RUST

MEMORANDUM

September 11, 1997

To: Participants in the Village of Grafton - Lime Kiln Park Scoping Meeting

From: Joan Underwood

Subject: Agenda and Background Materials
Village of Grafton - Lime Kiln Park
REI Job ID No. 101688.10001

Attached are the agenda and resource materials for the scoping meeting for the Work Plan for the Village of Grafton - Lime Kiln Park Investigation. The agenda lists the items to be discussed at the scoping meeting, the discussion leader for each item, and the approximate time anticipated for each item. The resource materials are organized by discussion item number.

The purpose of the scoping meeting is to identify all of the data needs associated with site characterization and potential remedial measures and to discuss the procedures for obtaining the required data. By the end of the meeting, we hope to have the site investigation procedures outlined, the number of samples specified, and the laboratory analysis requirements for each sample specified. Normally, the duration of the scoping meeting is 4 hours.

Please review the materials before the meeting. If you have any questions prior to the meeting concerning any of the materials, please contact me.

Attachment: As Noted

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VILLAGE OF GRAFTON - LIME KILN PARK

SCOPING MEETING

AGENDA ATTACHMENTS

AGENDA ITEM I

PROJECT GOALS

VILLAGE OF GRAFTON - LIME KILN PARK
SCOPING MEETING AGENDA
FOR
SITE CHARACTERIZATION AND REMEDIAL ACTIONS STUDY BREAK
WORK PLAN PREPARATION

I. Project Description and Goals of Meeting	J. Underwood	5 minutes
II. Site Background Information		
A. Site History	J. Underwood/ M. Gottlieb	10 minutes
1. Construction 2. Period of Operation 3. Waste Types Accepted 4. Operation Procedures		
B. Site Plan (Current and Historical Air Photos)	J. Underwood/ M. Gottlieb	15 minutes
1. Waste Mass Location 2. Topography 3. Surface Waters 4. Land Use 5. Water Supply Facilities 6. Other Potential Sources		
C. Site General Geologic Cross Section	K. Elias	10 minutes
1. General Subsurface Conditions 2. Water Table 3. Geologic Controls to Groundwater and Contaminant Flow		
D. Groundwater Flow Direction and Rate	K. Elias	10 minutes
E. Contaminated Media and Contaminants	J. Underwood	20 minutes
1. Data Summary 2. Data Sources		
III. Site Conceptual Model	J. Underwood	20 minutes

IV. Cleanup Objectives by Media	C. Zeal	10 minutes
V. Preliminary Identification of Alternatives	C. Zeal	20 minutes

A. Surface Water

B. Soil

C. Groundwater/Leachate

D. Gas

VI. Data Needs	Group	30 minutes

A. Source Characterization

B. Risk Assessment

1. Human Health
2. Environment

C. Alternative Evaluation

VII. Specific Field Approach and Activities	J. Underwood	60 minutes

A. Locational Criteria (State or Federal Threatened or Endangered Species, Sensitive Ecosystems, Wetlands, Outstanding or Exceptional Resource Waters)

B. Geophysics

C. Soil Samples

1. Surface
2. Deep Cores
3. Test Pits

D. Leachate Samples

E. Gas Samples

F. Surface Water

G. Sediment

H. Private Wells

I. Monitor Wells (Including Characterization Needed to Locate Wells)

J. Cover

K. Air

L. Source(s)

M. Other

VIII. Future Activities and Schedule

PURPOSE AND SCOPE OF PROJECT

Groundwater sampling was conducted in 1995 on private wells located in the Manchester Subdivision adjacent to the Village of Grafton. Sampling of these and additional wells since 1995 indicate that there has been a release of contaminants to the groundwater which has caused contaminant levels to exceed the NR 140 standards for select compounds. One potential source of these contaminants is the old Lime Kiln Park Landfill located west of the subdivision. The WDNR requested access to the park to install three groundwater monitoring wells. However, the Village decided to initiate the work themselves including investigating the site and reviewing potential engineering modifications, if necessary, to limit landfill impacts to the environment.

1.0 WORK PLAN

The Work Plan will detail the requirements for the completion of a site investigation based on potential remedial actions at the Lime Kiln Park. It should follow pertinent sections of NR 700. Therefore, the objectives of the Work Plan will be to:

1. Provide a scope of work for the site investigation and considering remedial options. It should follow requirements of NR 716 and NR 722 (Attachment 1).

2. Document and control the technical conduct of the work.

3. Provide a mechanism of assigning responsibilities and controlling the cost and schedule of the work.

4. Provide a mechanism for communicating to regulatory agencies on management of this effort.

2.0 SITE INVESTIGATIONS AND REMEDIAL ACTION EVALUATION

The purpose of the site investigation and remedial action evaluation will be:

1. Determine the nature, degree, and extent, both areal and vertical, of the contaminants in all affected media.

2. Provide sufficient information to evaluate remedial action alternatives and the need for interim actions.

This purpose will be met through the evaluation of the following:

1. Potential pathways for migration.

2. Impacts of contamination on receptors.

3. Known or potential impacts on natural resources.

4. Hydrogeology of the area.

5. Definition of other potential source areas that could impact the same area.

6. Identification of potential mitigation measures including natural attenuation.

3.0 SCOPE OF THE WORK PLAN

The Work Plan will recognize the interactive and iterative nature of the investigation and evaluation process. The collection of data in the investigative phase is meaningful to both site characterization and the selection of appropriate remedial actions. That work is most efficient if certain evaluations associated with the remedial evaluation are completed during the investigation.

The findings of the investigation are expected to affect evaluations of remedial actions which, in turn, may generate additional data needs. Accordingly, the Work Plan will be scoped to take into account such iterations.

The scope of the tasks outlined in the investigation portion of the Work Plan will address the following:

- The location of any potential contaminant source areas (on-site and off-site).

- Characterization of the hydrogeology of the area of study, particularly in relation to mechanisms of contaminant transport.

- The nature, concentration, and lateral and vertical extent of impacted soil and groundwater.

- The existing and projected future migration pathways of impacted groundwater from the site.

- Nature and migration of gas from the landfill, if present.

It is anticipated the majority of the field work will be conducted during the investigation. However, it is understood that supplementary exploration and analysis may be required to eliminate any remaining data needs.

To accomplish the foregoing, the investigation will utilize available site hydrogeologic data, as well as complete additional site characterization in areas which are not well studied. We will also use other existing site data (private well sampling results, the Tecumseh Products Company Grafton Site Investigation, etc.).

It is anticipated that the following tasks may be necessary to complete the investigation:

- Review of existing data (70 percent complete).
- Analysis of potential contaminant sources.
- Soil borings and soil sampling.

- Installation of monitoring and observation wells.
- Hydrologic testing.
- Surface geophysics and geophysical logging.
- Surface water sampling and analysis.
- Groundwater/leachate sampling and analysis.
- Surveying.
- Geotechnical laboratory testing.
- Gas sampling.

If the findings of the investigation warrant, we will evaluate remedial alternatives for the site, which will be designed to protect human health and the environment. The end results will be a document which will form the basis for the Village of Grafton to select a remedial alternative for the site.

The engineering evaluation will:

- Discuss the current knowledge of the site, including data developed during the investigation.

- Identify the existing and projected future contaminant migration pathways to be addressed by the remedial actions.

