lower incidence than expected. The greatest threat to aquatic life may be the chronic toxicity effects of these pollutants in the receiving stream itself. Continuous exposure of aquatic organisms to water from Lincoln Creek in Milwaukee results in significant chronic toxicity, including death (Masterson, John. 1994). Researchers are only beginning to decipher the exact relationship between pollutant concentrations, the form of pollutants (dissolved, particulate), and interactions between pollutants and other environmental factors.

The impact, however, is real. Aquatic communities in urban streams show signs of extreme stress including low species diversity, low biomass, and poor condition (Pitt, R., and J. Voorhees. 1989). In addition, storm water runoff is contaminated with fecal coliform bacteria at levels that greatly exceed Wisconsin surface water standards. Human pathogens including pathogenic bacteria and viruses are also present in urban runoff. It is unclear, however, exactly how significant a threat is posed to humans by these pathogens at the concentrations they appear in storm water runoff (Pitt, R., et al. 1994).

Table 3 also shows that water carried in storm sewer pipes exceeds groundwater preventive action limits and enforcement standards for several pollutants. It is not generally known if, or to what degree, the infiltration of urban storm water results in violations of groundwater standards. Researchers are continuing to investigate environmental factors that determine the fate and transport of urban storm water pollutants (Armstrong, D.E. and R. Llena. 1992).

Local Drainage Problems: These occur when storm water runoff is discharged at rates that exceed the conveyance capacity of "minor" storm water drainage system components such as storm sewers and small swales. These drainage system components are typically designed to pass the storm water discharge produced by the 5-year or 10-year, 24-hour rainfall event. As imperviousness of an area increases, peak flow discharges also increase and may no longer pass unrestricted through these drainage facilities. The result is surcharging and back-ups, which can result in local ponding of water. This can cause nuisance conditions and property damage.

Local and Regional Flooding Problems: These occur when storm water runoff is discharged at rates that exceed the conveyance capacity of "major" storm water drainage system components. These include engineered storm water practices as well as the natural channel capacities of creeks, streams, and rivers. Engineered components of the major drainage system are typically designed to safely pass the peak flow discharges produced by the 50-year or 100-year event. Local zoning typically restricts development within the 100-year floodplain of natural creeks, steams, and rivers so that the flood waters can be discharged without significant loss of property or loss of life. As imperviousness is increased, major system components can be surcharged and the elevation of the 100 year floodplain can be increased.

S.03: PURPOSE AND INTENT

INTENT

This section sets forth the purpose, or goal, of the ordinance and a statement of basic objectives that describe how the municipality intends to meet the ordinance goals. The basic statements of purpose and intent should enhance the public's general understanding of the municipality's storm water management program, and can serve as a checklist for a periodic review of the ordinance's success.

DISCUSSION

Purpose: The specific statements of purpose contained in subsections a-d are taken from two separate portions of s. 144.266 Wis. Stats. The legislature specifically lists in s. 144.266 Wis. Stats. eight separate items that are to comprise the purpose of municipal ordinances (construction site erosion & storm water management). These eight statements of purpose are included in parts (a), (b), and (d) of S.03(1). In addition, the legislature includes a list of additional circumstances in s. 144.266(3)(c)(4) that should be addressed by storm water regulations. Although not specifically identified in s. 144.266 Wis. Stats. as statements of purpose, they help to clarify the goals of the ordinance and are therefore included in S.03(1)(c).

It is envisioned that each of the basic statements of purpose will be served by this ordinance in the following ways:

Safe and Healthful Conditions: S.03(1)(a) is really a simple umbrella clause to all the others which follow. It is a very important statement, however, because it establishes that the municipality is regulating and restricting property rights in the public interest, a legitimate exercise of municipal police powers.

General Adverse Effects, Soil Erosion, Water Pollution, Aquatic Life: S.03(1)(b) will be served by the ordinance in several ways. The ordinance will minimize public exposure to health hazards (pathogenic bacteria, viruses, contaminated fish, contaminated drinking water) in ground and surface waters by regulating the allowable pollutant loading from urban development. The ordinance will also minimize the discharge of pollutants or the creation of conditions that impair beneficial uses (recreation; fish & aquatic life: support of bird, plant, and animal life) of surface waters. Similarly, it will minimize the discharge of pollutants that threaten the exceedence of groundwater preventive action limits or enforcement standards, or that threaten the functional values of wetlands. Pollutants that the ordinance would control include: chemical pollutants (metals, nutrients, pesticides, organics, salts); physical pollutants (excessive water volumes and peak flows, temperature); biological pollutants (bacteria, viruses); and sediment. In addition, the ordinance will help to maintain groundwater recharge, and will help to reduce hydrologic impacts on wetlands and surface waters.

Long-term control of soil erosion at sites regulated by this ordinance will be achieved primarily by meeting the design standards for storm water best management practices that will be specified in the Wisconsin Storm Water Manual, Part Two: Technical Design Guidelines for Storm Water BMP's (Wisconsin Department of Natural Resources, In Preparation). This is different than the short-term control of erosion at active construction sites, which will be achieved through adoption and enforcement of local construction erosion control ordinances, and state regulations administered by DILHR (Uniform Dwelling Code; Commercial Code) and DNR (WPDES Storm Water Permits for Construction Sites).

Safe Drainage Capacity, Property Protection: S.03(1)(c) will be served by the ordinance through the restrictions it places on peak flow discharges. Standards address increases in discharge rates associated with surcharging minor drainage facilities, causing stream bank erosion, and contributing to increases in the floodplain.

