

## *Hydrostratigraphic Database of West-Central Wisconsin*

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<b>Site:</b>	Trout Brook Road / Parkview Estates Area
<b>Location:</b>	Hudson, St. Croix County, Wisconsin
<b>Unit Evaluated:</b>	Ordovician Prairie du Chien at Hastings-Lake Owen Fault

### ***File includes excerpts from:***

Braun Intertec Environmental, Inc., 1992, In-Field Conditions Report, Trout Brook Road/  
Parkview Estates Area, on file at Wisconsin Department of Natural Resources.

- Text, including discussion of hydrogeology, slug testing, gradient analyses
- Tables (interspersed with text)
- Figures: area maps, cross-sections, bedrock surface map, water table maps
- Appendix 24: Seismic reflection survey, prepared by Geosphere Midwest, including text and figures.

**In-Field Conditions Report**  
**Trout Brook Road/Parkview Estates Area**

Prepared For

**State of Wisconsin, Department of Natural Resources**

Project Number: CMKX-91-0118  
**Braun Intertec Environmental, Inc.**

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## **1.0 Introduction**

This in-field conditions report is being submitted in accordance with the signed contract dated October 2, 1990 between the State of Wisconsin, Department of Natural Resources (DNR) and Braun Intertec Environmental, Inc. (Braun Intertec). The contracted work was detailed in the Proposal for In-field Conditions Study, Trout Brook Road/Parkview Estates Area, June, 1990 prepared by Braun Intertec. That proposal contained a detailed description of services to be performed as part of the investigation and is listed in the reference section.

### **1.1 Purpose**

The purpose of the investigation was to delineate subsurface geologic conditions, define groundwater flow conditions, evaluate hydraulic relationships between different aquifers in the study area, and determine the extent of volatile organic compound (VOC) contamination in the area. The results will be used to determine potential sources of the VOC contamination and to form a basis for evaluating possible remedial actions.

The study area is located in Sections 15, 16, 17, 18, 21, and 22 of Township 29 North, Range 19 West, in the Township of Hudson, St. Croix County, Wisconsin. A study area location map is attached as Figure 1.

The study area has not been assigned a facility monitoring identification number. This would require submission of form 4400-39 after assignment of a number by the DNR.

### **1.2 Previous Investigations**

Braun Intertec identified a number of investigations relating to known sources of VOC contamination in the area. These studies centered around the former Junker Landfill, Nor-Lake, Inc., and a residential well sampling program by the DNR. The reports that have been obtained are listed in reference section along with other documents used in the investigation. The results of these investigations, as presented in the reports, were used as reference data for this investigation.

### **1.3 Scope of Services**

A detailed scope of services can be found in the Proposal for In-field Conditions Study, Trout Brook Road/Parkview Estates Area, June, 1990 prepared by Braun Intertec. A summary of the project tasks is listed below:

- Project Administration
- Historical Review and Study Area Reconnaissance
- Well Log Search and Soil/Water Quality Data Base
- Seismic Reflection Geophysical Survey
- Study Area Plan
- Revise Drilling Plan
- Drilling and Soil Sampling
- Water Sampling and Analysis
- Existing Conditions Report (Draft)
- Final Report

## 2.0 Historical Review and Study Area Reconnaissance

The information presented in section 2.0 has previously been sent to the DNR for comment. It is included in this report, along with revisions.

### 2.1 Introduction

**2.1.1 Objectives.** Braun Intertec was authorized by the DNR to perform a Historical Review and Study Area Reconnaissance of the referenced property (*Study area*). The objective of this investigation was to evaluate past and present potential environmental hazards in the *Study area*.

**2.1.2 Scope of Services.** The services provided for this project task consisted of the following:

- a review of selected file information made available by the DNR;
- a review of Wisconsin Geological and Natural History Survey well log files;
- a review of previous land use activities in the *Study area*; and
- a reconnaissance of the *Study area* to visually evaluate present or potential environmental hazards.

This Historical Review and *Study Area* Reconnaissance text was prepared based on the results of these activities.

**2.1.3 Study Area Description.** The *Study area* (including the Trout Brook Road and Parkview Estates area) is located primarily within Section 17 of Township 29 North and Range 19 West, just east of the city of Hudson, St. Croix County, Wisconsin. At the time of this investigation, the *Study area* consisted of land under residential development. Land use in the vicinity of the *Study area*



included residential, agricultural and industrial. A *Study area* Map is attached as Figure 2 and Sheet 1. Also, a Study Area Base Map with ground surface contours is included on Sheet 2.

## 2.2 Land-Use History

Information regarding past and present land use activities at the *Study area* was obtained from:

- the University of Wisconsin Map Library;
- the Wisconsin Geological and Natural History Survey;
- the DNR;
- St. Croix County; and
- the City of Hudson.

Topographic maps and geologic maps were also reviewed for this investigation.

**2.2.1 Fire Insurance Company Atlases.** Braun Intertec contacted city, county, and state offices for information regarding fire insurance atlases for the vicinity of Hudson. Fire insurance atlases were not available for the *Study area* as mapping was discontinued prior to development of the *Study area* and surrounding area.

**2.2.2 Aerial Photographs.** Braun Intertec obtained aerial photographs (dated 1939, 1951, 1965 and 1973) from the University of Wisconsin Map Library. Copies of these aerial photographs are attached in Appendix 1.

The 1939 aerial photograph indicated that the *Study area* contained land used primarily for agricultural purposes. What appeared to be two farmsteads were noted along what is now called Green Mill Lane. The Nor-Lake facility and Duro Bag facility were not yet constructed.

The 1951 aerial photograph indicated that the *Study area* contained land used primarily for agricultural purposes. What appeared to be two farmsteads were noted along what is now called Green Mill Lane (noted in the previous aerial photograph). The Nor-Lake facility and Duro Bag facility were not yet constructed.

The 1965 aerial photograph indicated that the *Study area* contained land used primarily for agricultural purposes. What appeared to be two farmsteads were noted along what is now called Green Mill Lane (noted in the previous aerial photographs). The Nor-Lake facility building was noted southeast of the *Study area* on the northeast corner of the intersection of Highway 12 and County Road A. What appeared to be a commercial or industrial building was noted on the current Duro Bag property.

The 1973 aerial photograph indicated that the *Study area* contained land used primarily for agricultural purposes. What appeared to be two farmsteads were noted along what is now called Green Mill Lane (noted in the previous aerial photographs). The Nor-Lake facility building was noted southeast of the *Study area* on the northeast corner of the intersection of Highway 12 and County Road A. What appeared to be a commercial or industrial building was noted on the current Duro Bag property.

A review of each of the aerial photographs indicated that land use in the vicinity of the *Study area* has progressed from primarily agricultural (1939 aerial photograph) to primarily agricultural and residential (1951, 1965 and 1973 aerial photographs). The only industrial developments noted in the vicinity of the *Study area* were on the Nor-Lake and the Duro Bag facilities.

**2.2.3 Wisconsin Geological and Natural History Survey Information.** Braun Intertec reviewed Wisconsin Geological and Natural History Survey (WGNHS) files for records of water wells in the vicinity of the *Study area*. Well logs are filed by the WGNHS according to Township, Range and Section. Braun Intertec reviewed well logs within Sections 14, 15, 16, 17, 18, 20, 21, 22, and 23 of Township 29N and Range 19W. Approximately 300 well logs for these sections were on file at the WGNHS. Copies of these well logs are attached in Appendix 2. A list of located well logs proceeds the logs. The well logs are arranged according to date of installation and then were numbered by Braun Intertec for identification purposes. We were able to locate approximately 80 of these wells with the information provided in the records. The locations of these wells were plotted on a USGS topographic map of the area, see Figure 3. In addition, the well logs that were given to Braun Intertec by the DNR, but are not official logs, are included in this list.

**2.2.4 State of Wisconsin, Department of Natural Resources Information.** The DNR was contacted by Braun Intertec for information concerning hazardous waste problem sites in the vicinity of the *Study area*.

The DNR made available a list of the spills within St. Croix County (attached in Appendix 3) and a list of the leaking underground storage tanks within St. Croix County (attached in Appendix 4). A review of these lists indicated that no spills or leaking underground storage tanks within a 1 mile radius of the *Study area* have been reported.

The DNR also made available the Wisconsin Environmental Response and Repair Program's "Registry of Waste Disposal Sites in Wisconsin" (St. Croix County excerpt attached in Appendix 5). A review of this registry indicated that the Nor-Lake, Inc. site is listed as a Waste Disposal Site. Braun Intertec reviewed files at the Eau Claire office of the DNR that contained information regarding the Nor-Lake, Inc. site. A review of the DNR files indicated that VOCs have been

detected in groundwater beneath two relatively distinct locations. One VOC plume (including 1,1-Dichloroethane, 1,1-Dichloroethylene, 1,1,1-Trichloroethane and Trichloroethylene) has been observed beneath the Nor-Lake, Inc. property. The other VOC plume (including 1,1,1-Trichloroethane and Trichloroethylene) has been observed near the intersection of Daily Road and Green Mill Lane, located in the *Study area*. Work has been conducted by other environmental consultants since 1984 in order to determine the extent and source of the groundwater contamination in the vicinity of Nor-Lake, Inc.

A Chronology of Events was created for this Historical Review to describe what has taken place since the beginning of these investigations. The Chronology of Events, attached in Appendix 6, is based upon DNR file information.

On July 11, 1984, a previous employee of Nor-Lake, Inc. contacted the DNR to make a complaint concerning previous disposal practices at the facility. According to the informant, 25 barrels of unusable paint, putty sealants and pumpable mastics were dumped into an 8-foot deep trench (20' x 20' in size) located on the property, located east of the original plant building. The materials were described as being "bad" and according to the informant, were dumped in the trench by Nor-Lake to avoid proper disposal costs. The barrels were not sealed according to the informant. Since the trench was created, an addition to the plant has been built over the trench location. A summary letter containing information on the paint is also included in Appendix 6.

A soil boring investigation was performed in the area of the trench through the concrete floor on October 27, 1984. Two soil borings were advanced to nine (9) feet and four soil samples were analyzed for volatile organic compounds (VOCs). There was no visual evidence of soil contamination, however, the soil sample from boring #2, sample 1, 1.6 - 2.0 feet contained trichloroethylene at 4 ug/l. No other VOCs were detected in the soils above method detection limits. A copy of the investigation report is attached in Appendix 7. This report also includes a summary letter of a meeting between the DNR and Nor-Lake, Inc.

As a result of a conference held on November 2, 1984 (present were representatives of Nor-Lake, DNR and Twin City Testing), it was determined that two septic tanks located beneath the Nor-Lake property should be properly abandoned. The septic tanks contained either solutions or sludges containing VOCs. It was also noted that Nor-Lake was in the process of changing its processes to eliminate the use of hazardous substances and hoped to be removed from the "hazardous waste generator" status. It was noted that the Nor-Lake representatives were cooperative and were committed to resolving the issues at hand.

Nor-Lake's investigative efforts consisted of the installation of groundwater monitoring wells and sampling of groundwater monitoring wells and private water wells in the vicinity of the Nor-Lake plant. In the fall of 1984, six groundwater monitoring wells (MW-1 through 6) were installed in the vicinity of the Nor-Lake property. The six wells were sampled along with nine other private wells located in area.

During 1985, two additional groundwater monitoring wells were installed (MW-5-deep, and MW-7). As a result of the sampling of the private wells in the area, it was determined that carbon filter units needed to be installed in five private homes in the vicinity of the Nor-Lake plant.

MW-8 and MW-9 were installed in 1987 and MW-10 was installed in 1988. Each of the monitoring wells were sampled at regular intervals along with private wells in the area in order to determine the extent, movement, and source of the contamination. The locations of the Nor-Lake, Inc. groundwater monitoring wells are depicted in Figure 2.

A groundwater recovery and VOC volatilization system was installed at the Nor-Lake plant in 1985. The recovery system is located adjacent to MW-6, just north of the Nor-Lake plant. The aeration system, located approximately 1,000 feet east of the recovery well, treated approximately 750 gallons of water per minute and ran from April to November of each year, from 1985 until November 1990. There has been intermittent operation of the extraction system for testing purposes.

It was also determined in 1985 that an additional groundwater problem existed west-northwest of the Nor-Lake property near the Parkview Estates. It was determined at that time that at least 13 private wells were contaminated with VOCs, although it was not determined whether or not this contamination was connected with the contamination around the Nor-Lake facility.

Water wells at the Duro Bag property were tested by DNR in 1986. The Duro Bag plant is located southeast of the Trout Brook Road/Parkview Estates area and is the closest industrial site to the *Study area*. VOC contamination was not found in the Duro Bag wells. Also, no VOC contamination was found in private wells located between Duro Bag and the contaminated private wells. A Chronology of Events was developed for this investigation to describe what has taken place at the Duro Bag facility. The Chronology of Events, attached in Appendix 8, is based on DNR file information. According to the Chronology of Events, the Duro Bag facility was cited in 1980 for the illegal dumping of approximately 130 barrels of ink and glue near their facility. A former Duro Bag employee stated that the plant manager of Duro Bag had given the order to dump the material, and continue to do so until they were finished, even if it took [until] midnight (see October 31, 1980 entry in Appendix 8). According to a Duro Bag employee one or two of the inks may have been lead-based. Soil samples taken at the Duro Bag facility indicated elevated levels of lead and chromium.

George Anderson (of the DNR) inspected the spill on November 4, 1980, and the chronology states that the material appeared to have been cleaned up properly. Mr. Anderson also sent a letter to Duro Bag on November 10, 1980 on the inspection, containment, and disposal actions at the plant.

Based on results of groundwater investigations at the *Study area*, at the Nor-Lake property and at a site known locally as the former Junker Landfill (located approximately four miles east of the *Study area*), it was determined that the groundwater flow in the surficial deposits is generally to the west-northwest in the study area. VOC groundwater contamination has been discovered east-northeast of Nor-Lake, Inc. and is believed to be associated with the former Junker Landfill. The landfill has been graded and capped and a passive methane venting system is in place. An active gas extraction system is needed due to high levels of methane (a potentially explosive gas) in the vicinity, and planning is being done for installation this summer. This work is being done using state Environmental Funds under the direction of the Department of Natural Resources staff.