- Define remedial action objectives for the site.

- Develop a list of potentially feasible remedial technologies and screen the list to retain those which are feasible and applicable.

- Conduct an initial screening of alternative remedial actions eliminating those which do not meet remedial action objectives or are not practical for this site. Appropriate remedial actions are evaluated based on 1) technical criteria including long and short term effectiveness, implementability and restoration time frame, 2) economic feasibility, 3) other considerations such as the practicality, minimization of harmful effects, and other applicable regulations.

- Complete rough-order-of-magnitude (ROM) performance and reliability evaluations of each alternative.

- Recommend selection of remedial actions which is preferred on a basis of technical and economic feasibility.

- Complete a conceptual design of the system once the Village of Grafton concurs with the recommended preferred corrective measure(s).

It is anticipated that the following tasks will be necessary to complete the engineering evaluation.

- Identify performance criteria.

- Identify remedial technologies.

- Identify appropriate alternative remedial actions.
- Treatability conditions (may include bench studies).
- Evaluate alternative remedial actions.

AGENDA ITEM II

BACKGROUND INFORMATION

INTRODUCTION

1.0 PURPOSE

This document provides site background information on the Lime Kiln Landfill to be utilized while preparing a work plan for gathering site-specific data. The site background provides general facility information, facility history, land use information, regional geotechnical information, and site-specific geotechnical information.

GENERAL FACILITY INFORMATION

2.0 PROJECT TITLE

The title of this project is Village of Grafton Lime Kiln landfill.

3.0 PROJECT TEAM

Owner:

Village of Grafton - Mr. Mark Gottleib, P.E., Director of Public Works
1300 Hickory Street
P.O. Box 125
Grafton, WI 53024

Consultant:

REI
4738 N. 40th Street
Sheboygan, WI 53083
Phone: 920-458-8711

Joan Underwood, P.G., Project Manager
Charlie Zeal, P.E., Remedial Engineer
Mike Crosser, Senior Chemist
Kim Elias, Geologist
Lisa Smith, Chemist
Paul Wintheiser, Landfill Engineer

WDNR:

Southeast District:
John Feeney (414) 229-0850
Chad Czarkowski (414) 229-0828

WDOH:

Chuck Warzecha (608) 267-3732

USEPA:

Ken Theisen (312) 886-1959

4.0 PROPERTY OWNERS

Lime Kiln Park and the Lime Kiln Landfill are owned by the Village of Grafton (Figures 1a and 1b).

5.0 FACILITY LOCATION

The site is located in the SE 1/4 of the NW 1/4 of Section 25, Township 10 North, Range 21 East. The Lime Kiln Landfill site is located within the limits of Lime Kiln Park located in the limits of the Village of Grafton, Ozaukee County. Lime Kiln Park is located off (SE) of Green Bay Road, just south of the intersection of Falls Road and Green Bay Road (Figure 2).

The Milwaukee River borders the south and east edges of the Park, while residential areas border the northeast, west, and southwest sides of the Park, as well as the east side of the Milwaukee River. Industries and businesses are located northwest of the Park, along Wisconsin Avenue.

6.0 SITE CAPACITY

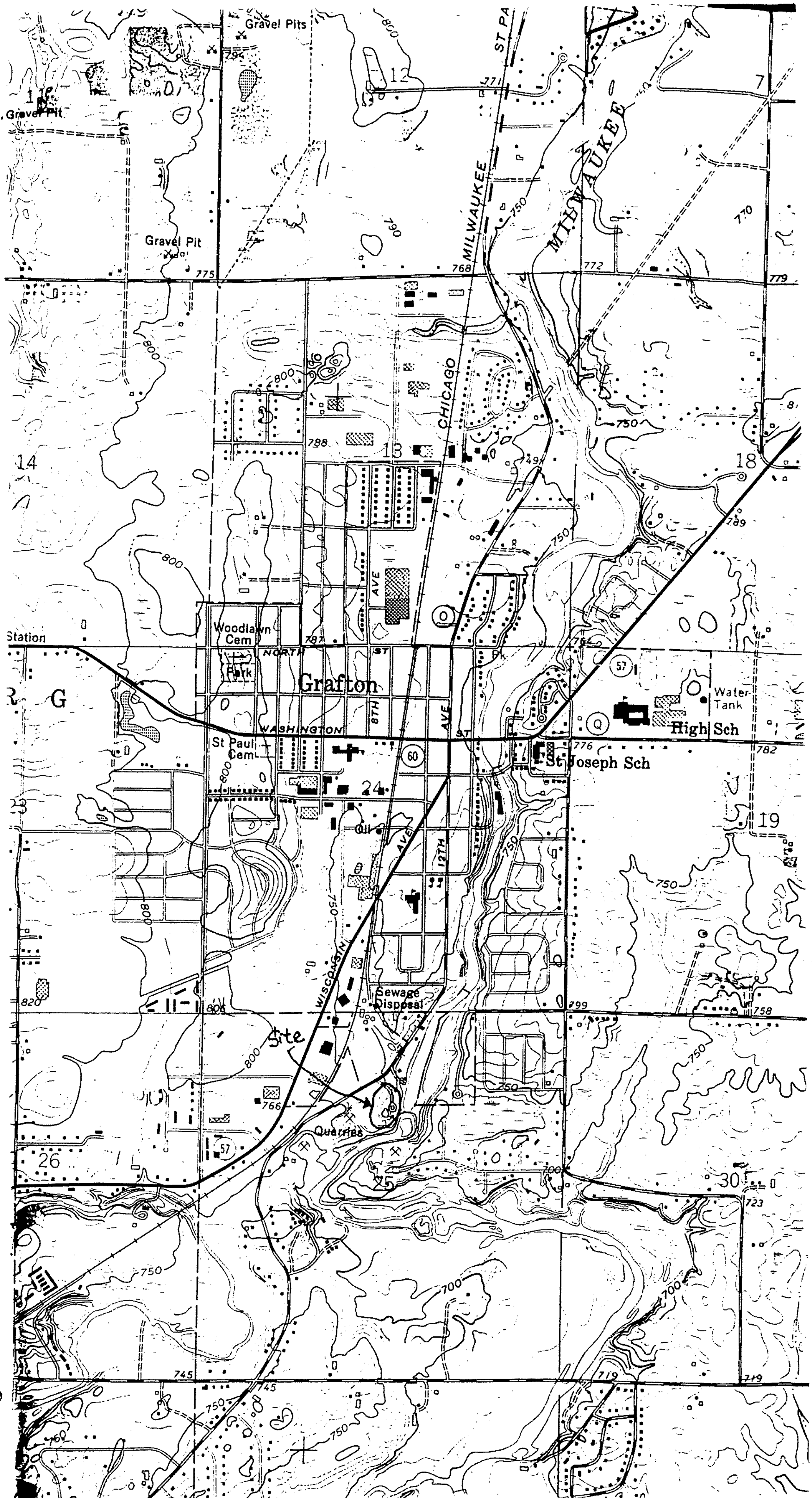
The size of the site is unknown but is estimated to be approximately 1 acre of deposited waste. It is suspected that the site received demolition, municipal solid waste, waste solvents, and waste oils. The depth of waste is unknown but is suspected to be as much as approximately 80 feet on the western portion of the site and 15 feet towards the east (based on the depth of the nearby existing quarry). It abuts the Milwaukee River. The best information available on the potential size and depth of the landfill is the USGS map (Figures 1a and 1b).