Building Sites, Structures, Land Use, Scenic Beauty, Economic Growth: The storm water management requirements contained in the ordinance should help preserve ground cover and scenic beauty by maintaining natural stream channels, natural on-site infiltration capacity, and by referencing design standards that incorporate aesthetics into storm water management devices. The ordinance will promote sound economic growth by minimizing drainage and flood hazards that damage public and private property and reduce property values. The ordinance will also lessen the burden on tax-payers for remedial flood and drainage control projects, repair to flood-damaged public facilities and utilities, and correction of channel erosion problems.

Intent: Three major points are made in this section. One point is that this ordinance is meant to cover long-term storm water discharges after construction has been completed. Consequently, this model ordinance should complement, but does not overlap, construction site erosion control regulations.

A second point is that the regulation will address long-term storm water runoff from new development only, as opposed to regulating storm water runoff from areas that have already been urbanized. This focus on new development, as opposed to dealing with runoff from established urban areas, is consistent with the minimum requirements set forth in the introduction to s. 144.266(3)(c). This clause of the statute requires that at a minimum storm water standards shall provide for the regulation of construction activity, which is interpreted to mean new development and re-development.

The third clause is a recognition that watershed based storm water planning should be the long-term goal of the municipality. Such comprehensive studies can best identify the most cost-effective approaches to municipal and regional storm water management. Ultimately, this concept is particularly important in developing measures to protect the hydrology of receiving water systems, and is also an important tool that the municipality can use to optimize the location and sizing of storm water practices and to better coordinate administration and funding of its storm water management program. Site-by-site application of storm water performance standards, such as those identified in this ordinance, can be used until such time as the municipality can prepare a comprehensive, watershed based storm water plan.

S.05: APPLICABILITY AND JURISDICTION

INTENT

The intent of this section is to identify which land development activities must comply with the ordinance provisions, and which activities will routinely be exempted from applicability of the ordinance. The section should also clarify how the ordinance is to apply within the extra-territorial areas over which the municipality has certain statutory authorities.

DISCUSSION

Applicability: Two important clarifications are included for determining whether or not a particular land development activity falls within the acreage limitations specified in the ordinance. The term "gross aggregate area" is used in the statute, and indicates that the entire area within the legal description of the land parcel on which the land developing activity is to take place should be included in the areal measurement to determine if the regulation is applicable. In addition, the ordinance requires that for sites included within a larger common plan of development or sale, that acreage of the entire proposed development must be used in determining whether or not the regulation applies. This will reduce the amount of incremental, unregulated development which could eventually lead to the creation of storm water problems. This approach is consistent with that in NR 216 Subchapter III Wis. Admin. Code, which the Department uses to regulate construction site erosion on sites 5 acres and larger.

The legislature has identified under Section 144.266(3)(c)(1-4) Wis. Stats. four classes of activity which, at a minimum, should be covered by local storm water management regulations. Three of these (S.05(1)(a,b,e)) are adopted verbatim from the statute. The minimum requirements for non-residential developments (S.05(1)(c)), however, have been made more stringent than the minimum requirements set forth in the state statute. Although the state statute lists 3 acres as the minimum aggregate acreage of non-residential development to be regulated under the ordinance, the Department of Natural Resources believes there is adequate justification to reduce this minimum for these land uses.

The justification for establishing a more stringent applicability criterion for non-residential land development activity is based on recent studies that point out the significance of pollutant contributions from these land uses in Madison, Wisconsin (Bannerman, et al., 1993). These studies have identified that parking lots contribute a significant portion (27%-39%) of the annual pollutant loading in commercial areas. Parking lots also contribute a significant portion (50%) of the annual water loading in commercial areas. Rooftops contribute 20% of the annual water loading and 22% of the annual zinc loading from commercial land use. Since commercial type land uses tend to produce pollutants at an overall higher rate than many other land uses, and since parking lots and rooftops are significant source areas within the commercial land use, the ordinance must assure that parking lot and rooftop runoff is adequately controlled.

A similar argument can be made for industrial areas with some qualifications. The WPDES Storm Water Permit Program will require that runoff contaminated from industrial activities at these sites be controlled. Consequently, runoff from only certain portions of the industrial sites will be controlled under WPDES permits. However, the WPDES Permits will not control water runoff uncontaminated by industrial processes. This leaves a concern with pollutants generated by non-industrial activity, such as auto-related pollutants generated from separate employee parking areas, pollutants generated from building materials (60% of the zinc in industrial area runoff comes from rooftops, probably from the galvanized steel used in roofing and gutter materials), and water volumes from all industrial areas.

Table 4 shows that there is a legitimate concern that the acreage limitations included in the statutes will not provide adequate control of parking lots and rooftops in smaller non-residential developments, such as commercial, industrial, or institutional. Table 1 shows the smallest rooftop and parking areas that would, on average, be controlled under the minimum provisions of the statute. This analysis assumes typical land development characteristics for Milwaukee, Wisconsin land uses (Pitt, R., and John Voorhees, 1989). The data shows that many relatively large parking lots and rooftops could be created without control under the ordinance. For example, a parking lot created on 2.9 acre shopping center development could be expected to be about 1.8 acres in size. Such a parking lot would not be regulated under the statutory minimum.

Consequently, a decision was made to reduce the applicability criterion to from 3.0 acres to 1.5 acres, and to also specify that any non-residential development creating at least .5 acres of impervious area will also be regulated. This latter criterion protects against site developments that contain an above-average proportion of rooftop and parking area, and can also be used to cover the additions of parking lots and rooftop areas to already established urban development. *Table 5* shows the approximate size of non-residential developments that would be regulated under the criterion set forth in S.05(1)(c).