Ayres Associates has conducted groundwater studies on behalf of Nor-Lake, Inc. Computer generated models (contour plots) of the groundwater table and the VOC plumes were created for the Nor-Lake and *Study area*. Copies of these plots, which were made in 1988, are attached in Appendix 9. The data presented in Appendix 9 was interpreted by Ayres Associates to indicate that on September 9, 1988 the groundwater flow direction in the vicinity of the *Study area* was generally to the west-northwest. The plots also were interpreted by Ayres Associates to indicate the presence of two distinct VOC plumes, one centered on the Nor-Lake plant, the other located near Green Mill Lane and Daily Road. The contour plots are an interpretation of data and do not provide conclusive evidence of two separate plumes. The data that was presented could be interpreted/contoured a number of different ways, depending on the assumptions made in interpretation.

With the discovery of the contamination in Trout Brook Road/Parkview Estates area, it was determined by the DNR that additional environmental testing was necessary to determine the extent of the contamination and the responsible party. Nor-Lake was not willing to conduct this additional investigation until it was proven that they were the responsible party. Nor-Lake contended that based upon the information available, no obvious responsible party existed for the plume located near Green Mill Lane and Daily Road. The DNR used the State Environmental Fund to hire Braun Intertec to conduct a limited environmental investigation in the Trout Brook Road/Parkview Estates area.

**2.2.5 St. Croix County Information.** Braun Intertec contacted the Emergency Government Director (a state mandated office operated by the County) for information regarding hazardous material and hazardous waste activity in the vicinity of the *Study area*. According to an Emergency Government official, the only reported hazardous waste activity in the vicinity of the *Study area* is at the Nor-Lake facility. According to the official, the Nor-Lake facility currently produces

approximately five 55-gallon drums per year of hazardous waste. The material is removed from the facility by Safety-Kleen. The official indicated that a complete list of the wastes produced by Nor-Lake was not currently available.

The official indicated that no other records exist of hazardous waste activity in the vicinity of the *Study area*, including the Duro Bag facility. The official, however, did mention that their program currently does not deal in actively investigating potential sites that may produce hazardous materials. Their capabilities only include hazardous waste plan development for those sites which report hazardous waste activity to their office and to the DNR.

Braun Intertec also contacted the St. Croix County Zoning Administration office for information pertaining to the *Study area*. According to a Zoning Administration official, the *Study area* was used for agricultural purposes prior to development. The official mentioned that he was not aware of spills, leaks or dumping of potentially hazardous materials in the *Study area*. The official, however, did mention that during a walk-through of the *Study area* (conducted in the early 1980's) that a moderate amount of abandoned farm machinery was located in the ravine on the northwest corner of Daily Road and Green Mill Lane. It was determined at that time that the presence of the machinery had prevented the further erosion of the ravine. The official did not see indications of spills or dumping of hazardous appearing materials. The official, however, did state that the purpose of the walk-through was not to collect information regarding dumping in the *Study area*, and therefore it is possible that indications of dumping may have been overlooked.

**2.2.6 City of Hudson Information.** Braun Intertec contacted the City of Hudson City Planner for information pertaining to the *Study area*. The City Planner was not aware of underground or aboveground storage tanks, leaks or spills of chemicals and/or petroleum, landfilling, or other potential environmental hazards in the *Study area*. The City Planner, however, was aware of groundwater contamination in the vicinity of the *Study area* and understood that an investigation was being conducted by the DNR to determine the cause of the contamination.

Braun Intertec also contacted the City of Hudson Public Works office for similar information. A Public Works official indicated that he was aware of the contamination associated with both the *Study area* and the Nor-Lake facility. The official also mentioned that the Duro Bag facility was previously cited for the illegal dumping of potentially hazardous materials. The official, however, had no record of this event and did not know from whom such a record could be obtained.

**2.2.7 Hudson Township Information.** Braun Intertec contacted the Clerk of Hudson Township for information pertaining to the *Study area*. The Clerk indicated that she was not aware of spills or dumping of hazardous materials in the *Study area*. The Clerk indicated that she knew of three

potential sources of groundwater contamination: the Nor-Lake plant, the Duro Bag plant and the former Junker Landfill. The Clerk was aware of some of the activities we have described, but did not provide any new information.

### 2.3 Study Area Reconnaissance

*Study area* reconnaissances were conducted by an environmental geologist on November 2, 6, and 28, 1990. At the time of the reconnaissances, the *Study area* and vicinity contained land used for residential, agricultural and industrial purposes. Reconnaissance photographs are attached in Appendix 10. It should be noted that the reconnaissance area was snow-covered during the last reconnaissance.

The Nor-Lake, Inc. plant was observed to be located near the intersection of Highway 12 and County Road A (Photograph #1). A recovery well and an aeration system were noted just north of the Nor-Lake building (Photographs #2 and #3). Numerous groundwater monitoring wells were noted in the vicinity of the Nor-Lake plant (Photograph #4). No signs of leaks, spills or dumping of hazardous appearing materials were noted near the Nor-Lake building. However, the Nor-Lake lot was used for the storage of drums (contents unknown) and the storage of pallets and crates (Photographs #5 and #6).

Residential homes, surrounded by land used for agricultural purposes, were noted to the west of the Nor-Lake property toward the Duro Bag plant. The Duro Bag plant was observed on the northwestern corner of County Road A and Daily Road (Photograph #7). No signs of leaks, spills or dumping of hazardous appearing materials were noted near the Duro Bag plant. An electrical power station was noted just east of the Duro Bag plant (Photograph #8). A small pond was noted just east of Daily Road (Photograph #9). No signs of stressed vegetation were noted.

Land use north of the Duro Bag plant, toward the Trout Brook Road/Parkview Estates was primarily agricultural (Photograph #10).

Newly built residential homes were noted throughout the vicinity of Green Mill Lane and the Parkview Estates (Photograph #11). A large, primarily grass-covered ravine was noted northwest of the corner of Green Mill Lane and Daily Road (Photograph #12). As presented in the Nor-Lake, Inc. 1988 data, this was interpreted as the eastern point of the VOC plume associated with the *Study area*. No signs of stressed vegetation or soil staining were noted in the ravine. A water well was observed at each home in this housing development.

Land use along McCutcheon Road, northeast of the Parkview Estates, was noted to be residential and agricultural. According to maps of the area, a railroad bed was formerly located between

McCutcheon Road and County Road A, trending northeast-southwest. The railroad bed may be a potential source of contaminants; however, based on the historical information obtained as part of this study, there are no indications that the railroad is a source of the plume.

The former Junker Landfill was observed on the eastern side of Alexander Road between McCutcheon Road and Highway 12 (Photographs #13 and #14). The landfill is no longer in operation and is grass-covered. Methane vents were noted on the landfill.

## **2.4 PETREX Study**

The following is a summary of the PETREX report performed for the Wisconsin Department of Natural Resources by Northeast Research Institute, Inc. (NERI). A copy of the report is included in Appendix 11.

The Wisconsin Department of Natural Resources contracted with NERI for a PETREX study to identify near surface sources of contamination. The objective of the survey was to characterize the gases and vapors emanating from near surface contaminants in the study area and to assess the possible sources of the contamination.

Six (6) sections were identified in the study area for installation of PETREX survey equipment. The locations of these sections are shown on Figure 4. In summary, the survey detected trichloroethylene, trichloroethane, tetrachloroethylene, benzene, toluene, ethyl benzene, and xylenes in laboratory analysis.

The highest response for trichloroethylene and trichloroethane was found in section 6, near the Nor-Lake, Inc. plant. A trichloroethylene response was also detected in section 5. Trichloroethane responses above background threshold levels were detected in sections 1, 3, 4, and 5. Responses for trichloroethane of 205-295 ion counts, below the threshold value of 300, was seen in section 2.

Tetrachloroethylene response above threshold values was seen in sections 1, 3, 4, 5, and 6, but this compound was not detected by previous quantitative investigations. It was pointed out in the report that the PETREX soil gas method is extremely sensitive to tetrachloroethylene.

NERI interpreted the above results as possibly indicating an origin of chlorinated compound from Nor-Lake, Inc.; however it was noted that other sources may exist.

The detection of the aromatic compounds (benzene, toluene, ethyl benzene, and xylenes) were noted in sections 2, 3, 4, and 5, with the highest response in section 3. A positive identification of the aromatic compounds was not possible due to interference with terpene. The interpretation was made



that additional potential source areas (other than Nor-Lake, Inc.) may exist for these compounds. Further study would be necessary to determine if there are other potential source areas.

## 2.5 Conclusions

Based upon the data collected during the Historical Review, it is our opinion there are four possible explanations or potential sources for the VOC groundwater contamination beneath the *Study area*.

- migration of the Nor-Lake VOC contamination;
- migration of VOC contamination from the former Junker Landfill;
- an as-yet unidentified source at the *Study area* which is not associated with the above potential sources; or
- a combination of the above.

The first two possible explanations follow naturally from the material reviewed for and described in this report. The third explanation stems from the nature of the plume discovered in the *Study area*. Nor-Lake, Inc. consultants have interpreted the results of water well sampling in the vicinity to mean that the Nor-Lake, Inc. plume is a physically separate plume from the plume in the Trout Brook Road/Parkview Estates area. There are other plausible explanations for what has been identified as two distinct plumes. Releases of varying amounts of contaminants over time rather than a constant source could appear as two plumes. Changes in the hydraulics due to variable geologic settings of the area can also change the concentration of contaminants in groundwater, again appearing as two plumes. It should be noted that no evidence was obtained thus far in this investigation which would indicate another source.

These conclusions are based on available *Study area* history information and *Study area* reconnaissance efforts conducted for this project. Soil borings and/or the installation of groundwater monitoring wells and the laboratory analysis of soil and/or groundwater samples were not part of this project phase.

## 3.0 Field Investigation Methods and Procedures

### 3.1 Drilling and Sampling Point Installation

During the field work, the groundwater monitoring wells were coded with letters. The wells have since been assigned numbers for data retrieval purposes. The table below provides a cross reference for data that may contain wells referenced by letters.

Table 1 - Names of Monitoring Wells

Well Number	Well Letter
MW-50S	MW-A
MW-50D	MW-AD
MW-51	MW-B
MW-52	MW-C
MW-53	MW-D
MW-54	MW-E
MW-55S	MW-F
MW-55D	MW-FD
MW-56	MW-G
MW-57S	MW-H
MW-57D	MW-HD

**3.1.1 Revised Drilling Work Plan.** As specified in the Proposal for In-field Conditions Study, Trout Brook Road/Parkview Estates Area, a drilling work plan was finalized and copies distributed prior to the start of drilling operations. The DNR and Braun Intertec met prior to finalization of the document in order to include any necessary revisions. This document is included in the list of references, and it is titled Drilling Work Plan, May 1, 1991.

**3.1.2 Drilling Methods and Soil Classification.**

**3.1.2.1 Rota-Sonic Drilling.** During the Trout Brook/Parkview Estates VOC Investigation, 11 geologic borings were performed using the Rota-Sonic drilling method. Water table observation wells and piezometers were installed in the soil borings. The monitoring network at the study area consists of seven water table observation wells (MW-50S, MW-51, MW-52, MW-53, MW-55S, MW-56, and MW-57S) and four piezometers (MW-50D, MW-54, MW-55D, and MW-57D). Monitoring well nests consisting of one water table observation well and one piezometer were installed at Locations 50, 54, 55, and 57. MW-54 is a nest piezometer with MW-10, which was installed by Nor-Lake, Inc. The location of the borings/wells can be found on the Study Area Map, Figure 2.

North Star Drilling, Inc was hired by Braun Intertec Environmental, Inc. to perform 11 geologic borings using the Rota-Sonic drilling method. The truck-mounted Rota-Sonic drill rig utilizes an oscillator-type drill head consisting of two unbalanced counter rotating rollers or oscillators which impart a vibrating response upon the drill pipe. The rollers are synchronized to allow the vertical components of the vibrating forces to be directed directly along the drill pipe and outer casing. As a result, the entire length of the drill rod and outer casing becomes a penetrating tool with the resonant effect becoming greatly magnified at the leading edges. The drill pipe and/or outer casing are isolated from the oscillator housing by compressed air driven pistons which form an air spring which ensures that the maximum vibratory forces generated are transferred downward through the drill pipe and/or outer casing. In addition, the drill head uses rotational drive that effects contact of solid material with the drill bits on the sample barrel and outer casing to maintain continuous penetration through unconsolidated and bedrock formations. A variance was granted to North Star Drilling, Inc. to use this drilling method.

Due to the difficulty of advancing the 6-inch diameter steel casing employed by the Rota-Sonic drilling method, drilling fluid was used to advance the boreholes. After receiving permission from the DNR Project Manager, pure bentonite, polymer-free powder was prepared with water obtained from the City of Hudson Water Department to create drilling fluid. Barroid Quick Gel was used on water table observation well MW-52 and for a portion of the drilling at MW-53. The drilling fluid was used only to advance the 6-inch diameter outer casing to the desired borehole depth. Depending upon the density of the soils above the static water table, drilling fluid was not introduced into the borehole anywhere from 10 to 20 feet above the static water table. This practice was necessary in order to keep the bentonite drilling fluid from altering the natural groundwater quality and to allow groundwater to more easily enter the borehole after reaching the static water table. Please refer to the Log of Boring sheets and Soil Boring Log Information, Form 4400-122 in Appendix 12 to determine the depths which drilling fluid was used to advance each borehole.

Barrels (55 gallon) were used to transport the sand/drilling fluid mixture from wells MW-55S and MW-55D to a designated land-spreading area approved and arranged by the DNR Project Manager. The initial spreading study area was near wells MW-50S and MW-50D. The material from the redrilling of MW-55S (see section 3.2.1.3.) was barreled and was to be spread in the field directly east of the well location. The snow and cold weather that occurred did not allow for this material to be spread. It is currently stored in 13 barrels on the Nor-Lake, Inc. facility. The drilling fluid from the other wells was not contaminated and was wasted in the area immediately adjacent to the respective wells. The methods used to test the investigative wastes are included in Appendix 13.

**3.1.2.2**      *Air/Mud rotary.* The piezometer and water table observation wells at location MW-50S and MW-50D differed in their method of drilling, since both the piezometer and water table observation wells were completed through the overlying glacial sediments and into the underlying bedrock. The boreholes were advanced to the desired casing depth by a 10-inch diameter tri-cone roller bit and mud rotary drilling methods. The 6-inch diameter casings were installed to 33.5 feet and 30 feet and approximately 2.5 feet above grade at MW-50S and MW-50D, respectively. The steel casings terminated above the regional water table and were tremie-grouted into position at each location. MW-50D was originally sampled with Rota-Sonic drilling methods, using a drill rod and sample barrel to 120 feet. The 6 inch I.D. outer casing remained at approximately 40 feet due to the hardness of the rock and excessive wear on the bit of the outer casing and was not able to be advanced to the termination depth of the boring. Mud rotary methods were used to set the casing at 33.5 feet, and was continued with air rotary through the casing to the termination depth of the boring.