7.0 BASE MAP

The base map available for the work plan is attached (Figure 2). The need for any additional mapping will be discussed.

8.0 DRINKING WATER WELL LOCATIONS

Private well locations in the vicinity of Lime Kiln Park have been identified and are shown on Figure 3. Well logs on record with the State of Wisconsin for wells with addresses located within the Manchester subdivision, along Green Bay Road and Highknoll, are available in the project file. Well logs have not been correlated to addresses at this time.



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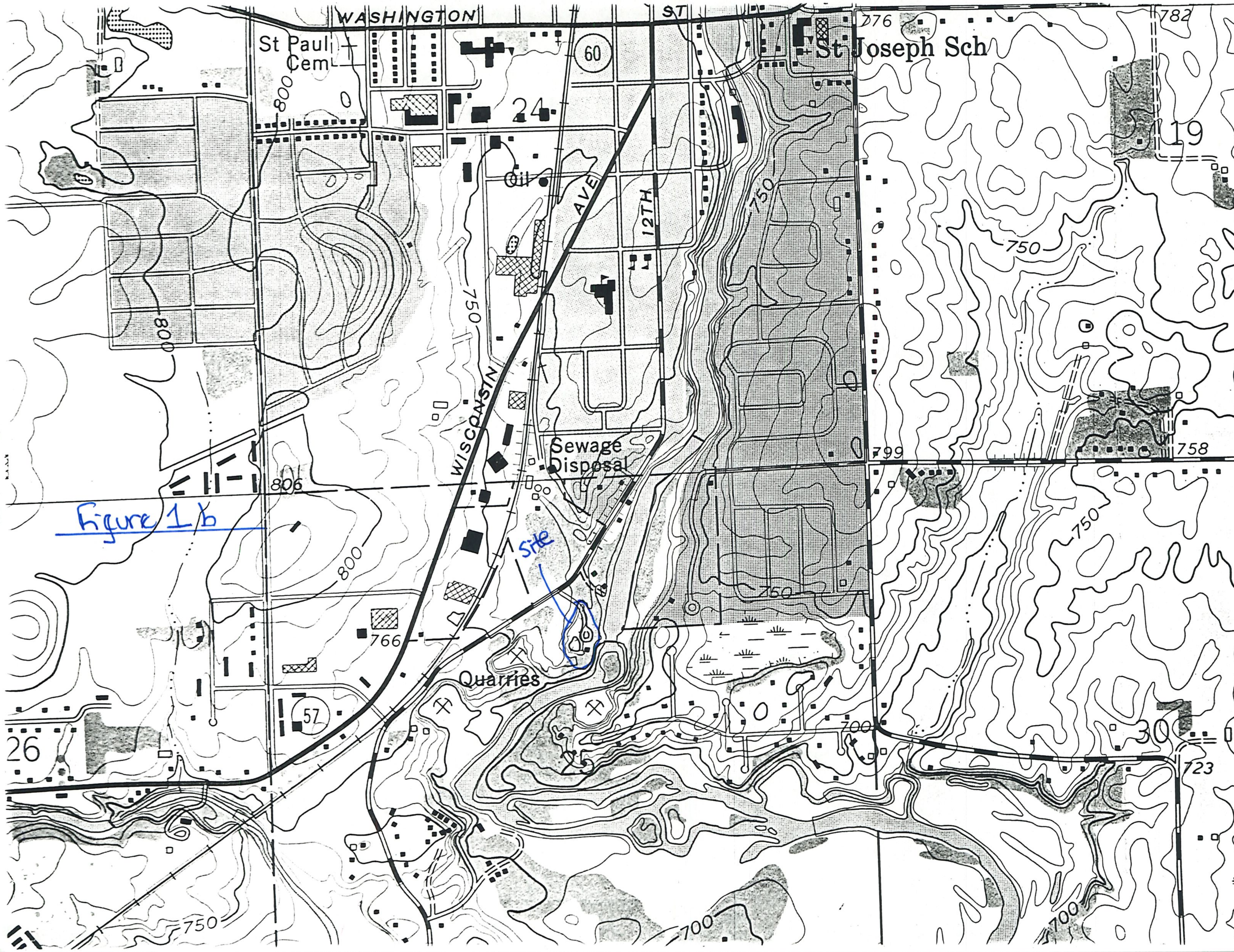
1" = 1000'

Cedarburg, Wis
USGS Quadrangle
Photorevised 1971 + 1976

Figure 1a


WASHINGTON
ST
St Paul
Cem
60
24
St Joseph Sch
776
782
19
Oil
AVE
12TH
750
800
WISCONSIN
Sewage
Disposal
799
758
806
Figure 1 b
Site
766
Quarries
57
700
26
30
723

A portion of these wells have been sampled and sampling is continuing through WDOH to move from wells that are most likely to be impacted to wells that are less likely to be impacted.

9.0 PRIVATE WELL SAMPLING RESULTS

The WDOH and WDNR have sampled about 75 residential homes in the vicinity of the site during July 1996 and May 1997. EPA has also performed additional groundwater sampling during this period. The EPA analysis Method 8021 was utilized for most of the analyses, however, EPA also used Method 502.2 or 542.2. Samples were obtained during the WDNR sampling from the faucets located prior to the pressure tank. EPA sampled the residential groundwater from the outside hose bibs. Most of the homes received one round of sampling, however, less than 10 of these homes were resampled and 2 to 4 homes were sampled 4 times as a result of EPA resampling.

Below is a summary of the analytes detected from these sampling events.

Analytes	Maximum Results (ug/l)	d
Vinyl Chloride	47	1.2
TCE	59 - 240	1.46
cis-1,2-DCE 3733	240	
Trans-1,2-DCE 3733	4 - 1.5	
PCE 85	0.61 - 0.54	1.58
Vinyl Chloride	47 - 18	1.2
1,1,1-TCA	28 - 19	
1,1-DCA	58 - 46	
1,1-DCE	5.7 - 4	
Freon 9320, 3038, 1822, 2599,	140 6555	1.49, 1.49, 1.89, 1.53
Chloroform	4.4	1.48
Toluene	0.66	0.866
Chloromethane	1.0	

10.0 FACILITY HISTORY

10.1 OPERATION

There are no clear records on the operation history of the site. However, filling was thought to have started between 1942 - 1946 and continued to 1970. The site was closed and became Lime Kiln Park about 1971. The WDNR Parts Department files indicated that funding was provided by the WDNR for site grading. The original agreement was dated June 1972 and amended in 1973 and 1974. The closure was supposedly reviewed by WDNR although no records have been found at this time. In the late 1950s, the Village leased the site from a private owner; the Village became owner about 1961. The site received general residential garbage and industrial waste from Grafton and surrounding communities. It was an open dump with no gate. Closure was precipitated by both the inability to get it licensed and the startup of the incinerator in 1971.