The following is meant to help clarify the types of development included under each part of the applicability section of the ordinance:

Residential Development of at Least 5 Acres (S.05(1)(a)): This includes all types of residential developments such as trailer parks, suburban, low density, medium density, high density, multi-family, and high rises.

Residential Land Development at Least 3 Acres, but Less than 5 Acres, if at Least 1.5 Acres is Impervious (S.05(1)(b)): This class of development is described a bit differently than the description contained in s. 144.266(3)(c)(2), which says: "Is a residential development with a gross aggregate area of 3 acres or more with at least 1.5 acres of impervious surfaces." The clarification added in this ordinance ("... development at least 3 acres, but less than 5 acres

...") is meant to avoid confusion by eliminating any perceived overlap between this and the other category of residential development.

Table 4. Estimated size of roofs & parking lots associated with a 3 acre non-residential development.

LAND USE	PARKING LOTS		ROOF TOPS	
	Estimated % of Land Use	Estimated Acres	Estimated % of Land Use	Estimated Acres
Comm Office	40%	**1.2**	10%	**0.3**
Comm Hotel	45%	**1.4**	20%	**0.6**
Comm Strip	40%	**1.2**	20%	**0.6**
Comm Center	60%	**1.8**	20%	**0.6**
Indus (heavy)	25%	**0.8**	25%	**0.8**
Indus (medium)	25%	**0.8**	25%	**0.8**
Indus (light)	35%	**1.0**	25%	**0.8**
Hospital	20%	**0.6**	40%	**1.2**
School	10%	**0.3**	15%	**0.5**
Other Instit.	25%	**0.8**	15%	**0.5**

Table 5. Typical land uses that would be regulated under S.05(1)(c), based on approximate percentages of anticipated imperviousness.

LAND USE	Estimated Size of Development That Would Be Regulated
Commercial: Office	1.0 acres
Commercial: Hotel & Strip	.8 acres
Commercial: Shopping Center	.6 acres
Indus (heavy/medium)	1.0 acre
Indus (light)	.8 acres
Hospital	.8 acres
School	1.5 acres

Other Institutional	1.25 acres

Based on land development characteristics studied in the Milwaukee Metropolitan Area (Pitt, R., and John Voorhees, 1989), this class would include the following residential developments between 3-5 acres in area: high rise (62% impervious), high density (55% impervious), multi-family (50% impervious), trailer parks (43% impervious), and medium density (35% impervious) developments.

Non-Residential Land Development (S.05(1)(c)): This category includes land uses such as commercial (offices, hotels, strip development, shopping centers, downtown areas), industrial, institutional (hospitals, schools, government centers), freeway and other transportation.

Other (S.05(1)(e)): The statute also provides for the regulation of other land development activities that are likely to result in storm water discharge quantities (volumes and peak flows) that are damaging to drainage facilities, streambanks, and which may cause an expansion of the floodplain.

Jurisdiction: Cities and villages adopting this ordinance should make it clear whether they intend to apply the ordinance to their extraterritorial areas under the authority provided in 62.234(6) and 61.354(6). A legal opinion concerning the construction site erosion control authorities for cities and villages, presented by counsel for the League of Wisconsin Municipalities in 1989, seems to be directly applicable to this storm water ordinance (Schneider, 1989). Legal counsel proposed three options for municipalities, which are directly reflected in this model ordinance. The first choice is for municipalities that do not want the ordinance to apply to areas within the extraterritorial jurisdiction. The second choice is for cities and villages that want the ordinance to apply only to extraterritorial plat approvals. The third choice is for cities and villages that want the ordinance to apply to the entire geographic extraterritorial area, even if plat approval is not involved (i.e. to existing recorded lots as well as other land tracts.)

Exemptions: The sections of the enabling legislation that give cities, counties, towns, and villages the power to adopt comprehensive storm water management zoning ordinances (ss. 59.974, 60.627, 61.354, 62.234 Wis. Stats.) specifically prohibit local municipalities from applying the regulation to state agencies. This exemption for projects funded or contracted for by state agencies is included because s. 144.266(2) Wis. Stats. requires all state agencies to comply with storm water performance standards developed by the Department. At this time, the Department intends that the performance standards developed for state agencies will not conflict with those specified in this model ordinance.

S.06: DESIGN CRITERIA, STANDARDS, AND SPECIFICATIONS

INTENT

The intent of this section is to clearly specify any restrictions on the type of analytical tools that can be used by permittees in evaluating storm water hydrology and designing best management practices. The intent is to promote consistency in storm water planning and design, and to reduce the number of alternative methods with which the reviewing agency must develop a high level of proficiency. To retain some flexibility, the ordinance allows use of alternative methods with prior approval of the administering authority.

DISCUSSION

Methods are specified for addressing two areas: storm water quality and storm water quantity.

Water Quality Methods: The most restrictions are imposed on methodology for addressing storm water quality, the performance standards for which are set forth in S.07(2). For this element, storm water planning and practice design must be in accordance with the Wisconsin Storm Water Manual, Part 2: Technical Design Guidelines for Storm Water BMP's. Of equal importance, the method for calculating the water quality volume of storm water practices is also set forth. This method, "Small Storm Hydrology", must be used in order to correctly estimate this critical parameter. If traditional tools, such as TR-55, are used in estimating practice volume needs for the design rain required by this ordinance, then the storm water practices will be routinely undersized and will not reduce pollutant loads by an adequate amount. This hydrology method is detailed in Part 2 of this manual.

Water Quantity Methods: These restrictions are imposed on methodology for addressing storm water quantity, the performance standards for which are set forth in S.07(1). Principles contained in TR-55 must be used in calculating runoff volumes and peak flow rates that are used in practice designs. Other components of practices necessary to reduce peak flow discharges for larger storm events must be designed in accordance to standard engineering practice.