Upon completion of the installation of the 6-inch diameter steel casings at MW-50S and MW-50D, the casings remained undisturbed for at least 48 hours, in order to allow the neat cement grout to harden and secure the steel casings. The remaining portion of each borehole was advanced to the desired depth through the steel casings by air rotary drilling methods. Prior to piezometer and water table observation well installation, the pulverized rock and sediment was flushed from the borehole with water. The water table observation well construction materials consisted of the same materials used to construct the piezometers and water table observation wells in the unconsolidated glacial sediments located across the remaining portion of the study area. The PVC well casing material was installed to the level of the steel casing above the ground surface and a sliding, bolted, steel, locking cover was placed over the top of the exposed steel casing.

**3.1.2.3**      *Abandonment.* During the initial well development for MW-55S, groundwater levels were found to be below the bottom of the well screen. Groundwater had been in the well, prior to development activities. After receiving permission by the DNR Project Manager, the well was abandoned according to Chapter NR141.25 of the Wisconsin Administrative Code. The monitoring well abandonment was completed during the installation of the replacement water table observation well (MW-55S) by North Star Drilling, Inc. Documentation of the abandonment of the initial well MW-55S can be found on form 3300-5B (Well/Drill hole Abandonment) in Appendix 14.

Similarly, the initial 85 foot borehole located adjacent to MW-56 near Duro Bag was also abandoned according to Chapter NR141.25. While advancing the 6-inch diameter steel casing during drilling at the initial borehole location, the steel casing became locked in the ground,

and the Rota-Sonic Drill Rig was not able to remove it. Later, a larger diameter casing was advanced over the 6-inch diameter casing, freeing the locked casing. Neat cement grout was then tremie pumped into the annulus of the borehole and the 6-inch diameter steel casing removed. After completion of borehole abandonment at this location, DNR form 3300-5B was completed. This complete form can also be found in Appendix 14.

**3.1.3 Field Testing and Sampling.** Bedrock and unconsolidated soil samples were obtained by advancing a ten-foot long sample barrel attached to four-inch diameter drill rod. The sample barrel and drill rod were advanced ahead of 6-inch diameter outer casing into the unconsolidated and bedrock formations. Once the six-inch outer casing was advanced to the desired depth, the sample barrel was removed from the borehole and extruded into a five-foot long clear plastic bag placed over the sample barrel. Immediately, the unconsolidated soil or bedrock sample was extruded into the clear plastic bag by utilizing the vibratory forces of the drill head. Once the sample was extruded, the field geologist tied the top of the sample bag and placed it out upon the ground in stratigraphic sequence for logging and scanning. Once all of the sample bags were retrieved from the sample interval, the field geologist pierced the sample bag with a knife and slowly cut the sample bag open from top to bottom while scanning and exposing the soils to the intake probe of a Flame Ionization Detector (FID). Soil samples were then collected for logging purposes from unconsolidated soils with field readings above background levels and/or the major soil units from the sample interval. These soils samples were retained in labeled, clear jars with screw lids and covered with aluminum foil to perform Jar Headspace Analyses, and were retained by Braun Intertec for further examination. The Jar Headspace Analyses were performed according to guidelines provided by the DNR as referenced in the document "Field Instrument Techniques."

All soil samples collected from the geologic boreholes across the study area will be retained for the DNR at the Braun Intertec Mendota Heights office for approximately 60 days after final project payment. The soil samples will then be turned over to the DNR. All of the soils encountered while performing the geologic boreholes were visually and manually classified in the field by the field geologist according to ASTM D 2487 "Unified Soils Classification System" and ASTM D 2488 "Recommended Practice for Visual and Manual Description of Soils."

In addition, soil samples for lithologic classification were collected from selected locations for geotechnical analysis. The Drilling Work Plan allowed for the collection of both lithologic samples and geotechnical samples for soil permeability, but during the field investigation, attempts to retrieve undisturbed Shelby Tube samples from dense unconsolidated materials directly above the water table were not successful. As a result, the soil undisturbed vertical permeability analyses were not performed. The geotechnical laboratory results can be found in Appendix 15. These soils were also classified according to ASTM D 2487 "Unified Soils Classification System".

FID analyses of the soils samples are presented in Appendix 16. The samples were checked by initial screening of the sample bag and then by Jar Headspace procedures.

Lastly, soil samples were collected for chemical analysis when field readings and Jar Headspace readings were elevated above background levels. Upon the request of the DNR Project Manager, two soil samples from Location MW-55D, 235 to 240 feet and 307 to 312 feet, were analyzed for VOCs by MN 466A (which is similar to EPA Method 601 but has more analytes). The revised laboratory report documenting the results of these chemical analyses is in Appendix 17. The original report that was issued, incorrectly listed the sample matrix as a liquid.

**3.1.4 Water Table Observation Well and Piezometer Construction.** All water table observation wells and piezometers within the study area were constructed according to Wisconsin Administrative Code, Chapter NR 141. Water table observation well casing material consisted of a ten-foot long, flush-threaded, two-inch I.D., schedule 80, polyvinyl chloride (PVC) well casing manufactured by Johnson Filtration Systems. The depth of the piezometers was determined by offset from the water table observation well depth as proposed in the Proposal for In-Field Conditions Study, Braun Intertec, June, 1990. During well installation, the plastic wrapping covering each casing and well screen section was perforated, removed and the casing and screen inspected.

The water table observation well screen material consisted of a 15-foot long, flush-threaded, 2-inch I.D., continuous 10 slot, PVC well screen and PVC well plug. The piezometer well screens were of the same material but only five (5) feet in length. The well screen was permanently joined to the PVC well casing by threading both ends together until a seal was formed. The piezometer well screens consisted of the same materials except that a five-foot long well screen was used. During well installation, the PVC casing and well screen were centered in the borehole by a stainless steel well centralizer placed approximately seven feet above the base of the well screen.

The well screen was then placed upon at least six inches of filter pack material (medium-grained silica sand) at the base of the borehole. The filter pack material was introduced as a sand/water mixture into the borehole through a tremie pipe and allowed to settle to the bottom of the borehole and around the well screen and base of the riser pipe. The filter pack material was brought to a level of two feet above the top of the well screen. Directly above the filter pack material two feet of fine-grained silica sand was added as the filter pack seal. A three-foot thick bentonite seal consisting of 3/8-inch bentonite pellets poured into the borehole was allowed to settle above the filter pack seal, as described in the work plan. Lastly, neat cement grout was pumped into the annulus of the borehole through a tremie pipe placed directly above the bentonite seal. The borehole annulus was filled to the surface as the neat cement grout flushed any remaining groundwater from the borehole annulus. Finally, the neat cement grout was allowed to settle and its level topped off to the appropriate height. The grout

was allowed to settle for at least 12 hours before installation of the concrete surface seal and steel protective casing.

At least twelve hours after completion of the grouting procedure a four-inch diameter five-foot long steel protective casing with locking cap was placed over the exposed PVC well casing and the annulus around the pipe filled with concrete as a surface seal. At ground level the concrete surface seal was mounded up and around the protective pipe in order to facilitate drainage away from the well. Each water table observation well received three, four-inch diameter, five-foot long steel protective posts for additional protection. At nested well locations, two steel protective posts were placed around both the water table observation well and piezometer.

Upon completion of the seven water table observation wells and piezometers, the State of Wisconsin, Department of Natural Resources Form 4400-122 "Soil Boring Log Information Form" and Form 4400-113A "Monitoring Well Construction Form" were completed. These forms document the soils encountered and the final construction schematic for each water table observation well and piezometer installed during the investigation. This information can be found in Appendix 12 and 18. The Log of Boring sheets are also found in Appendix 12.

**3.1.5 Well Development.** In order to obtain representative groundwater unaffected by drilling, North Star Drilling, Inc. surged, bailed, and pumped each water table observation well and piezometer. Well development was not performed until at least 24 hours after completion of each well. The total amount of water removed from each well was determined by using the following calculation presented in Section NR 141.21 of the Wisconsin Administrative Code.

$$\begin{aligned} V_1 &= \text{volume of water in well casing} = \pi(D_1/2)^2 \times H_1 \\ V_2 &= \text{volume of water in filter pack} = N\pi H_2[(D_3/2)^2 - (D_2/2)^2] \\ V_1 + V_2 &= \text{well volume} \end{aligned}$$

where

$$\begin{aligned} N &= \text{porosity of filter pack} \\ D_1 &= \text{inside diameter of well casing} \\ D_2 &= \text{outside diameter of well casing} \\ D_3 &= \text{diameter of the borehole} \\ H_1 &= \text{height of water column} \\ H_2 &= \text{length of filter pack height or height of the water column in water table observation wells} \end{aligned}$$

The table below details the development calculations.

Table 2 - Well Development Calculations

$D_1 = 0.17, D_2 = 0.20, D_3 = 0.52$													
WELL	DEPTH TO GROUND WATER (FT)	WELL DEPTH (FT)	WATER COLUMN, $H_1$ (FT)	SCREEN LENGTH (FT)	$H_2$ (FT)	SAND- PACK (FT)	$V_1$ (FT <sup>3</sup> )	$V_2$ (FT <sup>3</sup> )	WELL VOL. (FT <sup>3</sup> )	WELL VOL. (GAL)	10 WELL VOL. (GAL)	ACTUAL REMOVED VOLUME (GAL)	COMMENTS
MW-50S	55.96	65.00	9.04	15.00	9.04	21.00	0.20	0.49	0.69	5.17	51.75	52.50	
MW-50D	78.71	120.85	42.14	5.00	11.00	11.00	0.92	0.60	1.52	11.38	113.80	179.00	
MW-51	179.05	193.30	14.25	15.00	14.25	21.00	0.31	0.78	1.09	8.16	81.57	113.00	
MW-52	71.75	81.60	9.85	15.00	9.85	24.00	0.21	0.54	0.75	5.64	56.38	60.00	
MW-53	130.42	140.40	9.98	15.00	9.98	23.00	0.22	0.55	0.76	5.71	57.13	64.60	
MW-54	172.65	237.60	64.95	5.00	8.00	8.00	1.42	0.44	1.85	13.88	138.76	148.00	
MW-55S	188.00	204.00	16.00	15.00	16.00	24.00	0.35	0.87	1.22	9.16	91.59	95.00	
MW-55D	191.93	262.20	70.27	5.00	8.50	8.50	1.53	0.46	2.00	14.95	149.49	90.00	SLOW RECOVERY
MW-56	168.40	174.50	6.10	15.00	6.10	20.50	0.13	0.33	0.47	3.49	34.92	58.00	
MW-57S	34.02	43.00	8.98	15.00	8.98	19.00	0.20	0.49	0.69	5.14	51.40	100.00	
MW-57D	35.18	82.65	47.47	5.00	12.00	12.00	1.04	0.66	1.69	12.66	126.59	357.00	

The table above lists the final volume of water removed from each well. Wells MW-50D, MW-51, MW-52, MW-53, MW-55D, MW-56, MW-57S, and MW-57D were developed a second time to remove the necessary volume of water and to remove any remaining drilling fluid.

Upon arriving at the water table observation well or piezometer to be developed, the well was unlocked and an initial depth to groundwater and well depth were taken with an electronic water level indicator and referenced to the top of the PVC well casing. Well development began by inserting a 3-foot long, stainless steel bailer into the well and bailing and surging the well until sediment free water was obtained. Prior to this portion of well development, the 3-foot long stainless steel bailer was cleaned with a non-phosphate detergent, rinsed with tap water, steam cleaned, and rinsed with deionized water. The same cleaning process was used before the 3-foot long stainless steel bailer was lowered into the next well for development. Well development was completed by pumping additional well volumes from the well and performing a well stabilization test. This portion of the well development process involved installing either a Grundfos Redi-Flo 2-inch diameter submersible pump



or AccuWell 2-inch diameter bladder pump to remove the remaining well volumes. After the groundwater volumes were removed from the well, pH, temperature, and specific conductance were taken until three consecutive readings were obtained, the total calculated well volume had been removed from the well (with the exception of well MW-55D), and sediment free water obtained. The range of pH, temperature and specific conductance readings specified in the proposal were as follows:

specific conductance	±	5% of the reading range
pH	±	0.1 pH units
temperature	±	0.5 degrees C

The pH, temperature, and conductivity readings taken during well development were within the specified tolerance range.

The equipment used to obtain the pH, temperature and specific conductance readings during the stabilization tests included a Hach One pH and temperature meter and a Hach digital conductivity and TDS meter (Model No. 44600). Both meters were calibrated daily with buffer solutions prior to the first well stabilization test. The monitoring well development forms (4400-113B) can be found in Appendix 18, and the results of the stabilization tests taken during well development by North Star Drilling can be found in Appendix 19.

**3.1.6 Slug Tests.** Single well response (i.e., slug) tests were performed on all piezometers and water table observation wells installed in this investigation. The test procedure consisted of inserting a solid PVC cylinder into the well, instantaneously raising the water level. As groundwater recovered to its static level (falling head), successive water levels were recorded on a data acquisition system (Hermit SE1000B). Following recovery to static level, the cylinder was subsequently removed, effectively lowering the water level within the well. Again, successive groundwater measurements were recorded as groundwater returned to static level (rising head).

Slug tests were analyzed by the Bouwer and Rice method detailed in "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers With Completely or Partially Penetrating Well" (Bouwer and Rice, 1976) and "The Bouwer and Rice Slug Test - An Update" (Bouwer, 1989). The Bouwer and Rice method is applicable to completely or partially penetrating wells in unconfined aquifers for a wide range of geometry conditions. In some cases, the method is also applicable for confined aquifers. The method is based on the Thiem equation of steady state flow into a well. The rising head slug test data is used in calculating the hydraulic conductivity of the aquifer materials in the near-well environment. The falling head test data may not be appropriate for determining the hydraulic conductivity of some geometry conditions but were used for this project as a check of the rising head data.

### **3.2 Sampling Investigation**

**3.2.1 Sampling Procedures.** Groundwater elevation measurements were taken prior to and immediately after completion of the stabilization test performed at each water table observation well and piezometer. During the first groundwater sampling event, the water table observation wells and piezometers were sampled from an anticipated upgradient to downgradient direction until a sampling sequence based upon actual groundwater quality from across the study area could be established. Two groundwater sampling events for VOC analyses were performed, one in September and one in October of 1991.