10.2 TYPES AND GENERATORS OF WASTE

Several types of industries are in the area and types of wastes that could be expected to have been disposed at the site include:

1.	Metal stamping	TCE, toluene, xylene, lacquer thinner
2.	Tool and die	PERC (tetrachloroethylene), TCE
3.	Porcelainized, enamel finisher	Unknown
4.	Printed circuits	Acetone, plastic resins, TCE, silver screen process, toluene
5.	Unknown	MEK, hydraulic fluids, dry cleaners solvents
6.	Silk screening (paint)	Toluene, acetone, MIBK (methylisobutyl-ketone or 4-methyl 2-pentonone), methyl amyl ketone, n-propyl acetate, Dowanol® PM glycol ether, Dowanol® EB consolve 100, xylene
7.	Vinyl coated products	MEK
8.	WDNR records	Solvents, volatile solvents (lithograph industry), oils, dieldrin, possible medical wastes (autoclaved serums) from Fromm Laboratories.

11.0 ADJACENT LAND OWNERS

Refer to Figure 2 for adjacent land owners.

Several other potential sources are located in the vicinity of the site, as shown on Figure 2, and as identified in the ERIIS report.

- UST (ERIIS information).
- Quarry east of Milwaukee River.

11.1 UTILITY LOCATIONS

The only Village utility on-site is a storm sewer (see project file).

12.0 GAS MIGRATION RISK

The possibility of lateral gas migration beyond the limits of waste exists and would most likely occur in fractured rock located above the groundwater. Gas migration may also occur in utility trenches which are backfilled with sand or gravel which abut the area.

The horizontal extent of gas migration will vary through the year, depending on the state of surficial soils, for example:

> If the surficial soils are very wet, due to frequent rain or freezing, as typically occurs in the winter, the horizontal extent of gas migration could be quite far (up to 2,000 feet). If the

surficial soils are very dry, due to lack of rain, or have many cracks, gas migration may not occur.

It is important to note that no lateral gas migration problems have been reported at this site. There was also no evidence of distressed vegetation during the site walk-over.

13.0 REGIONAL GEOTECHNICAL INFORMATION

13.1 TOPOGRAPHY

The Lime Kiln Landfill is located in the Village of Grafton, Ozaukee County, as shown on the attached USGS map (Figures 1a and 1b). Ozaukee County's topography is a product of the Wisconsin stage of Pleistocene glaciation. Ozaukee County consists primarily of ground moraines and end moraines (USGS, Hydrologic Investigations Atlas). The end moraines in Ozaukee County are mainly parallel to the Lake Michigan shore and mark various stages of the advancement or recession of glaciers from the Lake Michigan Basin. An end moraine runs north to south through most of Ozaukee County and the Village of Grafton. The Milwaukee River valley eroded through this end moraine immediately south of the site. The river borders the south-southeast sides of the Park.

The Lime Kiln Park topography consists primarily of a sloping river valley. The topography slopes southeast towards the Milwaukee river, and varies from gentle to steep sloping. The dolomite bedrock outcrops along a northeast to southwest ledge which parallels Green Bay Road near the western portion of the Park. A quarry exists near the center of the site and drops approximately 80 feet on the western edge. At one time, it was used for snow removal dumping. A small pond is located at the bottom of this quarry. (See the aerial photograph, Figures 4 and 5).

Historical information notes the following:

"Another old "water hole" is located in the Park between the lime kilns and the second quarry to the south. This pond is spring-fed with the water coming from the limestone cliffs in the area. Plans to have it cleared and made into a park-like setting have, to date, never materialized."

An additional larger quarry is located in the southwest section of the Park. Reportedly, the third quarry existed on the north-northeast side of the Park, which apparently was filled as the landfill.

13.2 SURFACE WATER

Surface water in the Lake Michigan Basin is generally in abundance and of good quality, although hardness is a persistent problem. Conductivity generally ranges from 500 to 750 micromhos, and dissolved solids generally range from 310 to 465 milligrams per liter (USGS Hydrogeologic Investigations Atlas).

The WDNR - Milwaukee River Section will be contacted for information on the Milwaukee River water quality.

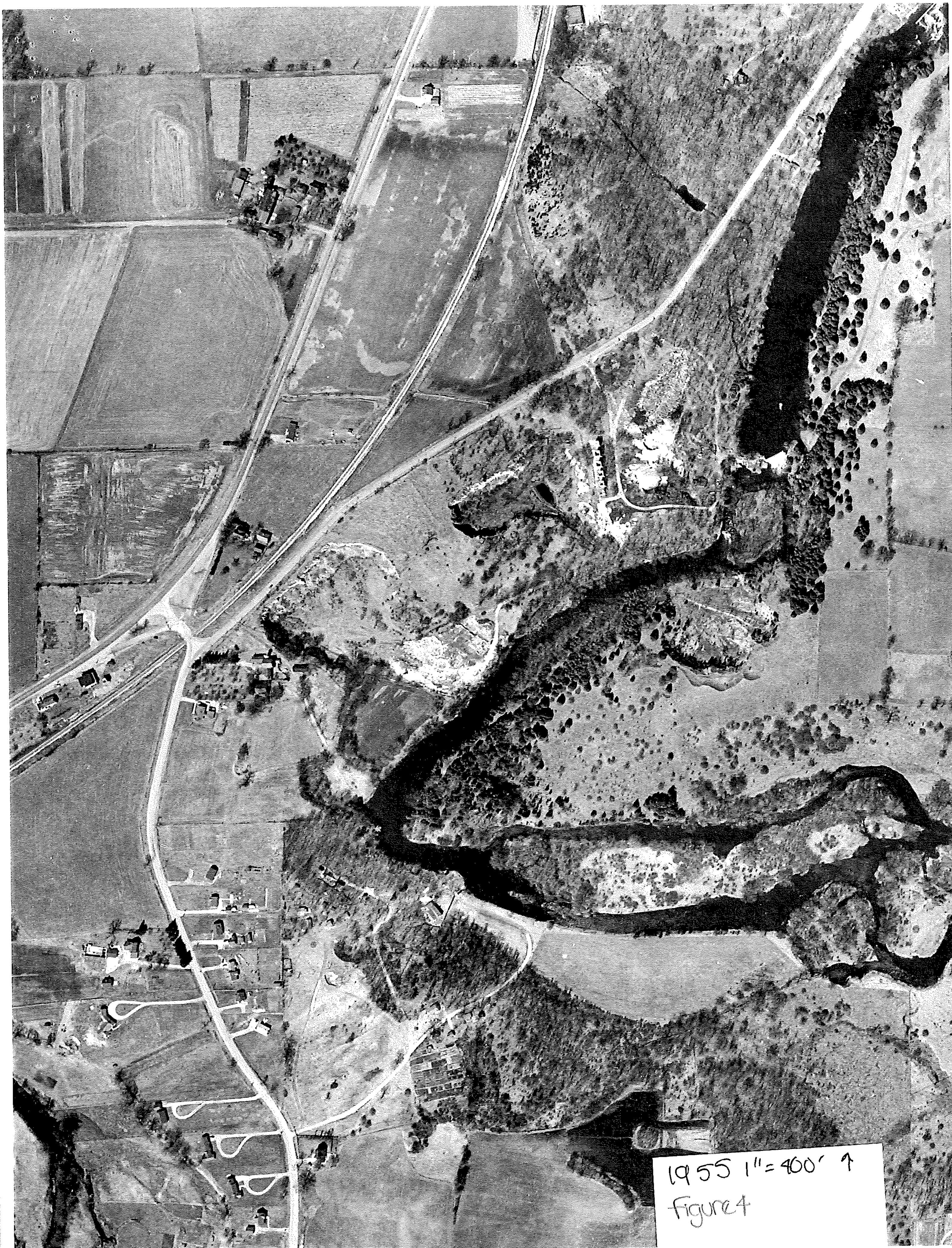

1955 1"=400' ↑
Figure 4

Figure 5
1992
1" = 400'
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13.3 SURFICIAL SOILS