S.07: STORM WATER MANAGEMENT STANDARDS

INTENT

The intent of this section is to identify site-based performance standards for storm water generated from land development activities. The goal of these performance standards is to maintain the natural pre-development hydrologic regime of the receiving waters to the extent possible, and to minimize the increase in urban pollutant loadings generated from these urban areas.

The performance standards are generalized, based on general principles of hydrology and general studies of urban storm water pollution. Both ***quantitative*** and ***qualitative*** standards are used. Quantitative standards reflect a level of management capability that is expected to be achievable under most circumstances, such as the control of peak flow discharges and particulate pollutants. Qualitative standards are used where site conditions may routinely limit the attainment of the desired goal, such as controlling discharge volumes through the use of infiltration.

This section of the storm water ordinance recognizes that site-based storm water management must be viewed as only one part of a more comprehensive approach to storm water management. The Department encourages communities to undertake a program of comprehensive, watershed based storm water planning and management as soon as possible. Such planning is valuable because it can identify: the need for modifications to the site-based performance standards contained in this model for purposes of water quality protection; restrictions on peak flow discharge timing to fully protect the hydrologic regime of downstream receiving waters; restrictions on allowable imperviousness in sensitive watersheds and minimum requirements for buffer zone areas along waterways; and locations that should be set aside for regional storm water practices. The model ordinance contains provisions that would allow alternative performance standards to be established consistent with more detailed and comprehensive storm water plans developed for specific areas.

DISCUSSION

Performance Standards for Discharge Quantity: Standards designed to protect against impacts caused by storm water quantities address both peak flow discharge rates and discharge volumes.

Peak Flow Rate: This section of the ordinance sets very specific, ***quantitative*** standards for peak flow discharge rates. The three design events chosen for peak flow rate management are related to the basic purposes of the ordinance. The two-year event is included to help control changes in the morphology of receiving streams and to control frequent scouring of benthic habitat. The ten-year event is included to reduce surcharging of minor drainage system components which can lead to inconvenience and property damage. The one hundred-year event is included to reduce increases in the regulatory floodplain, as defined in NR 116 Wis. Admin. Code, that may result in damage to property, threaten human health and safety, and lead to solutions that are catastrophic to aquatic habitat such as channel lining and re-alignment. **The constraints of this ordinance imposed on developments outside the regulatory floodplain are generally consistent with constraints for such developments imposed under NR 116 Wis. Admin. Code in rapidly urbanizing areas. However, there is the potential that compliance with NR 116 Wis. Admin. Code will require additional**

control of discharge rates and volumes depending on the location of the proposed development.

The determination of the "pre-development" condition is critical, since it sets the standard for managing peak flow discharge rates in urbanizing areas. It is important to firmly establish such limits on how the "pre-development" condition can be defined, since lands held for development are often abused. Such abused lands have reduced infiltration capacity, resulting in higher peak flow rates of runoff. This in turn results in higher peak flows in receiving streams, increasing the tendency for stream width and depths to increase through erosion. This unstable and destructive condition must not be used as a "pre-development" standard for urbanizing areas. To prevent this from occurring, the model ordinance requires that "pre-development" conditions reflect "good" land management, even though fair or poor management may actually be occurring. The range of curve numbers presented in the ordinance cover agricultural cropping, livestock pasturing, native fields, and native woodlands.

These controls on changes in peak flow discharge rates are consistent with the *New Development Management Measures* included in the federal guidance documents for the proposed Coastal Zone Nonpoint Pollution Control Program (US EPA, 1993). This program would require enforceable management measures be adopted that are at least as stringent as the federal guidance documents. The area that would be affected (shown in Figure 3) by this federal program has been delineated by US EPA, NOAA, and the Wisconsin DNR in association with other state agencies (WDNR and WDOA, 1994). Some municipalities may use a design storm other than the 10 year, 24-hour event for protection of local drainage systems. Consequently, alternatives for the ten-year design event should be considered if needed to more closely match storm sewer design standards for the community. Any such changes for the protection of local drainage systems should not affect the consistency of the ordinance with the federal coastal zone guidelines.

The separate wetland protection clause is required because wetlands are very susceptible to receiving, and becoming damaged by, uncontrolled storm water discharges. These areas are commonly unsuited for development and thus are convenient locations in which to discharge storm water runoff. This practice is also encouraged by the fact that wetlands play a natural role as floodwater and pollutant attenuators. However, a wetland's capability to store and cleanse runoff without incurring damage is limited. Wetlands can become overloaded, both hydraulically and with pollutants, leading to serious damage to the wetland itself. When this occurs, the wetland loses some of the functional values that make it a valuable habitat to begin with.

Figure 3. Proposed Coastal Nonpoint Pollution Control Program boundary for the State of Wisconsin.

The Wisconsin Department of Natural Resources is responsible for enforcing water quality standards for wetlands under NR 103 Wis. Admin. Code., and the US Army Corps of Engineers is responsible for enforcing wetland protection criteria as part of its federal section 404 permitting process. Where a development site falls under the regulatory purview of the state or federal regulation, the state and federal regulatory process will be used to determine if the land development activity complies with applicable state and federal standards.