In addition to the groundwater samples collected from each of the water table observation wells and piezometers during the first and second groundwater sampling events, duplicate groundwater samples were collected during both sampling events from designated monitoring points in order to check sample collection procedures and chemical analytical results. Field blanks, consisting of laboratory grade deionized water rinsed through a teflon-coated sampling bailer, were performed towards the middle of each sampling day to check laboratory bailer cleaning procedures. Trip blanks, consisting of laboratory grade deionized water poured into three 40 milliliter amber glass sample vials, were collected prior to each sampling day and carried along with the groundwater samples in a refrigerated cooler. Trip blanks were collected in order to check for any external factors which may effect the overall quality of the groundwater samples from the time they were collected until laboratory analysis.

Braun Intertec and Ayres Associates split three groundwater samples collected from Nor-Lake monitoring wells MW-3, MW-8 and MW-10 during the second groundwater sampling event. The location of the monitoring wells and piezometers of the existing Nor-Lake monitoring network and the seven water table observation wells and four piezometers comprising the newly installed monitoring network can be found on Figure 2.

**3.2.2 Water Level Measurements.** Prior to purging groundwater from the water table observation wells and piezometers an initial depth to groundwater was taken with an electric water level indicator. The depth to groundwater and well depth were measured to the nearest 0.01 foot and referenced to the top of the PVC well casing. When water table observation wells and piezometers were greater than 200 feet in depth, a weighted steel tape was used to determine well depth which was measured to the nearest 0.1 foot. The entire portion of the electronic water level indicator and weighted steel tape that came into contact with the groundwater was rinsed with deionized water and wiped free of moisture in order to prevent cross contamination between monitoring points during groundwater elevation measurements.

Water levels have been recalculated from existing data using current top of casing (TOC) elevations. A complete list of groundwater elevations can be found in Appendix 20. This list includes all available water table data.

**3.2.3 Purging and Stabilization.** Additional purging and well stabilization was performed prior to collecting groundwater samples during the first and second rounds of groundwater sampling. Once again, a depth to groundwater and well depth were taken with an electronic water level indicator and referenced to the top of the PVC well casing. This additional purging and well stabilization were necessary to remove stagnant groundwater that collected within the well screen and filter pack between well development and groundwater sampling. Depending upon the depth and recharge rate of the water table observation well or piezometer, the wells were purged by either a 2-foot long teflon-coated bailer, 6-foot long PVC bailer, Johnson-Keck submersible pump, or Bennett Nitrogen-lift pump. When the Johnson-Keck or Bennett Nitrogen-lift pump were used, the pump intake was placed at the top of the static water table and lowered during pumping until the pumping water level stabilized in the well. Occasionally, the pump was lowered to the bottom of the well in order to remove any fine sediment that may have accumulated in the bottom of the well screen.

Immediately after each well volume was purged during the stabilization test two groundwater samples were collected and pH, temperature and specific conductance readings taken. Since the one molar potassium chloride (KCl) solution contained in the pH probe can increase the specific conductance of the groundwater sample two groundwater samples were collected after each well volume. One sample container would receive the pH and temperature probes while the second sample container would receive the dip cell of the specific conductance meter. At least three well volumes were removed from the well during the stabilization tests with the pH, temperature and specific conductance range of readings, again, specified as follows:

- ± 5% of the reading range for specific conductance
- ± 0.1 pH units for pH and;
- ± 0.5 degrees C for temperature.

After three consecutive pH, temperature and specific conductance readings were obtained from within the desired tolerance ranges the 6-foot long PVC bailer, 2-foot long teflon-coated bailer, Johnson-Keck submersible pump, or Bennett Nitrogen-lift pump were removed from the well, and the depth to groundwater was taken. Prior to pumping the next well, the Johnson-Keck or Bennett Nitrogen-lift pump were field cleaned by pouring reagent grade methanol over the pump and then rinsing with deionized water. In addition, two gallons of deionized water were pumped through the pump to remove any groundwater remaining in the pump discharge line.

**3.2.4 In-Field Measurements.** The pH, temperature and specific conductance measurements taken during the stabilization tests were taken as soon as possible after groundwater samples were collected from the bailer or pump used during this purging process. Similarly, the depth to groundwater measurements taken after the stabilization tests were obtained as soon as the bailer or pump were removed from the well. This measurement was performed in order to obtain an elevation at which the groundwater recharge rate equaled the pumping or bailing rate. A tabulation of these measurements is presented in Appendix 21.

**3.2.4.1 Temperature and pH.** Groundwater pH and temperature readings collected during the stabilization tests were made with a Beckman phi series processing unit which utilizes a pH probe and Automatic Temperature Compensating (ATC) probe to determine pH and temperature. Each day, the Beckman pH processing unit was calibrated to pH 4 and pH 10 buffer solutions in order to standardize the processing unit. After each measurement, the pH and temperature probes were rinsed with deionized water and then placed into a container of deionized water until the next groundwater sample was taken.

**3.2.4.2 Specific Conductance.** Specific Conductance measurements were obtained using a Salinity-Conductivity-Temperature (S-C-T) meter manufactured by Yellow Springs Instrument Company, Inc. (YSI Model No. 33). Prior to taking the initial specific conductance reading, the meter was calibrated to the 370 micromho "Red Line" position, and the groundwater temperature dial adjusted. Later, the groundwater temperature dial was readjusted when temperature changes occurred during the stabilization test. In order to prevent the next readings from being influenced by the previous groundwater sample, the dip cell of the S-C-T meter was rinsed with deionized water after each groundwater measurement and then immersed in a container of deionized water. Since specific conductance is temperature dependent, the recorded field value was later corrected to a standard conductance at 25 degrees Celsius by the following formula:

$$\begin{aligned}
 C_f &= 1/[1 + 0.02 \times (T_s - 25^\circ\text{C})] \\
 SC_{25} &= SCT_s \times C_f \\
 T_s &= \text{temperature of sample } (^\circ\text{C}) \\
 C_f &= \text{correction factor} \\
 SCT_s &= \text{specific conductance at sample temperatures} \\
 SC_{25} &= \text{specific conductance at } 25^\circ\text{C}
 \end{aligned}$$

The table below lists the readings that were outside of the stabilization tolerance range.

Table 3 - Well Sampling - Fluctuations in Readings  
 (values in bold are outside of the acceptable range)

Well	Specific Conductance - Range of Last 3 Values (+/-5% of range)	Field Temperature - Range of Last 3 Values (+/-0.5)	pH - Range of Last 3 Values (+/-0.1)
MW-50S 9/16/91	493.05-544.95	0.60	<b>0.24</b>
MW-52 9/16/91	346.75-383.25	0.20	<b>0.66</b>
MW-54 10/15/91	<b>286.9 - 317.1</b>	0.40	0.20

Upon evaluating the field data, our records indicate that samples were collected from wells MW-50S (9/16/91), MW-52 (9/16/91), and MW-53 (10/15/91) prior to stabilization. Of these wells, MW-50S and MW-52 had significant well volumes (9 and 18 volumes, respectively) purged prior to sampling without the wells stabilizing. Removal of these well volumes should be adequate to assure representative samples of the groundwater, although the data does not indicate a stabilized condition.

Our record indicated that these wells were developed twice prior to the sampling events. Conductivity and pH readings between the September and October sampling events for these wells have significant differences and lead us to believe that the monitoring well installation procedures were still affecting the aquifer at the time of sampling. The table below lists the differences in the specific conductance and pH readings for the two sampling events.

Table 4 - Variation In Specific Conductance and pH

Well	Date	Specific Conductance	pH
MW-50S	9/16/91	504-526	7.25-7.61
	10/14/91	307-328	7.54-7.65
MW-52	9/16/91	314-366	6.47-7.81
	10/14/91	243-257	7.39-8.06
MW-54	9/18/91	446-459	6.69-6.83
	10/15/91	281-320	7.86-8.06

Well MW-54 only had 3 volumes of water removed prior to sampling, and under normal circumstances, the stabilization test should have been extended until the well had reached a stabilized condition; however, this well has a bow in the pipe that restricted the use of our pumps. We were able to purge the well by removing water with a bailer. This task was difficult due to the fact that the water level for this well was approximately 175 feet below ground surface. A decision was made to sample the well upon removal of three volumes of water.

**3.2.5 Groundwater Sampling.** After completion of the stabilization test at each water table observation well and piezometer in the study area, groundwater samples were collected with a dedicated, 2-foot long, teflon-coated, laboratory cleaned bailer manufactured by Fluoroware, Inc. All sample bailers were cleaned with non-phosphate detergent, rinsed three times with deionized water, and allowed to air dry at the Braun Intertec Laboratory in Eden Prairie, Minnesota. After the sample bailers were allowed to air dry, they were wrapped in aluminum foil for further protection during transport.

Groundwater samples were obtained by gently lowering the sample bailer into the well by a 3/16-inch polypropylene rope until groundwater was encountered in the well. Next, the bailer was gently lowered into the top of the water column and the bailer and sample was retrieved from the well while making sure not to agitate the bailer and sample during removal. Immediately upon removing the sample bailer from the well, the groundwater sample was slowly decanted into six 40 milliliter amber glass vials until no headspace remained in the containers. The 40 milliliter vials contained a dilute concentration of hydrochloric acid (HCl) as a preservative. Once all of the sample containers were filled, the vials were labeled according to sample time and location and placed into a foam carrying container within an ice-filled cooler.

Table 5 lists the time from development until the initial sampling of each well.

Table 5 - Time From Well Development Until Sampling

WELL	LAST DEVELOPMENT DATE	FIRST SAMPLING DATE	ELAPSED TIME (DAYS)
MW-50S	08/15/91	09/16/91	32
MW-50D	09/03/91	09/16/91	13
MW-51	09/04/91	09/17/91	13

WELL	LAST DEVELOPMENT DATE	FIRST SAMPLING DATE	ELAPSED TIME (DAYS)
MW-52	09/05/91	09/16/91	11
MW-53	09/05/91	09/16/91	11
MW-54	08/08/91	09/18/91	41
MW-55S	10/08/91	10/16/91	8
MW-55D	09/06/91	09/19/91	13
MW-56	09/06/91	09/17/91	11
MW-57S	09/04/91	09/18/91	14
MW-57D	09/04/91	09/18/91	14

**3.2.6 Quality Assurance/ Quality Control.** Several types of QA/QC samples were collected in the field in order to identify errors in analytical procedure. These samples include trip blanks, field blanks, blind duplicates and split groundwater samples.

Trip blanks consisting of three 40 milliliter amber glass vials filled with laboratory grade deionized water were obtained prior to each sampling event. The trip blank samples were placed into the sample cooler and remained with the groundwater samples until laboratory analysis. The trip blanks were carried with the groundwater samples at all times throughout the sampling period in order to check for the possibility of contamination from all environmental sources to which both samples were exposed.

Field blanks consisting of laboratory grade deionized water were rinsed through a teflon-coated sample bailer into three 40 milliliter amber glass vials. These samples make it possible to check the effect, if any, that the teflon-coated sample bailers had upon groundwater quality.

Blind duplicate samples were collected at predetermined monitoring points in order to check the sampling method and the precision of the laboratory analytical equipment.

Groundwater samples were split to evaluate analytical accuracy at two separate laboratories. During the second groundwater sampling event, groundwater samples were split at MW-3, MW-8 and MW-

10 of the Nor-Lake, Inc. monitoring network. Also at this time, Braun Intertec collected groundwater samples from the eleven monitoring points in the study area and Ayres Associates collected groundwater samples from the existing Nor-Lake groundwater monitoring network. The split groundwater samples collected by Braun Intertec were submitted to the Braun Intertec Laboratory in Eden Prairie, Minnesota and the samples collected by Ayres Associates were submitted to the Twin City Testing Laboratory in St. Paul, Minnesota.

## **4.0 Data bases**

In order to more readily access the analytic and geologic data available in the area, two data bases have been created for this investigation. There is a soil/well log data base and an analytic data base. The data has been entered into the data base program Paradox, version 3.5.

### **4.1 Soil/Well Log Data Base**

The geologic data base has the following format and contains information on the well logs in the study area. The fields are as follows: well number, owner, county/town, township, range, section, lot, coordinates (X, Y, Z), ground surface elevation, water level, approximate water table, unconsolidated material thickness, unit 1 thickness, unit 2 thickness, total depth, date of installation, and notes.

There are approximately 300 records contained in this data base. A hard copy of the information is included in Appendix 22.

### **4.2 Soil/Water Quality Data Base**

Data entered into the soil/water quality data base contains information from laboratory reports. The analytical data base has the following format:

Id number  
Well  
Date  
Units  
Lt  
Value  
Check



The analytical data base is connected to the PARAMS data base through the field CODE/PARAMO. The PARAMS data base was provided by the DNR. The code is representative of the groundwater monitoring parameter codes. This allows for access to the compound names and enforcement and prevention limits. There are over 21,000 records contained in this data base. The information is presented in Appendix 23.

#### **4.3 Submission to DNR**

The information comprising the data bases will be submitted upon final review of the document, according to the format specified by the DNR. The format is specified in the document "Groundwater Quality Monitoring Data Instructions." As listed above, hard copies of the data can be found in Appendices 22 and 23 for the geologic and analytic data bases, respectively.

### **5.0 Seismic work**

The information presented in this section summarizes the report presented by Geosphere Midwest, attached as Appendix 24.

#### **5.1 Introduction**

A geophysical survey consisting of four seismic reflection profiles was performed by Geosphere Midwest in the study area. The locations of the lines are shown in Figure 5.

The purpose of the geophysical investigation was to gain an understanding of the bedrock configuration, prior to performing the soil boring program. A fault was suspected to pass through the study area based on available well logs.

When interpreting the seismic reflection, available data from water wells, monitoring wells, and soil borings was used to convert the travel time to an actual depth. The final report was delayed until the information from the current drilling program could be included in the interpretation to help bracket the results of the investigation.

#### **5.2 Refraction data**

There are three distinct groups of refraction velocity data found in the survey area. These data were combined with the logs, and a velocity model for the study area was created. This is information that was obtained from a report generated for the study area by Bison Instruments in 1986.

Table 6 - Study Area Velocity Model

Depth	Velocity (ft/sec)
0 to 30'	1200
30' to water table	2000
water table to lower unconsolidated unit	6000
lower unconsolidated unit to bedrock	8000

### 5.3 Interpretation

Interpreted depths are based on the velocity model created for the study area. An exact match was not possible between the logs (in particular MW-5) and the seismic lines. Therefore, the velocity of the unit may be different than the model, and the interpreted depths of the geologic features may vary from actual values.