According to the Soil Survey of Ozaukee County (USDA, 1970), a majority of the soils on the site are disturbed. Two areas in the west and central portions of the site are identified on the soil survey map as "quarry" and one area in the east portion of the site is identified as "dump". The Ritchey soil series (0 to 20 percent slope) and an area designated as "loamy land" are identified in the south-central portion of the site. The Ritchey series consists of a well-drained silt loam soil found on nearly level to moderately steep positions in the landscape. This soil formed in a thin 10 to 20-inch layer of silt or glacial drift deposits overlying limestone bedrock. The subsoil ranges from silt loam to clay loam. The area designated as "loamy land" consists of areas on the landscape disturbed by cut and fill activities. The soil characteristics found in this area are dependent on the parent material source but typically consist of loamy glacial till with pockets of sand and gravel or clayey material.

The soil units identified on the surrounding land typify the soils likely present on the site prior to being disturbed. The Knowles soil series (0 to 6 percent slope), the Hochheim-Sisson-Casco complex (2 percent to 20 percent slope) and an area designated as "alluvial land" are identified on the surrounding land. The Knowles series consists of a well drained silt loam soil found on nearly level to gently sloping positions in the landscape. This soil formed in a 20 to 42-inch layer of silt or glacial drift deposits overlying limestone bedrock. The subsoil ranges from silt loam to clay loam. The Hochheim-Sisson-Casco complex consists of a well drained silt loam soil found on gently sloping and gently undulating positions in nearly circular upland areas. This complex formed in a thin mantel glacial till overlying limestone bedrock. The subsoil ranges from loam to clay loam intermixed with stratified layers of variable material which affect subsurface water flow. The area designated as "alluvial land" consists of low lying silt and sand deposits located near floodplains along major streams and drainageways. These areas are frequently flooding and indicate stratification in the soil profile. The soil material in these areas is dominated by silt loam but ranges from sandy loam to sand.

13.4 GEOLOGY

13.4.1 Regional Geology

The site is contained within Wisconsin's Eastern Ridges and Lowlands Province, an area characterized by alternating resistant and nonresistant Paleozoic sedimentary rocks overlain by a series of Wisconsinan tills and interbedded outwash deposits (Paull and Paull, 1977).

Generally, unconsolidated glacial Quaternary deposits unconformably overlie bedrock in Ozaukee County. The glacial deposits (drift) are Pleistocene in age and consist of a heterogeneous mixture of gravel, sand, silt, and clay. The glacial sediment in this area was deposited as glacial end moraines and ground moraines. The end moraines in Ozaukee County are mainly parallel to the Lake Michigan shore and mark various stages of the advancement or recession of glaciers from the Lake Michigan Basin. The unconsolidated deposits, which consist of mostly till, range in thickness from 0 (on-site where bedrock outcrops) to more than 50 feet to the west of the site (Young and Batten, 1980).

The unconsolidated glacial deposits are unconformably underlain by Paleozoic sedimentary rocks which dip gently to the east, toward the Lake Michigan Basin, at approximately an 0.5 percent slope. The Paleozoic bedrock throughout most of the Province is resistant Silurian dolomite. Devonian dolomite and shale are present along the eastern edge of Wisconsin. The sedimentary rocks consist of Silurian dolomite, which overlies Ordovician shales, dolomites, sandstones, and Cambrian sandstones. The Paleozoic sedimentary rock sequence unconformably overlies Precambrian crystalline rocks, which are present beneath the site at a depth of more than 1,200 feet below grade (Young and Batten, 1980).

The Silurian dolomite is the uppermost bedrock unit in the study area. The Silurian dolomite is generally fractured, massive to thinly bedded, with a total thickness of approximately 550 feet in the study area. The Silurian dolomite was originally divided into two formations, the Niagara and the Waubakee (Chamberlin, 1877; Foley and others, 1953). These formations have since been subdivided into several distinct lithostratigraphic units with characteristic hydraulic conductivity values, thicknesses, and lateral extents that are related to the deposition environments of the original sediments (Rovey, 1990; Rovey and Cherkauer, 1994a), as shown on Figure 6. From oldest to youngest, these included the Mayville, Byron, Manistique, Racine, and Waubakee (Figure 7). Overlying these units are the Devonian-age Thiensville and Milwaukee Formations.

A generalized north-south cross-section was constructed through southeast Wisconsin, as shown on Figure 8. This cross-section depicts the various units in the area of Grafton. The spatial distribution of the carbonate rock units is a result of the deposition environments present in the area during the Silurian and Devonian Periods (Rovey, 1990; Rovey and Cherkauer, 1994b). The most significant feature identified in Figure 8 is a northeast to southwest-trending barrier reef complex that passed through the vicinity of Grafton. Isolated reefs are characteristic of the Racine dolomite throughout Milwaukee County. The contact between typical non-reef Racine dolomite and the overlying Waubakee dolomite is gradational, but the contact between the Racine dolomite reef facies and the overlying Waubakee dolomite may be locally unconformable (Mikulic and Kluessendorf, 1988). The most permeable portions of the Racine Formation and the thickest sequences of the highly permeable Romeo Member of the Racine Formation are associated with the reef structure.

The late Silurian Racine dolomite consists of porous, light to dark gray, medium bedded, pure dolostone (Mikulic, 1977). Graziano (1993) describes the Racine dolomite in Milwaukee County as light to dark gray, thin to thick bedded, nonporous, slightly argillaceous, crystalline dolostone. Average thickness of the Racine dolomite in Milwaukee County is about 170 feet, but the formation thickness may increase to approximately 290 feet where reefs occur (Mikulic and Kluessendorf, 1988).

The Waubakee dolomite is Late Silurian based on its stratigraphic position above the Racine dolomite and its lithologic similarity to Late Silurian carbonates in the Michigan Basin. The Waubakee dolomite of Milwaukee County is light to dark gray, dense, crystalline, laminated to thin bedded, slightly argillaceous dolostone. Localized dolomitic breccia zones have been identified at the top of the Waubakee dolomite. The Waubakee dolomite is generally 60 to 110 feet thick in Milwaukee County, but is absent in some locations where Racine dolomite reefs extend upward to the unconformable Silurian-Devonian boundary (Mikulic and Kluessendorf, 1988). The Waubakee