However, these state and federal regulations are restricted in their applicability. **Even though there are many land development activities that will trigger the wetland standards review process under NR 103 (such as a pipe crossing a navigable waterway, a structural practice within 500 feet of a navigable waterway, or a proposal to excavate or discharge fill to a wetland), the state cannot require that NR 103 Wis. Admin. Code be applied to local zoning decisions per se.** Consequently, there are local decisions that should be reviewed in light of wetland protection since the state will not always have legal standing to get involved. It is the intent of this model ordinance to strongly encourage local municipalities to adopt standards, criteria, and procedures at the local level that will provide the same level of protection as the state standards.

The administering authority is encouraged to review NR 103 Wis. Admin Code as a guide to administering the wetland protection provisions of the model ordinance. The Department of Natural Resources has also prepared a guide to administering wetland standards that can serve as a handbook for the local authority charged with administering this ordinance (Water Quality Standards for Wetlands: A Regulator's Guide. Wisconsin DNR, Bureau of Water Regulation and Zoning. September, 1992). This guide references several wetland assessment methodologies that can be specified for use by the administering authority.

This wetland protection clause directs developers to do everything practical to protect wetlands from any hydrologic changes resulting from urban development. This will be difficult, since significant development in a wetland drainage area will result in some net change in wetland hydrology if surface and groundwater flows are affected. Recognizing that predicting wetland impacts can be very subjective, and that structural best management practices are rarely 100% effective in mitigating increased storm water runoff, the intent of this clause is to require that developers use all non-structural means at their disposal, such as maintaining as much site perviousness, during site development. Where such hydrologic changes are anticipated to occur, the ordinance requires that a wetland functional values assessment be conducted to determine if changes in wetland hydrology will impact wetland functional values. Where a determination is made that functional values will not be significantly affected, the wetland can be incorporated into the storm water drainage system, provided that adequate precautions are taken to protect the wetland from pollutant loading. However, where the functional values will be significantly affected, changes must be required in the land development plans.

Runoff Volume: Encouraging infiltration will serve those purposes of the ordinance related to maintaining base flows and to limiting the duration and frequency of bank-full flood flows for streams. Even though total infiltration of the design storm may not be practical, that which can be achieved should be pursued: some is better than none. In fact, studies in the midwestern United States have shown that 90% of the average annual rainfall depth is produced from rains equal to or less than about 1 inch (Roesner, L., et al, 1991; Pitt, R., 1991). These small events also produce a large portion of the average annual runoff. This section is ***qualitative*** because infiltration is very site specific and will not always be practical or desirable (Schueler, T.R., et al., 1992). Furthermore, the ordinance encourages routine infiltration of only that storm water which is generated from relatively clean source areas, including lawn areas, rooftops, sidewalks, and driveways. This limitation is due to general concerns over groundwater contamination and practice failure (plugging) that is more likely to occur when more highly contaminated runoff is discharged to an infiltration device. It should be recognized that storm water runoff from the more contaminated urban source areas, such as residential streets, commercial streets, commercial parking lots, and non-manufacturing industrial areas, may be safely infiltrated as long as several precautions are taken. These precautions include pre-treating the storm water from these sources prior to discharge to the infiltration device, reviewing site characteristics and practice designs, monitoring practice construction, and maintaining the pretreatment and infiltration devices. Because these extra precautions may be beyond the capabilities of some municipalities, infiltration of these more highly contaminated source areas is not being listed in the ordinance for routine consideration at this time.

Performance Standards for Discharge Quality: This performance standard requires that 80% of the average annual total suspended solids load washing off urban surfaces be removed prior to discharge to the receiving waters. This level of control is consistent with the federal Coastal Nonpoint Source Control Program's new development management measures (USEPA, 1993).

A key component of the performance standard is the identification of a design storm that must be used in sizing storm water practices. The federal Coastal Nonpoint Source Control Program indicates that a 2- year, 24 hour storm event is appropriate(USEPA. 1993). However, other researchers indicate a smaller design storm can be used to more cost-effectively attain the same reduction levels (Roesner et al, 1991: Pitt and Voorhees. 1989). In order to determine a design storm to use that would cost-effectively achieve this level of control, the Department of Natural Resources conducted a continuous simulation study using the Source Loading and Management Model(SLAMM). The purpose of the study was to determine the runoff volume that storm water practices must treat such that, on an average annual basis, the required level of solids reduction will be achieved.

All assumptions included in the modeling study were chosen to be protective of the environment. The continuous rainfall simulation selected represented an average year for the wettest station (Milwaukee) in the state. The land use used in the model was medium density residential. Finally, the particle size distribution, which is a very critical parameter, was selected to reflect a fairly large proportion of small sized particles which require a larger storm water practice to control. The results of the modeling study show that if the practices are designed to treat a runoff volume generated from a 1.5 inch rainfall, that the practice will be capable of reducing the average annual pollutant loading by 83%.

It should be noted that in cases where a watershed based storm water management plan is prepared, the local municipality can be much more flexible on the on-site performance standards provided that the overall level of control is consistent with the generic provisions of the ordinance. For example, it may be appropriate to down-size on-site practices if additional regional control practices will be installed as part of the overall control plan. In such cases, it may be appropriate to use the 1.5 inch rain for the design of on-site water quality practices, and then to handle larger design storms in regional practices meant to control increases of peak flow discharge rates.

The wetland protection clause is meant to restrict the circumstances under which storm water can be discharged to these potentially sensitive systems, similar to the restrictions established by the ordinance on changes to wetland hydrology. Wetlands should not be used as primary treatment systems for storm water runoff. As an added precaution, the ordinance requires that any storm water discharges to wetlands be pre-treated to remove particulate pollutants, oily residues, and other pollutants that can harm the wetland.