Line 1 was broken into two segments, due to the intersection of Highway A. Line 1 is east of the highway, and line 1A is west of the highway. The locations of all the lines are shown on Figure 5, and the geological interpretations are presented on Figures 6 and 7. These geologic interpretations are based on the well log data. The geologic interpretations made by Geosphere Midwest can be seen in their report included in Appendix 24.

Line 1/1A ran along the northern portion of the study area. It detected the bedrock surface along the east portion of the line at approximately 30 feet below the ground surface. An interpreted fault was encountered approximately 3000 feet west of County Road A. Bedrock west of the fault was interpreted to be greater than 300 feet from the ground surface. The drilling program did not encounter bedrock west of the inferred fault to a depth of 335 feet at location MW-55D. Bedrock was not encountered in the drilling program except at well MW-50S and MW-50D (in the east).

Line 2 also intercepted the fault, but at approximately 3800 feet west of Highway A. These two intersections give a possible orientation for the fault as shown on Figure 5. Again, bedrock was encountered along the east portion of the line, but not west of the fault. Along line 2, bedrock depths east of the fault are greater than 80 feet below ground surface.

Another feature was identified on line 2. This was a trough or channel in the bedrock. It is located approximately 2250 feet west of County Road A. Since it is a narrow channel, its true depth cannot be obtained from the seismic data. A similar feature is shown on the south portion of line 4. However, the evidence for the buried channel is not as conclusive as on line 2.

A broader channel is portrayed at a location 500 feet west of County Road A on line 2 (at the west end of the line) and towards the southern end of line 3. Combining this data with the log for MW-5 gives evidence that this may be a buried alluvial channel.

The inferred depths of the structures are based largely on seismic interpretation of the data, due to the limited available logs that intercept or are near the lines. Additional control is necessary to further define the bedrock depth and structures (apparent channels).

## **6.0 Results**

### **6.1 Geology/Hydrogeology**

**6.1.1 Regional Bedrock Geology.** Bedrock geologic units of the St. Croix River Basin, bounded on the north by Lake Superior; the Minnesota border, St. Croix and Mississippi Rivers on the west; Lake Pepin in the south; and southward from Bayfield County through Sawyer, Washburn, Barron, Polk, St. Croix, Pierce, and Pepin Counties on the east, span the Precambrian Era through the Cambrian and Ordovician Periods. An area west of a line from New Richmond south to Prescott delineates the portion of St. Croix County which contains the oldest to youngest sandstone units of the Cambrian System: the Mount Simon, Eau Claire, Galesville, Franconia, St. Lawrence and Jordan Formations; respectively. The remaining majority of St. Croix County is underlain by the Early Ordovician Shakopee and Oneota Formations of the Prairie du Chien Group. In addition, the southwest one-quarter of the county is underlain by the St. Peter, Glenwood, Platteville, Decorah, and Galena Formations.

Locally, the lithology of the uppermost geologic unit of the Prairie du Chien Group, the Shakopee Formation, was classified by Middleton and Williams at the Beyer Quarry in Troy Township, 2.8 miles south of Interstate 94 as a gray to tan sandy, micritic dolomite, oolitic dolomite, intraclastic dolomite, algal biolithite containing layers of gray-green shale and sandstone (Middleton and Williams, 1989).

The Oneota Formation in the area, as described by Middleton and Williams, has been described as a uniform, orange-brown, medium crystalline dolomite containing abundant quartz and calcite-lined vugs.

The majority of the study area lies within a structural feature called the Hudson-Afton Horst which represents an uplifted and offset fault block located between the Cottage Grove Fault on the west and the Hastings-Lake Owen Fault on the east. Both faults originate near the Mississippi River near Hastings, Minnesota and trend northeasterly to Afton, Minnesota through Hudson, Wisconsin northward to northern Polk County for the Cottage Grove Fault and northward to Bayfield County and Lake Superior along the Hastings-Lake Owen Fault. The city of Hudson is located above an upthrown fault block of Middle Proterozoic Keeweenawan Igneous rocks, which form the base of the Hudson-Afton Horst. This five kilometer wide structural feature was created approximately 1.3 billion years ago by a series of extensional tectonic forces originating within the earth's mantle creating an overall structure within the Precambrian Igneous rocks in the form of a syncline or elongate basin (Middleton, 1989). Deposition of younger Paleozoic sediments within this structural basin proceeded through the Cambrian and Ordovician Periods as the Mount Simon, Eau Claire, Galesville, Ironton, Franconia and Prairie du Chien Group were deposited. These geologic units represent the shifting margin of a transgressing and regressing inland seaway which reworked and deposited various sources of marine and terrigenous clastic material.

Post Cambrian rejuvenation of Precambrian Faults continued at least up through Early Ordovician. According to Middleton, vertical offset of the Paleozoic strata along portions of the Hastings-Lake Owen Fault is between 85 to 100 meters while a greater vertical offset of 112 to 127 meters has been observed along the Cottage Grove Fault. In addition, vertical offset of 46 meters between the same Paleozoic strata in the Hudson and North Hudson has been observed. As a result, a smaller, unrecognized fault of unknown orientation must exist in the vicinity of Lake Mallalieu (Middleton, 1989). Numerous tectonic events occurring over time has deformed the Paleozoic strata capping the Hudson-Afton Horst creating a southwest plunging anticlinal structure with shallow dips on its flanks orienting its fold axis parallel to the major faults lying directly to the east and west (Williams, 1989).

The Prairie du Chien Group marks the final transgression of the inland Sauk seaway which was present in the area during the Early Ordovician and was controlled by rejuvenated faults influencing depositional conditions. The Oneota Formation, the basal member of the Prairie du Chien Group, was deposited under a rather stable shallow carbonate reef environment recognizable from its more uniform lithology than the overlying Shakopee Formation. The Shakopee Formation was deposited under a more unstable and fluctuating marine environment that is similar to the shallow water intertidal carbonate shelf areas surrounding Florida and Australia today.

Evidence for the shallow intertidal carbonate shelf depositional environment can be found in lithologic features such as oolites, stromatolites, and detrital quartz along with mudcracks and truncated stromatolite beds. All of these lithologic features have been identified by Middleton and Williams at the Beyer Quarry.

Due to faulting, stream entrenchment, and erosion, the surface between the Prairie du Chien Group and the overlying unconsolidated Superior Lobe glacial deposits is quite variable. The Prairie du Chien Group has been encountered between the depths of 15 to 227 feet in sections 15, 16, 22, and 23. The termination depths of the borings and/or the last Prairie du Chien contact ranged from 98 to 262 feet below the ground surface. The units used from the logs were listed as dolomite, lime, or limestone on the logs.

Over the last one hundred years, the depth and orientation of Quaternary drainage systems of the Mississippi River and its tributaries such as the St. Croix River has been debated (Baker, 1989). It is still unclear whether river and stream entrenchment took place prior to the Pleistocene or during the Wisconsin glacial stage of the middle Pleistocene. Some authors feel that the greatest amount of stream entrenchment occurred during the late Pleistocene as meltwaters were directed through the Mississippi River drainage system. Recent studies by Baker conclude that in western Wisconsin and southeastern Minnesota entrenchment by tributaries of the Mississippi such as the Willow River and St. Croix River had a pre-Wisconsin glacial origin and occurred in the early Pleistocene.

Evidence supporting the timing for river and stream entrenchment in Western Wisconsin suggests that when pre-Illinoian glaciers advanced eastward into the state, these glaciers deposited over 150 meters of clay-rich till, such as the Kinnickinnic member of the Pierce Formation and blocked the outlet of several tributaries to the Mississippi River. As a result of this blockage, numerous meltwater lakes formed upon retreat of the glaciers. Paleomagnetic studies of these sediments possibly indicate that the entrenchment occurred between 2.1 billion years ago and 730,000 years ago. Therefore, the drainages that filled with these sediments must have been developed at least by this time (Baker, 1989). Since the St. Croix River acted as an outlet for glacial lakes Agassiz, Koochiching, Aitken, Upham, Grantsburg, and Duluth during the late Pleistocene, the Prairie du Chien Group may be deeply entrenched with numerous channels that represent former outlets to the St. Croix River (Baker, 1989).

**6.1.2 Regional Glacial Geology.** A majority of eastern St. Croix, northern Pierce, and western Dunn Counties as well as the entire study area contains the surficial geologic unit called the River Falls Formation. This geologic unit was deposited by a continental glacier advancing from the north-northeast and transporting sediment derived from the Lake Superior Basin and regions southwestward during the Wisconsin Stage of the Pleistocene Epoch.

The River Falls Formation is described as a basal till that is commonly weakly stratified and may contain discontinuous lenses of fine sand. This geologic unit is primarily a sandy, clay loam averaging 60 percent sand, 15 percent silt and 25 percent clay. The till units within the River Falls Formation are also classified as sandy, clay loam containing igneous, metamorphic and sedimentary

pebble lithologies (Mickelson, et al, 1984). The overall thickness of the River Falls Formation ranges from one meter over bedrock uplands to 10 meters in St. Croix County. The geologic contact with the underlying Hersey Member of the Pierce Formation and the St. Croix Moraine deposits to the north is sharp and distinct (Mickelson, et al, 1984).

Approximately one-third of the northwestern section of St. Croix County is covered by a glacial deposit called the Copper Falls Formation; a glaciofluvial sediment derived from the Lake Superior Basin. The southernmost limit of the Copper Falls Formation is observed in the St. Croix and Chippewa Moraines of northwestern St. Croix and southeastern Polk and northwestern Barron counties. The Copper Falls Formation is lithologically similar to the River Falls Formation except that it does not have igneous and metamorphic clasts and has a smaller proportion of sedimentary clasts (Mickelson, et al, 1984).

Roughly half of the Copper Falls formation consists of fluvial sand and gravel, while the remaining portion consists of a calcareous till containing on the average 35 to 80 percent sand, 15 to 50 percent silt, and 2 to 15 percent clay along with a minor amount of pebbles. This geologic unit was deposited by melt-water streams in front of a glacier, on stagnant ice, or beneath the glacier as an esker. The Copper Falls Formation was deposited during either the Early or Late Wisconsin Stages of the Pleistocene Epoch during the advance of the main Superior Lobe, Chippewa sublobe, Wisconsin Valley Lobe or Langlade Lobe during this time period (Mickelson, et al, 1984). A map showing the state wide distributions of the surficial lithostratigraphic units is included on Figure 8.

**6.1.3 Study Area Specific Geology.** The Superior Lobe unconsolidated soils encountered during the field investigation consisted primarily of glacial outwash and unstratified glacial till deposits. These deposits, especially the glacial outwash units, were extremely variable in lithology both with depth and between boreholes. Glacial outwash was the predominant unconsolidated material encountered during the drilling program and was present in every borehole within the study area. The glacial outwash samples from which grain size/hydrometer tests were performed indicated that this material was either a Poorly-Graded Sand (SP) or Poorly-Graded Sand with Silt (SP-SM) and included on the average 90 to 98 percent sand and 0 to 10 percent gravel content. Some of the tested glacial outwash deposits contained as little as 58 percent sand and 30 percent gravel. As previously mentioned, the amount of silt, intermixed gravel, and gravel layers varied significantly with depth and from borehole to borehole across the study area, making it difficult to determine both the vertical and horizontal extent of individual outwash deposits. In addition, cobble layers and small scale layers of silty sand (SM) were encountered within these glacial outwash deposits. In addition, five to ten-foot thick isolated layers of Well-Graded Gravel with Silt and Cobbles (GW-GM) and Poorly-Graded Gravel with Silt and Cobbles (GP-GM) glacial outwash deposits were encountered between 185 and 236 feet at MW-54. The grain size and hydrometer test performed on the sample from 231 to 236

feet shows a 56.9 percent gravel content and 37.5 percent sand content. These gravel layers most likely represent a closer proximity to the source of outwash material than the finer-grained sand and silty sands discussed above.

Only one glacial till unit was encountered in the eleven geologic borings performed within the study area. This geologic unit consisted of a medium to coarse-grained, Silty Clayey Sand (SC-SM) with gravel and was encountered at MW-55D between the depths of 235 and 256 feet and was overlain by a ten foot-thick layer of Well Graded Gravel with Silt (GW-GM). Therefore, it appears that the change from the glacial till to glacial outwash was transitional as the proximity of coarse-grained clastic receded from the immediate area.

Bedrock was encountered at MW-50S and MW-50D. The samples were described by the field geologist to be a light brown to buff, brownish-grey to grey, fractured, medium-grained dolomite and sandy dolomite, with calcite-lined vugs resembling the description of the Oneota Formation. Therefore, it appears that the Oneota Formation is present at MW-50S and MW-50D.

The study area is in an area known to have faulting in the bedrock units. A fault was suspected to pass through the study area, based on the available well logs. The seismic results, previously presented, also support this hypothesis. Bedrock contours available for the area show a bedrock high in the eastern portion of the study area; however, bedrock depths are highly variable (at a depth of approximately 40 feet in the area of MW-50S and MW-50D to a depth of approximately 208 feet at well MW-5D). This is likely due to an erosional surface below the glacial deposits. Bedrock is not encountered in the western portion of the study area in the residential well logs available for the area or the logs from the current investigation, except in the area near the Willow River.

Cross-sections can be found on Figures 9 - 11. These lines are labeled as A-A', B-B', and C-C' and are shown on Figure 2. Figure 9A provides a legend for the well logs. Well logs available for the area show that the bedrock in the area is highly variable, and since bedrock was only encountered in one of the borings, the cross-sections only show bedrock at one location. This does not allow for a slope of bedrock or an offset on the fault to be calculated. The cross-sections also show the relatively flat plateau that plunges over 150 feet from well MW-50S to MW-57S. The exception to the flat plateau is well MW-52, which was set in a depression near the center of the study area. Some of the Nor-Lake, Inc. wells (MW-2, MW-3, MW-5D, and MW-10) were included in the cross-section maps. This was to correlate previous results with the findings of the current investigation, and to show that the predominant geologic units are the glacial material over bedrock.

These cross-sections correlate to the geophysical cross-sections made by Geosphere Midwest. The geophysical cross-sections go a step further than the other cross-sections, by indicating channels in the

bedrock. Previous borings performed in the area (such as MW-5D) do indicate that the bedrock is highly variable in the area. The log from well MW-53 also supports the existence of variable bedrock or channels. MW-53 is located east of the inferred fault. Bedrock was not encountered to the termination depth of the boring, 142 feet below ground surface. The boring information combined with the geophysical data from lines 2 and 4 lead to an interpreted erosional feature in the bedrock, a channel. Another possible channel is indicated on the eastern portion of seismic line 2. This trace combined with the boring log from MW-5D (installed for Nor-Lake, Inc. which encountered bedrock at a depth of approximately 208 feet) again suggests a channel. Figure 12 shows the inferred bedrock elevations.