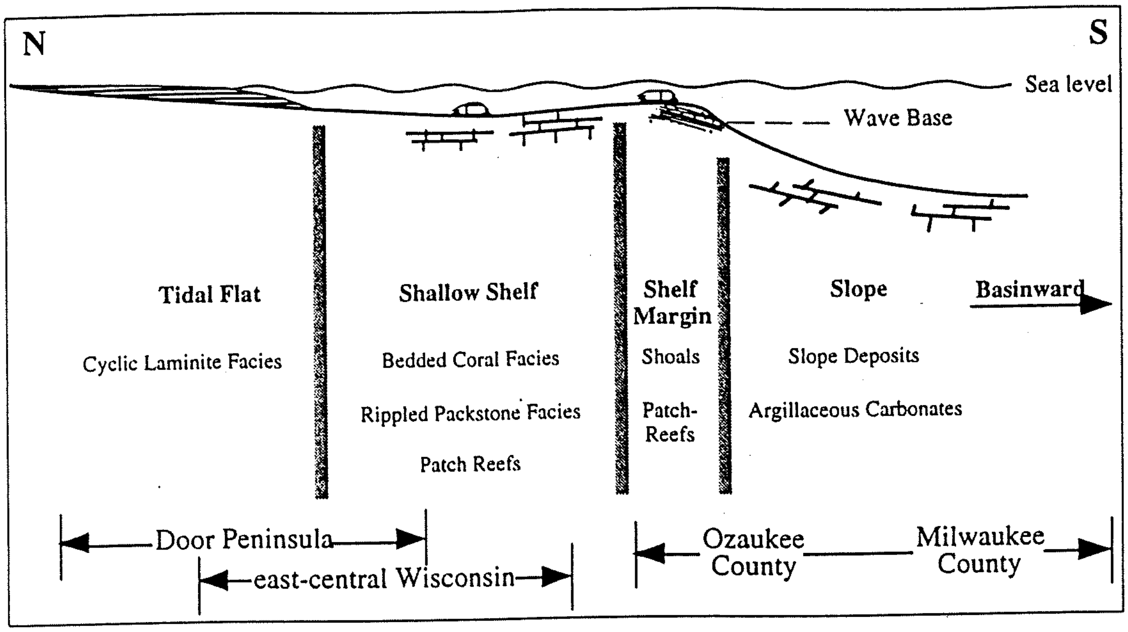

Figure 6 : Idealized transect from shallow to deeper water in eastern-Wisconsin.

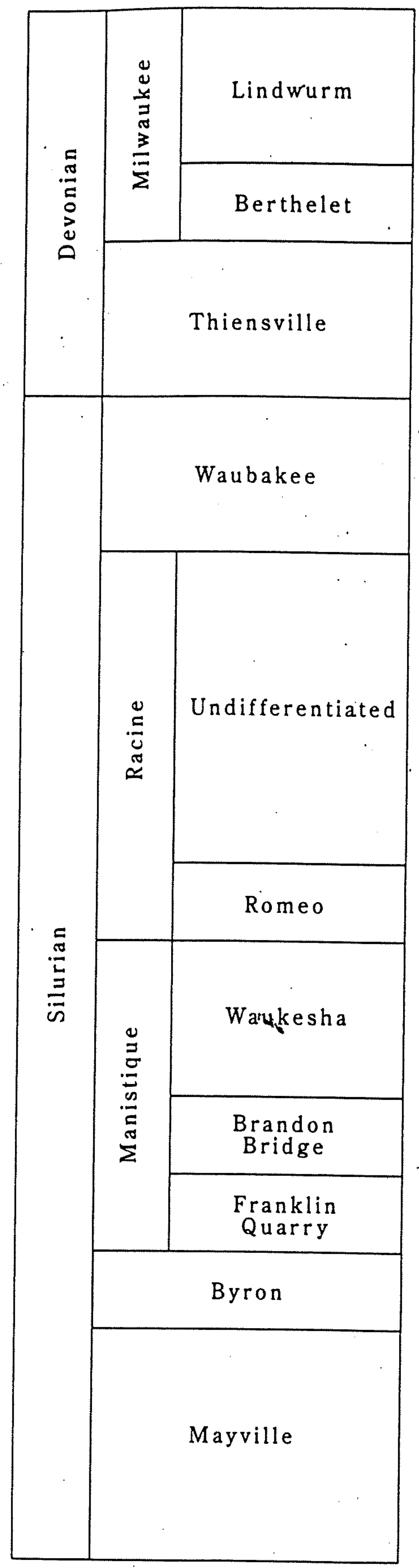

Fig. 1. Generalized stratigraphic column, Milwaukee County, Wisconsin. The primary subdivision is at the formation level. Subdivisions at the member level are informal, except within the Milwaukee Formation. See Figure 3 for geographic location. Source: Rovey and Cherkauer (1994).