In the event that a municipality intends to allow infiltration of storm water runoff from more heavily polluted surfaces (such as streets or parking lots), pretreatment should be required. This will reduce the risk of groundwater contamination from many pollutants, and will also reduce the risk of practice failure due to clogging. Consequently, a clause is added to the ordinance requiring that storm water be pre-treated prior to infiltration. In addition, the ordinance references the prohibition on underground injection of pollutants under state law. Generally speaking, this prohibition includes discharge of storm water into the ground via openings or excavations, such as french drains or drywells, if such holes are deeper than wide. It is unclear at this time whether the federal Underground Injection Control Program will extend this prohibition to buried, horizontal, perforated piping.

Detention ponds and other storm water infiltration devices should not be located within a 1,200 foot radius of a community water supply well or within the defined recharge area surrounding a community water supply well for which a wellhead protection plan has been established unless, prior to construction, the installer of the pond or infiltration device consults with the community water system or its agent. Many water utilities have begun to establish wellhead protection plans for the areas around public water supply wells.
State administrative rules require these plans for all new community wells. EPA recognizes wellhead protection plans as an effective tool for preventing future contamination of public water supplies. Monitoring waivers may be issued for an entry point that is protected by a

wellhead protection plan. However, due to the wide variety of contaminants which may be present in storm water, siting storm water infiltration devices within 1,200 feet of a community well (or the recharge area defined in the wellhead protection plan) may limit a water system's eligibility for future monitoring waivers. Consequently, failure to obtain a waiver can result in a substantial increase in annual monitoring costs for the water system. The increase in monitoring costs must then be passed on to the users of the water system. Requiring consultation prior to siting infiltration devices within the recharge areas identified under established wellhead protection plans will help to safeguard the investment made by those water systems which have developed wellhead protection plans.

In addition, the municipality should discourage detention ponds, infiltration ponds and other infiltration devices from being located within 100 feet of the water systems listed. Locating practices closer than this may be permissible if a detailed hydrogeologic study shows that these types of water supplies will not be endangered. However, the local municipality may not be equipped to make these determinations. Generally speaking, these separation distances should be routinely observed.

Exceptions to Performance Standards: This section provides for alternative performance standards. Three types of conditions are listed that would qualify a site for the use of alternative standards: water quality; provisions for regional practices; technical limitations.

Site specific water quality information may justify the use of alternative standards. It is recommended that any such alternative standards be developed as part of a detailed systems level storm water plan. However there may be situations where the administering authority desires to reduce the risk of storm water impacts on highly sensitive resources by developing more stringent performance standards pending completion of a comprehensive plan. An option is included in the ordinance to allow for this.

Site specific standards can also be changed in cases where a regional (off-site) facility will provide the required degree of protection to receiving waters. The safeguards listed in association with this option are meant to assure that regional practices will actually be put in place and maintained. Where this occurs, the ordinance provides for the collection of a fee in lieu of meeting the on-site storm water discharge performance standard, so that the municipality can provide regional practices.

In some cases, practical considerations alone may prevent effective implementation of on-site practices. This can occur in situations of urban area in-filling or urban renewal, where sites may be very small and installation of on-site practices may be impractical. This model ordinance recognizes this potential problem, and allows for an exception to site-based performance standards for these types of situations. Where this occurs, the ordinance also provides for the collection of a fee in lieu of meeting the storm water discharge performance standard, so that the municipality can provide some sort of alternative storm water treatment.

Fees in Lieu of Practices: This section provides a mechanism for the municipality to generate income to provide alternatives to on-site storm water practices. Income is needed to prepare watershed based storm water plans that can identify alternative locations for storm water practices, to purchase land as needed for siting more centralized management practices, to construct municipal practices, and to carry out short and long-term maintenance responsibilities. Collection of fees will not, by itself, guarantee that storm water will be adequately managed. It is very important for a municipality that collects fees to have a plan for providing the off-site storm water management that the fees are collected to support.

General Planning Considerations: This section contains a ***qualitative*** requirement that careful consideration be given to retaining and using natural site characteristics to decrease the negative impacts of storm water runoff. This clause, although ***qualitative***, is very important as the greater the disturbance is to the natural hydrology and quality of storm water runoff at a site, the less likely it will be that storm water best management practices will be able to adequately compensate for the damage. This clause in the ordinance is consistent with some of the *Watershed Protection Measures and Site Development Management Measures* included in the federal guidelines for the Coastal Zone Nonpoint Source Control Program (USEPA, 1993).

S.08: PERMITTING REQUIREMENTS, PROCEDURES, AND FEES

INTENT

The intent of this section is to establish the requirement to obtain a permit, and to set forth the substantive and procedural requirements and responsibilities of both the applicant and the administering authority for completing the permitting process. This section also includes a set of basic conditions that the permit should contain to assure that the permit holder carries out the provisions of the approved storm water management plan.

DISCUSSION

The general philosophy behind this section is that the local administering authority will require the submittal of a storm water management plan, a maintenance agreement, and applicable fees as part of the permit application package. The model ordinance leaves it up to the local authority to specify an appropriate review period within which it is obligated to either approve or disapprove the plan and maintenance agreement. Such a time period is advisable so that developers can plan for the lead time required to get the permit. The local authority should give itself enough time so that permits will not be issued until the storm water plan or any required amendments to the plan have actually been approved. If the municipality finds itself with inadequate time to carry out the approval process, including careful review of storm water management plans, then the allowable time period specified in the ordinance for administrative reviews should be lengthened.

The ordinance identifies 11 general conditions under S.08(4) that apply to any permit holder. These embody several concepts, some of which are explained further.