The FID headspace readings of the soil samples ranged from 0 - 10 ppm in the borings except for MW-55D. The levels in MW-55D ranged up to 100 ppm at a depth of 235 - 240 feet. A laboratory soil sample was collected from two intervals (235 - 240' and 307 - 312'). Laboratory analysis did not detect any VOC compounds above method detection limits in either sample.

More specific information regarding the composition of soils encountered within the screened interval of the water table observation wells and piezometers can be found on the Grain Size/Hydrometer results in Appendix 15, and the Log of Boring sheets in Appendix 12. OVA sheets can be found in Appendix 16.

**6.1.4 Study Area Specific Hydrogeology.** The groundwater elevations from the water table observation wells and piezometers from within the unconsolidated Superior Lobe glacial outwash units range from 799.69 at MW-52 to 708.06 at MW-57S near the backwater of the Willow River. The latter groundwater elevation is approximately 8 feet above the elevation of the Willow River. The groundwater elevation at MW-50S, an upgradient bedrock water table observation well, is 864.89 feet and drops 65.2 feet to MW-52 located 3900 feet downgradient and 124.4 feet to MW-51, 5400 feet downgradient. The water table aquifer at MW-50S is located at 864.89 feet which places it approximately 14 feet below the competent bedrock at this location. Therefore, the water table aquifer located within the bedrock must be connected to the saturated unconsolidated glacial sediments located downgradient from MW-50S. In addition, it may be possible that the water table aquifer in the bedrock is roughly following the orientation of the bedrock erosional surface until the bedrock surface drops below the water table in the unconsolidated glacial sediments between MW-50S and MW-52 further downgradient.

## **6.2 Surveying**

The newly installed water table observation wells and piezometers were surveyed by Sunde Land Surveying, Inc. They performed a loop around the study area consisting of X, Y, and Z coordinates. In addition to the level loops, the coordinates of the new wells were surveyed. Table 7 below lists



the coordinates of the newly installed wells along with the recalculated information for the Nor-Lake, Inc. wells.

Table 7 - Well Coordinates

Well	X coordinate	Y coordinate	Z coordinate
MW-1	157020.00	8474.00	926.71
MW-10	10998.64	11666.05	918.31
MW-2	16273.00	9210.00	920.99
MW-3	15714.07	9511.02	913.54
MW-4	16340.35	9834.17	914.82
MW-5D	15384.40	9864.76	905.33
MW-5S	15394.85	9861.68	906.68
MW-6	15337.81	9362.23	919.82
MW-7	14209.85	9419.97	916.53
MW-8	12509.85	11099.97	909.89
MW-9	11268.39	11156.38	916.93
MW-50S	16478.79	12634.42	920.33
MW-50D	16473.44	12634.71	920.19
MW-51	11262.57	12831.72	919.39
MW-52	13176.69	10769.02	871.38
MW-53	12624.06	10234.91	920.13
MW-54	10999.31	11671.71	918.13
MW-55S	8726.20	12955.13	919.57
MW-55D	8725.33	12960.05	919.60
MW-56	9118.41	10912.22	903.87

Well	X coordinate	Y coordinate	Z coordinate
MW-57S	5673.59	13117.55	741.11
MW-57D	5671.93	13112.32	741.12

A map displaying the surface contours taking the surveyed information into account is shown on Sheet 2. Also, a copy of Sunde's field notes are included in Appendix 25.

### 6.3 Laboratory Soil Testing

Soil samples from each of the borings were submitted to the Braun Intertec soils laboratory for grain size/hydrometer analysis. The table below summarizes the results.

Table 8 - Grain Size - Hydrometer Analysis

Well	Interval (Depth)	Classification
MW-50D	20.0 - 23.0'	SP-SM: Poorly graded sand with silt, light brown
MW-51	180.0 - 185.0'	SP: Poorly graded sand, light brown
MW-51	190.0 - 195.0'	SP: Poorly graded sand with gravel, light brown
MW-52	73.0 - 80.0'	SM: Silty sand, light brown
MW-53	125.0 - 130.0'	SP: Poorly graded sand with gravel, light brown
MW-53	130.0 - 135.0'	SP: Poorly graded sand, trace of gravel, light brown
MW-54	231.0 - 236.0'	GP-GM: Poorly graded gravel with silt and sand, light brown
MW-55D	180.0 - 184.0'	SP-SM: Poorly graded sand with silt, light brown

Well	Interval (Depth)	Classification
MW-55D	185.0 - 187.0'	SP: Poorly graded sand, light brown
MW-56	160.0 - 165.0'	SP: Poorly graded sand, light brown
MW-56	168.0 - 170.0'	SP: Poorly graded sand, light brown
MW-57D	36.0 - 37.0'	SM: Silty sand, brown
MW-57D	39.0 - 40.0'	SP-SM: Poorly graded sand with silt, brown
MW-57D	75.0 - 80.0'	SP: Poorly graded sand, trace of gravel, brown

With the exception of well MW-54, the general soil classification is Poorly Graded Sand. The classifications are fairly consistent across the study area. The sample from MW-54 has a larger percentage of gravel. These samples are all from the glacial material. The sample from well MW-50D was taken from the glacial deposit above the bedrock. An average of all the samples appears as follows:

gravel	10.0%
sand	81.1%
silt & clay	8.9%
D10	0.17

Using the Hazen equation, an estimation of the hydraulic conductivity can be made. The formula is listed below:

$$K = A(D10)^2 \text{ [cm/sec]}$$

where  $A = 1$

$$= 1 \times 0.17^2 = 0.029 \text{ cm/sec} = 0.00095 \text{ ft/sec}$$

This value is within the range of hydraulic conductivities determined from the slug tests, see Section 6.6.

#### **6.4 Water Table Observation Wells**

Seven water table observation wells were installed during the investigation. Six of these wells were completed in glacial material. The other well (MW-50S) was completed in bedrock. Well depths ranged from 41.0 feet at MW-57S to 203.6 feet at MW-55S. Water was encountered at an elevation of 708.06 feet AMSL at MW-57S to 864.89 feet AMSL at MW-50S.

#### **6.5 Piezometers**

Four piezometers were installed to obtain data on the vertical gradient in the aquifers. The water levels in well nests MW-10 and MW-54, MW-55S and MW-55D, and MW-57S and MW-57D vary over the range of 0.23 - 2.00 feet. Piezometer MW-50D varies from its well (MW-50S) by more than 20 feet. The water table at MW-50D is at the lower elevation. This difference has raised questions about what water levels these two wells are monitoring.

A probable explanation for the large difference in head is due to the fact that the MW-50S and MW-50D well nest was completed in a fractured bedrock unit. The cores that were obtained during the drilling program consisted of pieces of bedrock smaller than four inches in length and could not be used to determine a rock quality designation (RQD); however, a significant amount of water was lost during drilling operations and approximately only half of the core run was returned in the sample barrel. The limited return suggests that the bedrock is highly fractured.

Water levels in fractured media are directly influenced by the dimensions of the fractures, interconnections, high water level gradients, and rate of surface infiltration. In general, the regional groundwater table will be reflected in the fractured media, but subjected to infiltration. The hydraulic loading of the particular fracture in which the well is screened will superimpose its recharge signature upon regional flow conditions. Depending upon the geologic conditions and the hydraulic characteristics of the fracture, this may cause a deviation from regional water level conditions. The boundary situations are where the rock is poorly fractured and each fracture is isolated, filling completely, to the other case where the rock is highly fractured (hydraulically resembling a porous medium) and each fracture is well connected to the aquifer, closely reflecting regional water levels. Variation in groundwater levels has commonly been seen over the range of 20 to 80 meters (Milanovic, 1981).

The interconnection of the fractures could be measured by performing additional chemical analyses on the groundwater. In particular, the samples would be tested for indicator parameters to fingerprint the background water quality and compare results to expected values. Samples would likely be analyzed for calcium, magnesium, carbonate, and bicarbonate to determine the contact time with the formation and correlate that value to flow through the fracture and interconnection to the aquifer. This would lead back to answering the question of what water level the wells are measuring.

**6.6 Single Well Response Tests (Slug Tests).** The results of the rising head slug tests are presented in Table 9 below. Appendix 26 contains the results of data analysis along with the field data obtained from the automatic field data logger.

Table 9 - Rising Head Slug Tests

BRISTA (BOUWER AND RICE) ANALYSIS	
WELL	K (cm/sec)
MW-50S	1.3E-03
MW-50D	5.0E-04
MW-51	9.7E-04
MW-52	2.7E-03
MW-53	3.7E-02
MW-54	5.6E-02
MW-55S	1.7E-02
MW-55D	1.7E-04
MW-56	1.9E-02
MW-57S	7.0E-04
MW-57D	2.8E-02

The horizontal hydraulic conductivity ranges from 0.00017 to 0.056 cm/sec (0.00033 to 0.11 feet/minute) with an average of 0.015 cm/sec (0.029 feet/minute). This range does not separate out

the bedrock wells (MW-50S and MW-50D). These values fall in the range of a sand deposit or a karst limestone (Freeze and Cherry, 1979).

Using the range of hydraulic conductivities (0.00033 - 0.11 feet/minute), the range of the gradient (0.006 - 0.02 feet/foot), and assuming a porosity of 30% (0.3), the average linear velocity ranges from 6.60E-06 to 7.33E-03 feet/minute (approximately 0.0094 to 10.56 feet/day) across the study area.

2 ft/day

## 6.7 Groundwater Sampling Program

**6.7.1 Water Levels.** A water table elevation map is presented on Figure 13 and Sheet 3. The general flow direction is to the west-northwest. In the area of the Nor-Lake facility, there appears to be groundwater mounding. This could be due to the infiltration of flow from the treatment system, another source on site, or the groundwater levels could be influenced by the bedrock topography in the area. The mounding has been seen in previous water table maps created for Nor-Lake, Inc. The horizontal gradient varies across the study area, ranging from approximately 0.006 feet/foot west of the inferred fault to 0.02 on the eastern portion of the study area. There does not seem to be any effect on the groundwater levels due to the pumping of the recovery well. The gradient in the west is consistent between both wells MW-51 to MW-55S and MW-51 to MW-57S, suggesting that the unit in which the water table is present is fairly homogeneous.

Vertical gradients in the well nests (MW-10 and MW-54, MW-50S and MW-50D, MW-55S and MW-55D, and MW-57S and MW-57D) are presented in the table below.

Table 10 - Vertical Gradients

WELL NEST	DATE	VERTICAL GRADIENT
MW-10, MW-54	10/14/91	0.0039
MW-50S, MW-50D	08/21/91	0.3925
MW-50S, MW-50D	09/03/91	0.3937
MW-50S, MW-50D	09/13/91	0.4025
MW-50S, MW-50D	09/16/91	0.4083
MW-50S, MW-50D	10/09/91	0.3967
MW-50S, MW-50D	10/14/91	0.3949
MW-55S, MW-55D	10/14/91	0.0018
MW-55S, MW-55D	10/23/91	0.0018
MW-57S, MW-57D	08/21/91	0.0190
MW-57S, MW-57D	09/03/91	0.0275
MW-57S, MW-57D	09/13/91	0.0335
MW-57S, MW-57D	09/16/91	0.0377
MW-57S, MW-57D	10/09/91	0.0392
MW-57S, MW-57D	10/14/91	0.0474

The vertical gradients in nests MW-10 and MW-54, MW-50S and MW-50D, MW-55S and MW-55D, and MW-57S and MW-57D are downward, into the aquifer. The nest at MW-50S and MW-50D has a vertical gradient of approximately 0.4 ft/ft into the aquifer. As previously discussed, this well is likely influenced by the fractures in the bedrock.

#### 6.7.2 Water Quality Analysis

**6.7.2.1 Results.** During the first round of groundwater sampling, wells MW-50S, MW-50D, MW-51, MW-52, MW-54, MW-56, and MW-57S did not have VOC contamination present above method detection limits. The table below lists the compounds found above method detection limits. Well MW-55S was not completed in time to be included in this round of sampling. Duplicate values are presented in the table below.

Table 11 - First Sampling

Well	Date	Units	1,2-DCA	PCE	1,1-DCA	1,1-DCE	1,1,1-TCA	TCE	CIS-1,2-DCE	Comments
			5	1	850	7	200	5	100	Enforcement Standard
			0.05	0.1	85	0.024	40	0.18	10	Preventive Action Limit
MW-53	09/16/91	UG/L	-	1.4	-	-	11	13	-	BRAUN INTERTEC
MW-55D	09/19/91	UG/L	1.3	-	1.4	1.4	22	17	0.5	BRAUN INTERTEC
MW-55D	09/19/91	UG/L	1.2	-	1.4	1.4	20	19	-	DUPLICATE BRAUN INTERTEC
MW-57D	09/18/91	UG/L	1.3	-	-	-	22	18	-	BRAUN INTERTEC

The table above shows that wells MW-53, MW-55D, and MW-57D all had VOCs above method detection limits. In addition, these three wells had values above the Preventive Action Limit and the Enforcement Standard. The compounds that were exceeded were Tetrachloroethylene, 1,1-Dichloroethylene, and Trichloroethylene. The comparisons to the Preventive Action Limit and the Enforcement Standard were made using the PARAMS data base information provided by the DNR.

The results from the second round of sampling indicated that wells MW-2, MW-50S, MW-50D, MW-51, MW-52, MW-56, and MW-57S did not have VOC contamination present above method detection limits. The table below lists the compounds found above method detection limits. Note that split samples were taken with Nor-Lake, Inc. (from wells MW-3, MW-8, and MW-10) during this sampling session. In addition, the data for other available Nor-Lake, Inc. wells is included in this table (MW-1, MW-2, MW-4, MW-5S, MW-5D, and MW-6).