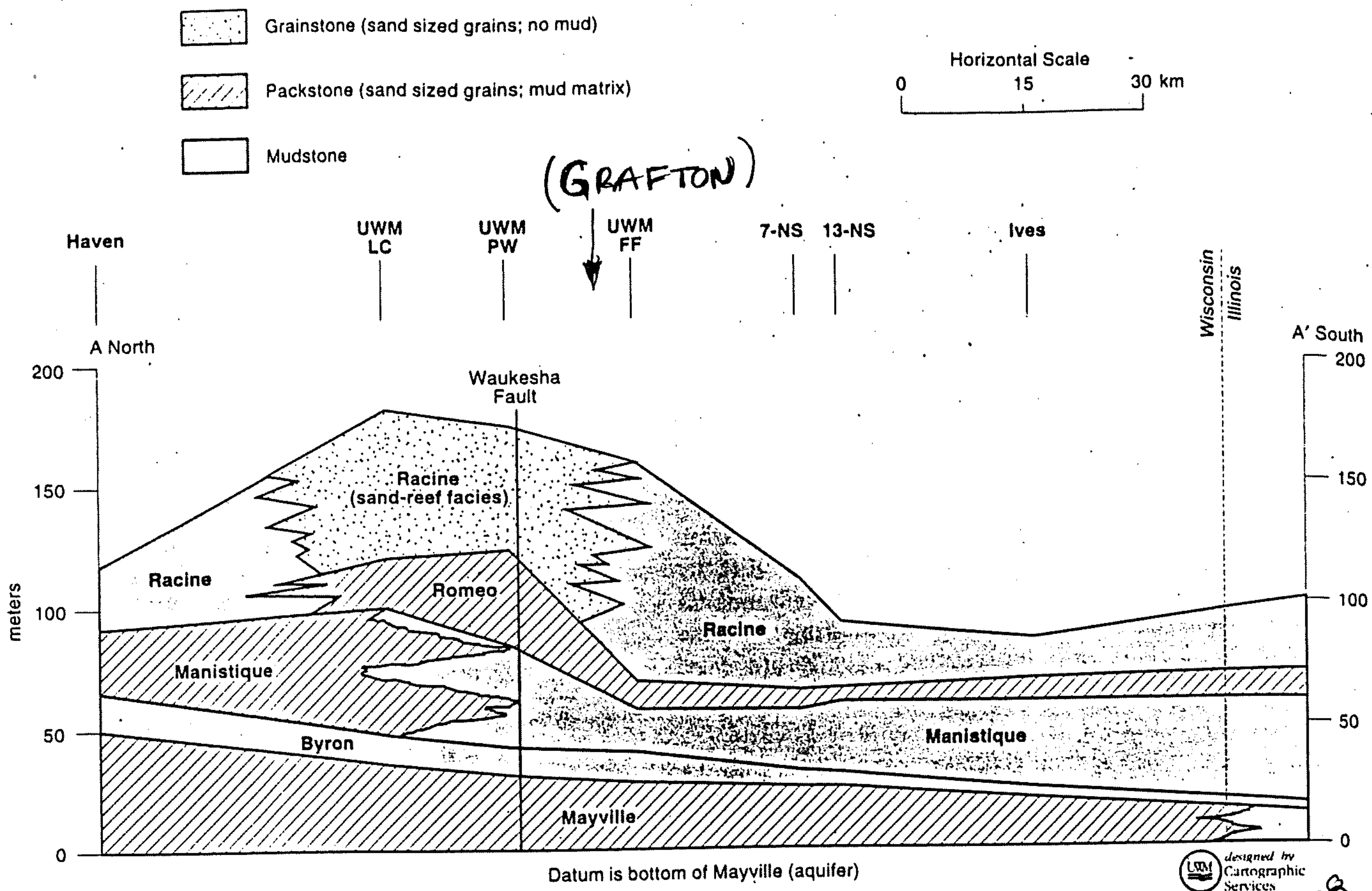

Fig 8. North-south cross section showing major hydrostratigraphic units, dominant textures and major facies changes. See Figure 8 for cross section location. The location of the facies change within the Mayville is highly generalized. Datum is the base of the aquifer; consequently, displacement along the Waukesha Fault is not shown. The apparent width of the Racine sand-reef facies is exaggerated, because the cross section is not perpendicular to strike. Units younger than the Racine are not shown, because of their restricted extent.

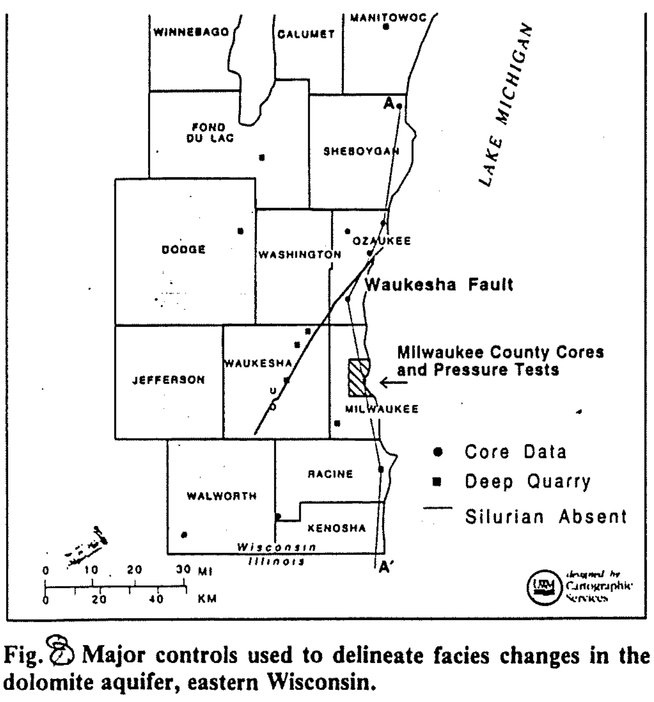

Fig. 8 Major controls used to delineate facies changes in the dolomite aquifer, eastern Wisconsin.

dolomite is separated from the overlying Middle Devonian Thiensville Formation by an erosional unconformity.

The age of the Thiensville Formation is Middle Devonian based on fossil occurrences. The Thiensville Formation of Milwaukee County is a lithologically complex unit that grades upward from poorly lithified argillaceous sediments, to dense, less argillaceous carbonates near the top. A characteristic lithologic feature of the Thiensville Formation is solution-derived breccias, commonly present in the middle and upper portions of the unit.

The Silurian dolomite is underlain by the Upper Ordovician Maquoketa Shale, which is primarily a blue-gray dolomitic shale, with some thin beds of dolomite. The dolomite layers are most common in the upper portion of the unit. The Maquoketa Shale occurs at a depth of approximately 600 feet below grade in the study area and is approximately 200 feet thick. The Maquoketa Shale acts as regional aquitard in the area, separating the Silurian aquifer from the underlying sandstone aquifer. Because of its low permeability, this unit yields little water and restricts the vertical movement of water (Young and Batten, 19890).

The Maquoketa Shale is underlain by a thick sequence of Cambrian through Middle Ordovician rock units, which are collectively referred to as the "sandstone aquifer." From youngest to oldest, the sandstone aquifer consists of the Galena-Platteville unit, the St. Peter Sandstone, the Prairie du Chien Group, and the Cambrian sandstones. The sandstone aquifer lies on relatively impermeable Precambrian rocks.

13.4.2 Local Geology

Pertinent findings from the Subsurface Investigation Report for Tecumseh Products Company (RMT, April 1997) are summarized in this section to enhance the regional geological and hydrogeological descriptions of the area surrounding the site. The Tecumseh site is located approximately 1 mile north of Lime Kiln Park.

In general, the geology at the Tecumseh site is consistent with the regional geology. The bedrock surface is present at a depth of 30 to 50 feet below grade. The four bedrock units identified by RMT to the depth they investigated (approximately 320 feet) are, from deepest to shallowest, the Romeo Member of the Racine Formation, undifferentiated Racine Formation, Lake Church Formation, and Thiensville Formation. However, the lithological units were difficult to define because of the size of the cuttings from the downhole hammer drilling techniques.

A photolineament study was performed by RMT using aerial photography to evaluate the presence and orientation of possible fractures in the bedrock. Two dominant sets of lineament, oriented at approximately 90 degrees to each other, were identified in the study area. One lineament set is oriented northeast-southwest at approximately 35 to 50 degrees, and one is oriented northwest-southeast of approximately 125 to 135 degrees. This is consistent with regional fracture orientation identified by Jensen (1995) for the Silurian dolomite of eastern Wisconsin, providing a strong indication that the photolieaments represent underlying fractures in the bedrock.

13.5 HYDROGEOLOGY

13.5.1 Regional

The primary sources of groundwater in the study area are the Silurian and the sandstone aquifers. The Maquoketa Shale acts as a regional confining unit, separating these two aquifers. Water in the Silurian aquifer is generally under water table conditions, and the deep sandstone aquifer is generally under artesian conditions. The Silurian aquifer is the primary aquifer for domestic, commercial, municipal, and subdivision water supplies in the area. The sandstone aquifer is rarely used for domestic supplies because the overlying Niagara aquifer generally has adequate yields. The regional groundwater flows across the study area generally to the east/southeast toward Lake Michigan (Young and Batten, 1980).

Highly porous packstones and grainstones have an intrinsically high hydraulic conductivity above that which is potentially provided by fractures and secondary dissolution. Hydraulic conductivity values for the Mayville Formation, Romeo Member of the Racine Formation, portions of the Racine Formation associated with reefs, and the Thiensville Formation may exceed 10^{-4} cm/s. Figure 9 depicts the general hydraulic characteristics of the various units.

Abundant, but discontinuous, crevices and solution cavities are also present in the dolomite. The upper few feet of the rock generally have a higher hydraulic conductivity than the remainder of the aquifer because of interconnected fractures, joints, and solution openings formed during preglacial erosion. The Silurian dolomite is the primary aquifer for domestic, commercial, municipal, and subdivision water supplies in the area.