Permit Condition (a) states that this permit does not relieve the requirement to comply with other local, state, and federal regulations. The list of other regulations is considerable. Those which contain portions that may be applicable to site development and storm water discharges include: local shoreland, wetland, and floodplain zoning ordinances adopted pursuant to ss. 59.97, 59.971, 59.99, 61.35, 61.351, 62.23, 62.231, 87.30, and 144.26 Wis. Stats; local zoning regulations adopted pursuant to ss 59,97, 62.23, and 61.35 Wis. Stats.(except those which are conflicting or contradictory); local regulations adopted pursuant to s. 92.11 and 92.17 Wis. Stats.; state water regulation laws enacted under Ch. 30 Wis. Stats; state storm water discharge permit regulations authorized under s. 147.21 Wis. Stats and administered under NR 216 Wis. Admin. Code; federal Section 404 regulations. Many of these programs are briefly described in The Wisconsin Storm Water Manual, Part One: Overview (Wisconsin DNR, 1994).

It is very important that holders of local storm water permits recognize that other regulations must be complied with in developing the storm water management plan. For example, Chapter 30 requirements or local shoreland zoning requirements can affect where practices are put. The issuance of a local storm water permit does not in any way guarantee that these other permits will be issued. Consequently, development proposals should be discussed concurrently with all state and federal authorities that will be involved in issuing permits.

Permit Conditions (b), (e), and (f) require that the permit holder be responsible for installing and maintaining storm water management practices as specified in the management plan, maintenance agreement, and the permit. In some cases, the permit holder may fail to live up to this agreement to the satisfaction of the administering authority. This is a permit violation that could have serious consequences for the environment as well as for the public health, safety, and welfare. Consequently, Conditions (g) and (i) of the permit authorize the local authority to enter the property to make inspections and, if required, to perform any work necessary to bring practices into conformance with the plan. Condition (g) authorizes the municipality to recoup its cost through placing a charge against the property.

Permit Condition (c) includes a clause allowing the administrative authority to set up a practice inspection schedule. This is particularly desirable if the local authority plans on eventually assuming maintenance responsibilities for the storm water practice, and wants to assure that it does not assume such a responsibility for a practice which has been improperly constructed. Such schedules should reflect the type of practice being installed and the critical phases of construction. This approach is definitely recommended for infiltration type devices, which are very sensitive to construction methods.

Permit condition (d) requires that all practices pass a final inspection. This is an important milestone in the site development process.

Permit Condition (h) extends the permit holder's liability for non-compliance. This is important, since the municipality is likely to have considerable investments in the construction and maintenance of storm water drainage and pollution control practices. It is not recommended that this liability be extended to damage of privately owned practices. This should be handled as a private matter between landowners, as is indicated under Condition (j).

Finally, Condition (k) allows the municipality to subject the permittee to enforceable actions specified in the ordinance if the permittee fails to comply with terms of the permit.

S.09: STORM WATER MANAGEMENT PLANS

INTENT

The intent of this section is to identify the substantive requirements for storm water management plans. This will help assure that the plans are sufficiently comprehensive for both the permit holder and the reviewing authority to determine whether or not performance requirements of the ordinance are being met.

DISCUSSION

A key component of successful storm water management is preparation of a storm water management plan. The introductory paragraph indicates that the intent of the plan submittal is to allow the administering authority to evaluate potential environmental impacts of the development and the efficacy of proposed control practices in mitigating these impacts. The requirements set forth in S.09 are further established as minimum submittal requirements. The intention is that additional information could be requested by the administering authority if need to fully carry out it's responsibilities to evaluate the proposed development.

The local administering authority may wish to standardize the process further to facilitate both the development and review of storm water plans. For example, the local authority may wish to develop a template for storm water management plans. In addition, the local authority may wish to develop a checklist for use by both developers and reviewers of these plans. The purpose of such a checklist would be to verify that the plan contains all required elements and that all performance standards have been met.

In addition to the hydrologic analyses identified, the municipality may also wish to impose on some permit holders a requirement to evaluate the impacts of detention on downstream areas. For example, the local authority might require hydrologic and hydraulic calculations necessary to evaluate the impact of hydrograph timing modifications on specified locations downstream such as dams, highways, or points of restricted streamflow. Such a requirement should be considered where structures or constrictions occur below a tributary whose drainage area exceeds that of the development area, or which has a peak discharge rate that exceeds the largest design release rate from proposed detention ponds in the development. Based on this information, the local authority may require that modifications in the storm water plan be made such that increases in downstream flooding or channel erosion caused by peak flow timing would be reduced or eliminated.

The maintenance plan is a critical component of the storm water plan. It sets forth expectations of the permit holder as well as of those to whom maintenance responsibility is transferred. In fact, S.08(4)(f) and S.10(2)(b) impose requirements of the permit holder that tie directly back to the maintenance portion of the storm water plan. The cost estimates required in the plan will be useful as a basis for determining the amount to be paid as a financial guarantee. In addition, estimates of long-term maintenance are an important piece of information for those who will assume long-term maintenance responsibilities.

It is important that the local authority identify the credentials that constitute a competent authority for purposes of certifying materials specified under S.09(1)(i). Certifications for soils and groundwater investigations should be made by a registered soil scientist or hydrogeologist. Certifications of storm water best management practice designs should probably be made by a civil or environmental engineer with expertise in storm water practice design.

This section allows for the administrative authority to modify plan requirements for situations where on-site practice requirements are waived under S.07(3). The local authority should be careful to assure that any modified requirements for plan content will still allow the municipality to make critical determinations. For example, where off-site practices are planned it will be necessary to calculate the capacity needed to accommodate flows from the development. In addition, sufficient information will be needed to calculate the amount of fees to be collected under S.11 of the ordinance.