Table 12 - Second Sampling  
 all units are UG/L

Well	Date	1,2-DCA	CHLORO-FORM	CHLORO-ETHANE	METHYLENE CHLORIDE	PCE	TRICHLORO-FLUORO-METHANE	1,1-DCA	1,1-DCE	1,1,1-TCA	1,1,2-TCA	TCE	CIS-1,2-DCE	Comments
		5	6		150	1	3490	850	7	200	0.6	5	100	Enforcement Standard
		0.05	0.6		15	0.1	698	85	0.024	40	0.06	0.18	10	Preventive Action Limit
MW-1	10/14/91	-	-	-	-	-	-	-	-	9	-	4	-	TCT FOR NOR-LAKE
MW-3	10/14/91	1.3	-	-	-	-	-	2.4	21	440	-	190	1.5	BRAUN INTERTEC
MW-3	10/14/91	-	-	-	20	-	-	-	24	400	-	200	-	TCT FOR NOR-LAKE
MW-4	10/14/91	-	-	-	-	-	-	-	-	9	-	8	-	TCT FOR NOR-LAKE
MW-5D	10/14/91	-	-	-	1	-	-	-	-	-	-	-	-	TCT FOR NOR-LAKE
MW-5S	10/14/91	-	-	-	14	-	-	54	14	210	-	780	-	TCT FOR NOR-LAKE
MW-6	10/14/91	-	-	-	-	64	-	-	-	>99	7	>920	-	TCT FOR NOR-LAKE
MW-7	10/17/91	-	2	-	3	-	-	-	2	26	-	23	-	
MW-8	10/14/91	-	-	-	2	-	-	-	-	-	-	-	-	TCT FOR NOR-LAKE
W-9	10/15/91	-	-	-	10	-	-	-	-	36	-	25	-	TCT FOR NOR-LAKE
MW-10	10/14/91	-	-	-	4	-	-	-	-	39	-	28	-	TCT FOR NOR-LAKE
MW-10	10/14/91	-	-	-	-	-	-	-	1.1	34	-	23	-	BRAUN INTERTEC
MW-53	10/15/91	-	-	2.4	-	1.6	1	-	-	12	-	12	-	BRAUN INTERTEC
MW-54	10/15/91	0.5	-	-	-	-	-	5.5	1.7	49	-	40	1.7	BRAUN INTERTEC
MW-55D	10/16/91	-	-	-	-	-	-	1	-	19	-	14	-	BRAUN INTERTEC
MW-55D	10/16/91	-	-	-	-	-	-	1.1	-	21	-	16	-	DUPLICATE-BRAUN INTERTEC
MW-55S	10/16/91	-	-	-	-	0.7	-	-	-	27	-	19	-	BRAUN INTERTEC
MW-57D	10/15/91	-	-	-	-	-	-	-	-	24	-	17	-	BRAUN INTERTEC

Except for MW-54, the wells showing non-detectable levels of VOCs were the same for both rounds of sampling. The sample from well MW-54 detected VOCs in the second round of sampling. The wells exceeding the Enforcement Standard and the Preventive Action Limit are also listed in the text. The wells exceeding the Enforcement Standard in both monitoring sessions included MW-53, MW-55D, and MW-57D.

Well MW-55S was sampled for a second time on October 23, 1991. The table below lists the compounds present above method detection limits.

Table 13 - Second Sampling at MW-55S

Well	Date	Units	PCE	1,1-DCE	1,1,1-TCA	TCE	Comments
			1	7	200	5	Enforcement Standard
			0.1	0.024	40	0.18	Preventive Action Limit
MW-55S	10/23/91	UG/L	0.6	0.7	26	20	BRAUN INTERTEC
MW-55S	10/23/91	UG/L	0.6	0.6	25	20	DUPLICATE-BRAUN INTERTEC

Well MW-55S exceeded the Enforcement Standard for Trichloroethylene in both groundwater samples taken for the well. The Preventive Action Limits for Tetrachloroethylene and 1,1-Dichloroethylene were also over acceptable levels.

Since wells MW-50S and MW-50D are between the residential area with VOC contamination and the former Junker Landfill, and since these wells are downgradient from the former Junker Landfill, available information indicated that the former Junker Landfill is not likely a source of the contamination.

This information has been entered into the data base. The laboratory reports are included in Appendix 27.

**6.7.2.2 Nature of Contaminants.** Liquids that do not readily dissolve in water and therefore can exist as a separate phase are known as Non-Aqueous Phase Liquids (NAPLs). Some of these liquids, such as gasoline and heating oil, are less dense than water. When these lighter-than-water liquids are released into the subsurface, they tend to float on the groundwater surface, thus limiting downward vertical migration of the contaminant. Liquids such as the chlorinated hydrocarbons trichloroethylene, trichloroethane, and tetrachloroethylene, that are denser than water tend to sink vertically downward through the water column when released into the subsurface. These heavier-than-water liquids are referred to as Dense Non-Aqueous Phase Liquids (DNAPLs). If the quantity of dense contaminant released is large enough, the DNAPL can sink through the groundwater until it reaches an impermeable layer or aquitard, where it forms DNAPL pools. The pool or contaminants may flow on top of the impermeable layer under the force of gravity along the slope orientation of the layer that impeded its vertical flow. Thus, DNAPLs are capable of migrating in directions other than the direction groundwater is flowing.

The solubility of compounds must also be taken into account. Undissolved tetrachloroethylene, present in an aquifer, can act as a secondary source for dissolved groundwater contamination for extremely long periods of time, due to its low solubility. DNAPL pools can be extremely difficult to locate and remediate.

Concentrations of contaminants will typically be highest near the source and decrease in a downgradient direction. Microbial degradation products of trichloroethylene, trichloroethane, and tetrachloroethylene may include cis- and trans-1,2-dichloroethylene, 1,1-dichloroethane, chloroethane, and vinyl chloride. Presence of these breakdown products, if not found at the source area, could indicate microbial degradation of the contaminants within the plume.

**6.7.2.3      *Graphs/Figures.*** The graphs shown in Appendix 28 show the relationship of contaminant concentrations versus time for the four parameters trichloroethylene, 1,1,1-trichloroethane, tetrachloroethylene, and 1,1-dichloroethylene. The wells installed for this investigation are included along with the graphs for the Nor-Lake, Inc. wells. The Nor-Lake, Inc. plots are not discussed in this report. The results should be presented by Nor-Lake, Inc. in the yearly monitoring report for the study area. Wells MW-50S, MW-50D, MW-51, MW-52, MW-56, MW-57S, and MW-8 did not detect VOCs above method detection limits, and are not plotted.

Since there are only two sampling dates for the wells at this time a discussion of trends is not very meaningful, but the following observations are made. The contaminant concentrations in wells MW-53, MW-55S, MW-54, MW-55D, and MW-57D were relatively constant. Well MW-54 showed the largest change, going from non-detect levels to a maximum value of 49 ug/l for 1,1,1-Trichloroethane. Well MW-10 which is the water table observation well nested with the piezometer MW-54 had a maximum value of 34 ug/l of 1,1,1-Trichloroethane during the same monitoring session.

There are two different maps of VOC contamination. The first map indicates what wells were sampled during 1991 and if contamination was found. If any of the four above mentioned VOCs were present, the concentration is also listed on the figure. The 1991 data is shown on Sheet 4. Sheet 5 represents the data in a similar way; however, the values are representative of the highest concentration found at the respective well since 1984. This figure will give an indication of where contamination has been found over time at the study area. Figure 14 depicts the sites that have been sampled and identifies the detects or non detects.

**6.7.2.4      *Quality Assurance/Quality Control.*** As listed in the In-Field Conditions Report requirements (NR 508), the statistical validity of the analytical results was reviewed. The following conclusions were made with respect to the available data.

Hypothesis testing techniques are recommended to determine whether or not average VOC levels at the Trout Brook study area exceed background VOC levels in a statistically significant way. Both parametric and non-parametric statistics, utilized in hypothesis testing, are based upon certain assumptions. In the case of parametric statistics, assumptions about the distribution of the data are made. In both cases, random sampling is assumed. The Trout Brook area monitoring wells were installed at locations in accordance with a specified work plan. Other groundwater data was obtained from pre-existing residential wells and monitoring wells. The statistical sampling plans required cannot be retro-fitted to these data locations. Therefore, the assumptions on which these tests are based cannot be satisfied.

Although the assumptions of random sampling and normally distributed data were not met, statistical hypothesis tests were conducted assuming the tests were robust. A Student's T distribution was used. The purpose was to determine whether there was a statistically significant exceedance of background levels of Trichloroethylene or 1,1,1-Trichloroethylene.

Available data obtained after August 30, 1991 were reviewed. All wells for which the substance under consideration was tested were included in the data base, with the exception of MW-50S and MW-50D. These were used as a measure of background concentrations. Where multiple data reflected a single well location, readings were averaged and entered as a single value. This provided for 25 data points. Data below method detection limits were assigned concentration values of 0.0 ppm.

Trichloroethylene: A hypothesis test was conducted using a null hypothesis of  $\mu = 0.0$  and an alternative hypothesis of  $\mu > 0.0$ . Alpha, the probability of rejecting the null hypothesis when it is indeed true, was set to 0.05. This dictated that the critical value for the mean concentration of trichloroethylene be 68.68 ppm under the conditions of this experiment. The mean concentration level was calculated to be 80.3 ppm, thus exceeding the critical value. Hence, the null hypothesis is rejected in favor of the alternative hypothesis. Therefore, the mean concentration of trichloroethylene exceeds the background levels in a statistically significant way.

1,1,1-Trichloroethane: A hypothesis test was conducted using a null hypothesis of  $\mu = 0.0$  and an alternative hypothesis of  $\mu > 0.0$ . Alpha was again set at 0.05. This dictated that the critical value for the mean concentration of 1,1,1-trichloroethylene be 38.51 ppm under the

conditions of this experiment. The mean concentration of 1,1,1-trichloroethylene was calculated to be 49.6, thus exceeding the critical value. On this basis, the null hypothesis is rejected in favor of the alternative. Therefore, the mean concentration of 1,1,1-trichloroethylene exceeds the background levels in a statistically significant manner in the area of interest.

The letter to Ron Arneson of the DNR from the Braun Intertec Laboratory addresses the field blank contamination found in some of the QA/QC samples taken for the analytical investigation. The conclusion made by the laboratory was that the field blank problem was caused by contamination of deionized water and/or the bailers. The low levels of benzene, toluene, ethyl benzene, and total xylenes found in the field blanks did not appear in the monitoring well samples. A copy of the letter is in Appendix 29.

## **6.8 Photos**

Appendix 30 contains photographs taken during the field investigation. A narrative describing the photos appears directly beneath the pictures.

## **7.0 Conclusions and Recommendations**

### **7.1 Summary**

The Rota-Sonic method was used to perform the drilling program for the investigation. Due to drilling difficulties, drilling fluid was necessary to advance the boreholes. The difficulties greatly extended the project time. Air rotary methods were used to drill the bedrock wells (MW-50S and MW-50D).

The barrels used to store the drilling fluid from location MW-55S are stored on the Nor-Lake, Inc. facility, pending disposal in the spring when weather permits.

The first well coded MW-55S was abandoned, since the water level fell to a level below the bottom of the screen. Also, the initial borehole for well MW-56 was abandoned because the casing became locked in the ground and could not be advanced any further.

Field soil samples and bedrock cores will be stored at Braun Intertec until they are given to the DNR.

FID results from the soil samples were in the range of 0 - 10 ppm for all borings except MW-55D. Analytical laboratory soil samples were taken from this boring, and the results did not indicate VOCs above method detection limits.

A geophysical survey (seismic) was performed across the study area. The interpretation of the data identified a probable fault across the study area and two channels or valleys in the bedrock surface. The evidence for a fault was supported by the boring program, although the evidence was not irrefutable, since bedrock was not encountered on the western side of the study area.

The wells at MW-50S and MW-50D encountered bedrock. The bedrock was identified as the Prairie du Chien Group. Well MW-5D, installed for Nor-Lake, Inc., also encountered weathered bedrock. The remaining wells encountered glacial material. Well MW-50S and MW-50D are finished in fractured bedrock and water levels in these wells are likely influenced by fracture flow. Additional information to determine the elevation of bedrock in the western area of the study area and identify channels is required.

Soil laboratory testing indicated the glacial material is fairly consistent across the study area, with an average sample containing 10% gravel, 81.1% sand, and 8.9% silt and clay.

Seven water table observation wells (MW-50S, MW-51, MW-52, MW-53, MW-55S, MW-56, and MW-57S) and four piezometers (MW-50D, MW-54, MW-55D, and MW-57D) were installed during this investigation. The water table observation wells and piezometers were developed to the specifications of NR 141 as listed in the work plan and detailed in this text.

Slug test analysis on the new wells provides a range of hydraulic conductivities of 0.00017 to 0.056 cm/second (0.00033 to 0.11 feet/minute).

The survey of the monitoring wells resulted in recalculation of the coordinates for the existing monitoring wells in the area and initial location of the new wells/piezometers.

The water table was encountered at an elevation between 708.06 and 864.89 feet AMSL. The general groundwater flow is west-northwest across the study area. There is a slight mounding seen in the area of the Nor-Lake, Inc. facility. The gradient across the study area varies from 0.02 feet/foot in the east to 0.006 feet/foot in the west. The calculated average linear groundwater velocity ranges from  $6.06\text{E-}06$  to  $7.33\text{E-}03$  feet/minute in the study area (3 to 3850 feet/year):-

Groundwater sampling consisted of two rounds of sampling at each well installed in the investigation and one sampling of three wells (MW-3, MW-8, MW-10) from the Nor-Lake, Inc. monitoring network. The water table observation wells/piezometers were purged and stabilized prior to obtaining a groundwater sample.

Of the eleven monitoring points installed for this investigation, six (MW-50S, MW-50D, MW-51, MW-52, MW-56, and MW-57S) have not had detectable levels of VOCs found in the groundwater. The contaminants are found in an area trending west-northwest from Nor-Lake, Inc. to the river. The contaminants are found both at the water table and at depth (in the piezometers) at locations MW-10 and MW-54; and MW-55S and MW-55D. Well nest MW-50 did not detect contamination. Well nest MW-57 displayed contamination only in the piezometer. The results obtained from these wells are for the groundwater at the screened level. This is depicted on the cross-sections, Figures 9-11.

The slight downward flow measured in the nested water table observation wells and the piezometers indicates that contamination of the underlying bedrock is possible. Locally, the Willow River is the discharge point for the area, as indicated by the groundwater levels and the springs present in the riverbed. The St. Croix River is the regional discharge point for groundwater. Depending on whether the contamination remains in a local flow system or enters a regional flow system will determine the flow pathway, and therefore determine if there is flow under the Willow River.

The maps displaying the sampling locations/detection of contaminants and the concentrations of selected contaminants indicate a plume of contamination from Nor-Lake, Inc. to the river along the general groundwater flow direction. Background wells do not exist southeast or northeast of the Nor-Lake facility to assess groundwater quality in that area.

A geologic data base and an analytic data base were created for the study area. The information includes data available from 1984 to the present.