Flow in the Sulurian aquifer is generally under water table conditions. The water table usually occurs within the unconsolidated deposits, but may be within bedrock where bedrock is close to the surface. Groundwater flow is general from west to east where Lake Michigan serves as a regional groundwater discharge area. Surface water bodies affect the local groundwater flow systems so that this general flow direction is perturbed. In the Grafton area, the water table slopes from west to east following the bedrock dip. This is the dominant flow system. Regional information depicts the Milwaukee River as a losing stream in the vicinity of Grafton, the result of the presence of several dams on the Milwaukee River. Just south of the site, the Milwaukee River changes from a losing to a gaining stream.

There is conflicting information on the strength of the influence the fractures and joints in the dolomite exert on the groundwater flow system. It appears that where the reef structure is present, primary porosity or bulk porosity will control flow more than the presence of jointing. Where pump tests have been conducted along fracture traces, a strong anisotropy has been found in the direction of the fracture.

13.5.2 Local

Results of the RMT study at the Tecumseh facility indicated that the hydraulic conductivity of most of the boreholes is comparable to the higher permeability units defined by Rovey and Cherkauer

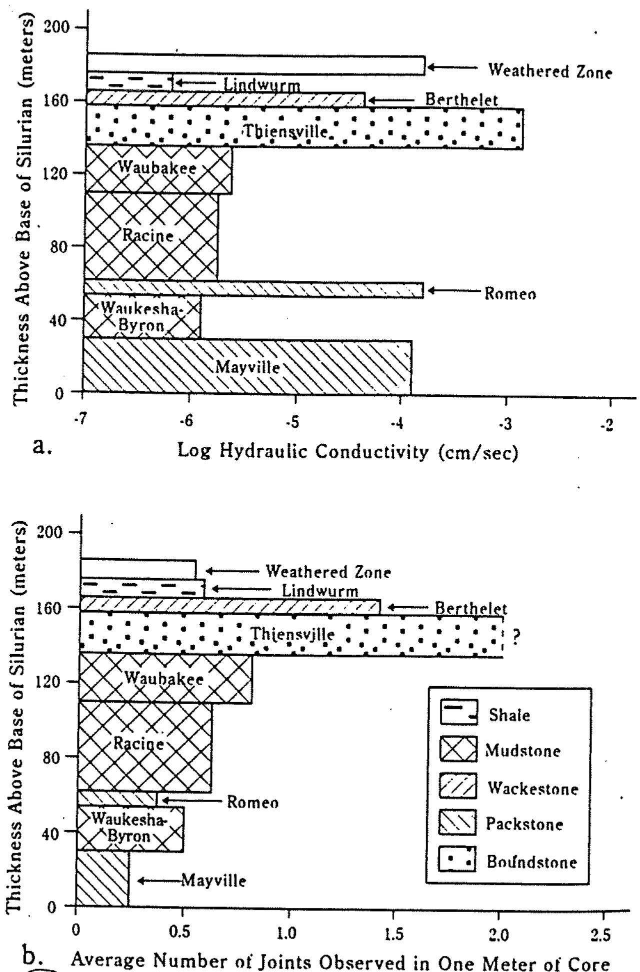

Fig. 1. Distribution of horizontal hydraulic conductivity and joint density within the dolomite aquifer by stratigraphic unit. Each bar is the average thickness of a particular unit and extends to the geometric and arithmetic means, respectively, of each unit's hydraulic conductivity and joint density. The patterns depict the dominant texture of each unit. Source: Rovey and Cherkauer (1994). a. Hydraulic conductivity. b. Joint density. The apparent high joint density in the Thiensville is caused by poor core recovery and is not typical of the Thiensville in situ.

(1994a): the Thiensville, Romeo, and Racine reef facies. It is believed that the Thiensville and Romeo formations were not encountered. The highest observed hydraulic conductivity at the site is much higher than any reported by Rovey (1990). The coarse-grained and granular nature of the rock described in two borings suggests the sand-reef facies of the Racine Formation as defined by Rovey (1990) and Rovey and Cherkauer (1994b) is present beneath the site.

The fracture characteristics of the dolomite bedrock were assessed based on the results of borehole video logging that was performed on the bedrock wells. The video logging tends to under-represent fracture frequency, since only the larger fractures are readily visible on the borehole wall. The borehole videos indicate that macroscopic porosity of the dolomite occurs primarily as bedding planes. Vuggs and small vertical fractures were also present. Highly porous zones ranging from 1 to 10 feet thick were noted in some of the borings. In addition, a cavern was found between the depths of 50 to 54 feet. There was no apparent correlation of these zones of secondary porosity between borings.

A distinctive change in the nature of the rock was observed in the deepest boring at the Tecumseh site. At an elevation of about 55 feet NGVD, the specific capacity as obtained from the packer tests performed on a boring increased by two to three orders of magnitude, indicating a significant increase in the hydraulic conductivity of the dolomite. There was also an increase in the number and size of fractures observed on the video log in the lower portion of the boring. This highly transmissive zone extends from 555 feet to at least 435 NGVD (bottom of boring). The lateral extent of the high-permeability zone observed at the boring is not well defined. The high-permeability zone was not observed in the lower portions of nearby borings, suggesting that the high-permeability zone is not laterally extensive to the west. The deep boring may have penetrated into the Silurian reef structure within the Racine Formation that is hypothesized to cross the area from northeast to southwest (Rovey and Cherkauer, 1994a and b).

Groundwater at the Tecumseh site flows to the east-southeast toward the Milwaukee River, with a horizontal hydraulic gradient of approximately 0.008. The vertical gradient in the unconsolidated material beneath the site is approximately 0.006 downward. The water level in the Milwaukee River in June 1996 was about 735 feet, which is lower than the water table observed in monitoring wells west of the river, and higher than the water table observed in monitoring wells east of the river. This shows that the river represents a partial recharge/discharge boundary for the dolomite aquifer.

The general pattern of potentiometric surface flow is of strong downward and southeastward gradients beneath the site, essentially horizontal gradients in the area of the Milwaukee River, and a return to strong downward gradients east of the river. The direction of groundwater flow in the bedrock parallels one of the regional fracture orientations identified by Jensen (1995) for the Silurian dolomite, indicating that groundwater in the bedrock flows primarily through discrete fracture zones rather than through intergranular porosity.

Based on the strong downward gradient observed in the bedrock, the Milwaukee River does not appear to have much influence on groundwater flow in the bedrock and will not likely intercept groundwater flowing from the Tecumseh Grafton facility.

The calculated horizontal hydraulic conductivity of five wells ranged from $3.2x10^{-3}$ to $2.9x10^{-2}$ cm/s, with a geometric mean gradient of 0.008 and an effective porosity of 0.01 for the portions of the aquifer represented by the mean hydraulic conductivity of $2x10^{-3}$ cm/s yielding a velocity on the order of 1,600 feet per year.

Contaminants from the Tecumseh facility had moved several thousand feet downgradient of the site and beneath the Milwaukee River. The total depth of the contamination was not determined, but concentrations remained fairly constant to a depth of 160 feet directly beneath the site. Because contaminants were found at this depth beneath the site, it was concluded that a DNAPL had been present that move contaminants directly downward at the site.

There was a qualitative correlation between fracturing and permeability.

Grafton city wells receive water from both the Sulurian and sandstone aquifers. Some wells are open to both formations. In addition, most private wells are constructed as an open borehole from near the top of rock to the total depth.

ATTACHMENT 1

NR 716 AND NR 722