S.10 MAINTENANCE AGREEMENT

INTENT

Structural storm water best management practices must be maintained to function properly and protect the public interest. Conditions in the permit will require maintenance of these practices for the short term, but some other vehicle is needed to require long-term maintenance of the practices after the original development has occurred and ownership of the land has changed. The purpose of this provision is to establish a chain of responsibility for the long-term maintenance of the storm water management practices.

DISCUSSION

Municipal ownership and maintenance responsibility for some types of practices, including larger detention and infiltration facilities, is strongly encouraged. The municipality can in turn bring its financial and technical capabilities to bear on practice maintenance. A less acceptable alternative is to assign long-term maintenance responsibility to individual landowners or property owners' associations.

Regardless of who accepts responsibility for long-term maintenance, the maintenance provisions and responsible party should be documented in a formal agreement that can be registered as a deed restriction. This will assure that maintenance agreement provisions pass from landowner to landowner. To assure that the agreement is actually entered into, it is required as part of the permit application package under S.08(2)(a).
The mere establishment of such an agreement will not, of course, assure practices are maintained. It is critical that all landowners or property owners' associations be kept informed on a regular basis of their specific maintenance responsibilities under the agreement, and the associated short and long-term maintenance costs. The maintenance provisions of the storm water management plan required under S.09(1)(f,g) should provide important information concerning these aspects of practice maintenance, and should allow parties responsible for long term maintenance to raise sufficient funds for future maintenance expenditures.

S.11 FINANCIAL GUARANTEE

INTENT

The model provides for the collection of a financial guarantee, at the discretion of the municipality. The purpose of the financial guarantee is to provide a fund for either practice installation, maintenance, or both that the municipality can draw upon in the event that the permit holder fails to meet the obligations of the permit and the storm water management plan. Such performance securities can include surety or cash bonds, irrevocable letters of credit, or similar instruments. This security would operate during the time that the permit is effective. Once the permit is terminated, the Maintenance Agreement provided for under S.10 would be used to insure that practices are maintained.

S.13 ENFORCEMENT AND PENALTIES

INTENT

The intent of this section is to set forth enforcement actions that the municipality can take against those who violate the provisions of the ordinance. The intent is to establish a clear procedure, to provide an incentive for compliance with the ordinance, and to provide a mechanism for on-site remediation by the municipality of violations that could affect the environment or public health.

DISCUSSION

A wide assortment of remedies is proposed. These include forfeitures, stop work orders, cease and desist orders, and judicial remedies. In addition, a provision is included to allow on-site remediation by the administering authority.

Once the permit has expired and the land has changed owners, the maintenance agreement developed pursuant to S.10 of this ordinance will be used as the primary enforcement vehicle to assure long term maintenance of storm water practices.

S.13 APPEALS

INTENT

The intent of this section is to identify a procedure for appealing decisions made by the administering authority. The section identifies who has the right of appeal, the responsibility and authority of the governing body to hear the appeal, appeal procedures, and any guidelines for granting appeals.

DISCUSSION

Section 59.974 Wis. Stats. enables counties to enact storm water management zoning ordinances applicable to unincorporated areas. Section 59.974(4)(b) Wis. Stats. requires that appeals regarding storm water management regulations are to be determined by the county board of adjustment, using procedures set forth in s. 59.99 Wis. Stats. Parallel language is contained in the enabling legislation for cities(62.234), villages(61.354), and towns(60.627(4) Under these sections, 62.234(4)(b) and 61.354(4)(b) require that appeals regarding storm water regulations be determined by the city or village boards of appeals, using procedures set forth in 62.23(7)(e).

There is no required language in this section providing for the granting of variances. Instead, this language is optional. The reason for this is as follows. There are provisions contained in S.07(3) and S.09(2) that allow the administering authority to grant exceptions to storm water standards and planning requirements based on site-specific factors. This approach is used because variances in zoning ordinances typically apply only to dimensional criteria such as building setbacks. The need for considering exceptions to performance standards and planning requirements can not be satisfied by a typical zoning variance procedure, since these requirements are not dimensional in nature. The exception clauses provide an avenue for adjustment of these ordinance requirements where they become cumbersome and unreasonable. The appeals process set forth in this section can still be used to resolve differences of opinion about ordinance interpretation and administration.

If a local municipality adopts additional provisions in its local ordinance that are not subject to the exception clauses in the model ordinance, and if such provisions may be challenged based on claims that they impose unnecessary hardship while failing to significantly protect the public interest, then the local municipality may choose to add an the optional clause to the ordinance providing for variances.

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APPENDIX G

Town of Grafton
Stormwater Management Planning Checklist
for New Developments

Property Owner: ______________________

Location: ______________________

Current zoning: ______________________

Planned zoning: ______________________

Sub watershed (size): ______________________

Property size: ______________________

- ☐ Are there any existing or planned 100-year ponding areas on the property and have they been incorporated into the development plan?
- ☐ Are there any zoned conservancy lands on the property (floodplain, corridor, wetlands)?
- ☐ Are the recommended water quality BMPs incorporated into the development plan (wet detention ponds, grassed swales, constructed wetland)?
- ☐ Are there any groundwater issues on the property (refer to Plate 2 - Appendix C) and have they been incorporated into the development plan?
- ☐ Are proper erosion control measures in development plan (silt fence, hay bales, temporary siltation basins)?
- ☐ Are any culverts proposed to be altered or installed on the property?
- ☐ Are there any eroded streambanks on the property?
- ☐ Will the natural drainage of the property be altered as to discharge into a new sub-basin?
- ☐ Does the Ulao Creek or one of its eight main tributaries flow through, or abut, the property?