Hypothesis tests were conducted to determine whether mean concentrations of trichloroethylene and 1,1,1-trichloroethylene exceeded background levels in a statistically significant way. A Student's T test was utilized. It was assumed that the tests were robust to assumptions of normally distributed and randomly sampled data. With the probability of a Type I error being set to 0.05, both test statistics exceeded the critical values dictated by the conditions of the experiments. It was therefore concluded that the null hypotheses ( $\mu = 0.0$  ppm) be rejected in favor of the alternative hypotheses ( $\mu > 0.0$  ppm). In other words, mean concentrations of trichloroethylene and 1,1,1-trichloroethylene exceeded background levels in a statistically significant way, in the studied area.

It is recommended that in subsequent phases of investigation, a statistically designed sampling plan be initiated, so that the data will better lend itself to analysis using statistical methods.

Based upon the data collected as part of this investigation, there are four potential sources for the VOC contamination found in the Trout Brook Road/Parkview Estates area:

- migration of the Nor-Lake VOC contamination;
- migration of VOC contamination from the former Junker Landfill;
- an unidentified source of contamination which is not associated with the above potential sources; or
- a combination of the above.

The delineation of the toe end of the former Junker Landfill plume was not part of this study. However, since there are documented clean wells between the former Junker Landfill plume and the study area, the information gathered to date does not indicate that the landfill is a source of the contamination in the area of Green Mill Lane and Daily Road.

The site reconnaissance and historical review has not produced evidence that the railway, depressions, or other potential sites are sources of the contamination at Green Mill Lane and Daily Road.

Based on the study area results, site reconnaissance, and historical review, there is no evidence to indicate that Duro Bag is a source of the plume in the area of Green Mill Lane and Daily Road.

The data gathered in this investigation suggests that there is a continuous plume which extends from the area of Nor-Lake to the Trout Brook Road area. This is supported by the contaminant detections as presented on Sheets 4 and 5. The information gathered to date indicates that the source of the contamination is the known release of contamination on the Nor-Lake, Inc. facility.

## **7.2 Recommendations**

The size of the area that is impacted by the contaminants makes remediation a difficult and time consuming process. The identified contaminants range over six sections not including the former Junker Landfill contaminant plume. In addition to the size of the area, the large depth to groundwater causes investigative costs for soil borings and monitoring wells to be very expensive. The practicality of restoring the aquifer to natural conditions must be assessed. Additional information is required to identify the limits of the impacted areas. Results of this study suggest that while remedial investigative efforts are continuing, the items below need to be addressed.

The safety of the water supply for the residents in the study area should be addressed. Drinking water of acceptable quality should be provided to homes with identified contaminated water above appropriate limits. A plan for a long term water supply for these residents is necessary.

Remediation of known sources should be initiated or continued if action is already taking place. This will reduce the possibility of continued contamination of the aquifer.



## 8.0 References

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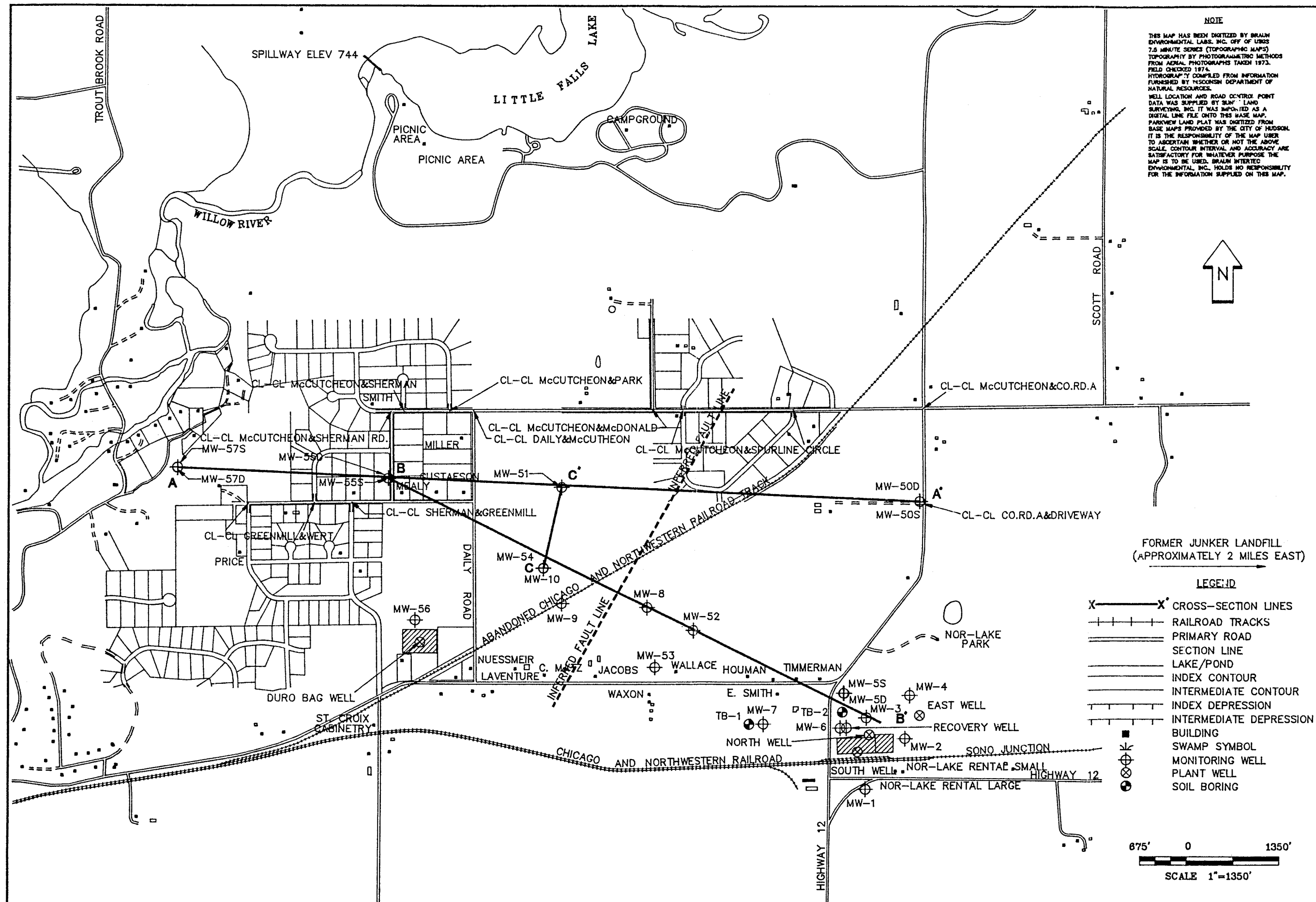
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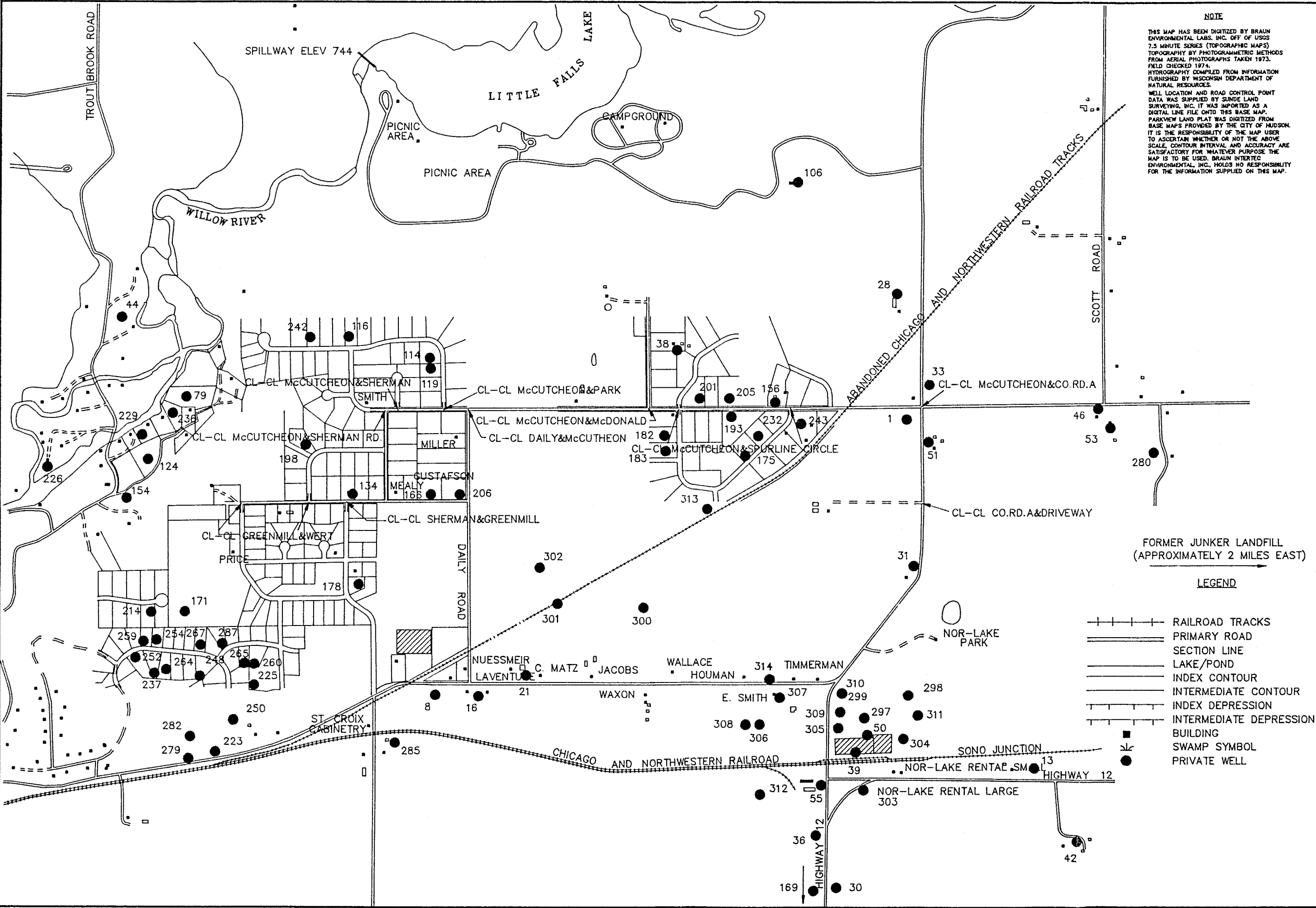


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STUDY AREA: MAP W/CROSS-SECTIONS AND FAULT  
In-Field Conditions Report  
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JOB No. CMKX-91-0118	
DWG No. MK10118B	
SCALE 1"=1350'	SHEET 2 OF 14

FIGURE # 2

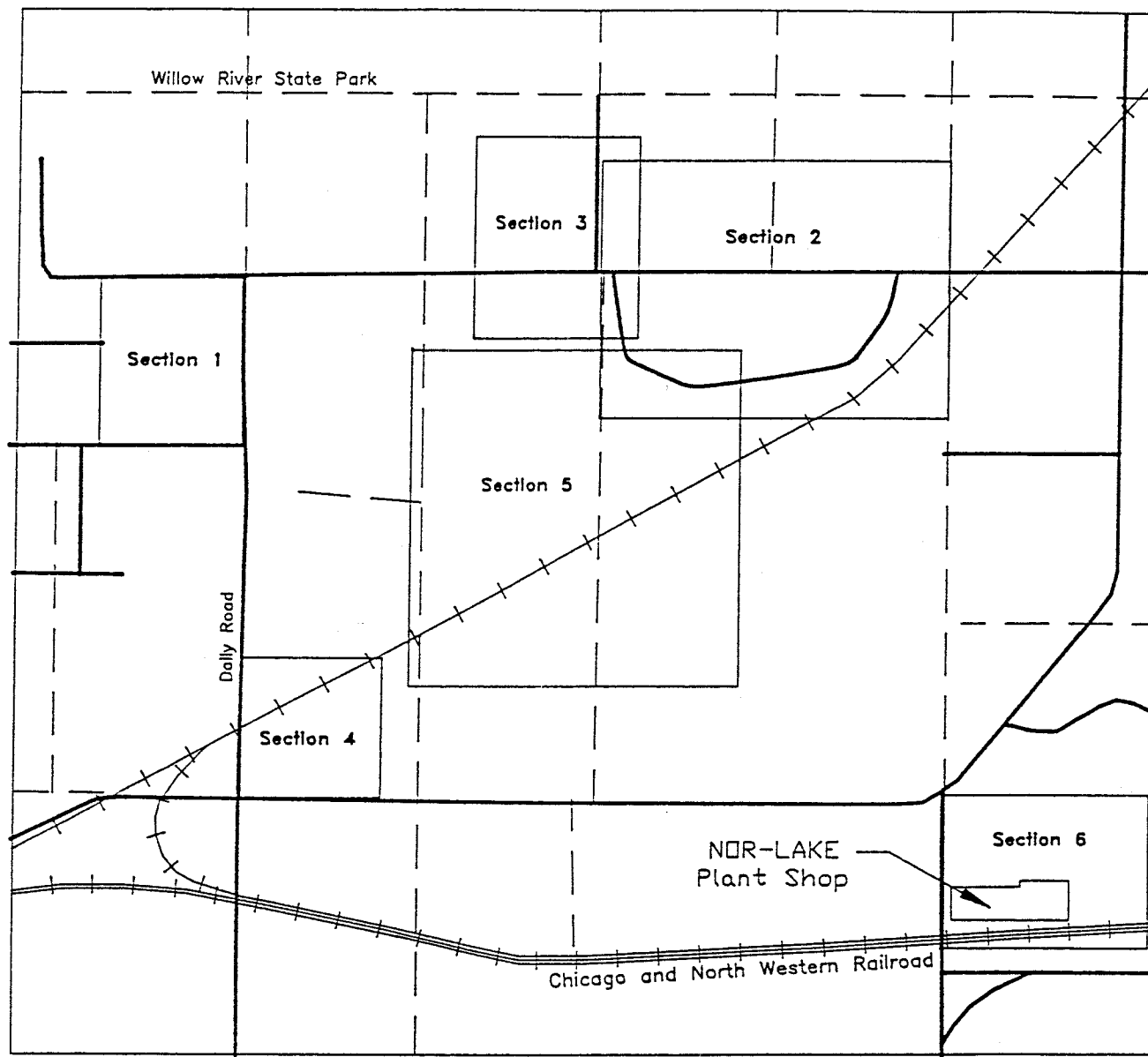


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WELL LOG MAP (REFER TO APPENDIX 2 WELL LOG FORMS)  
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APP'D BY: LMH			
JOB No. CMKX-91-0118			
DWG.No. MK10118B			

FIGURE # 3

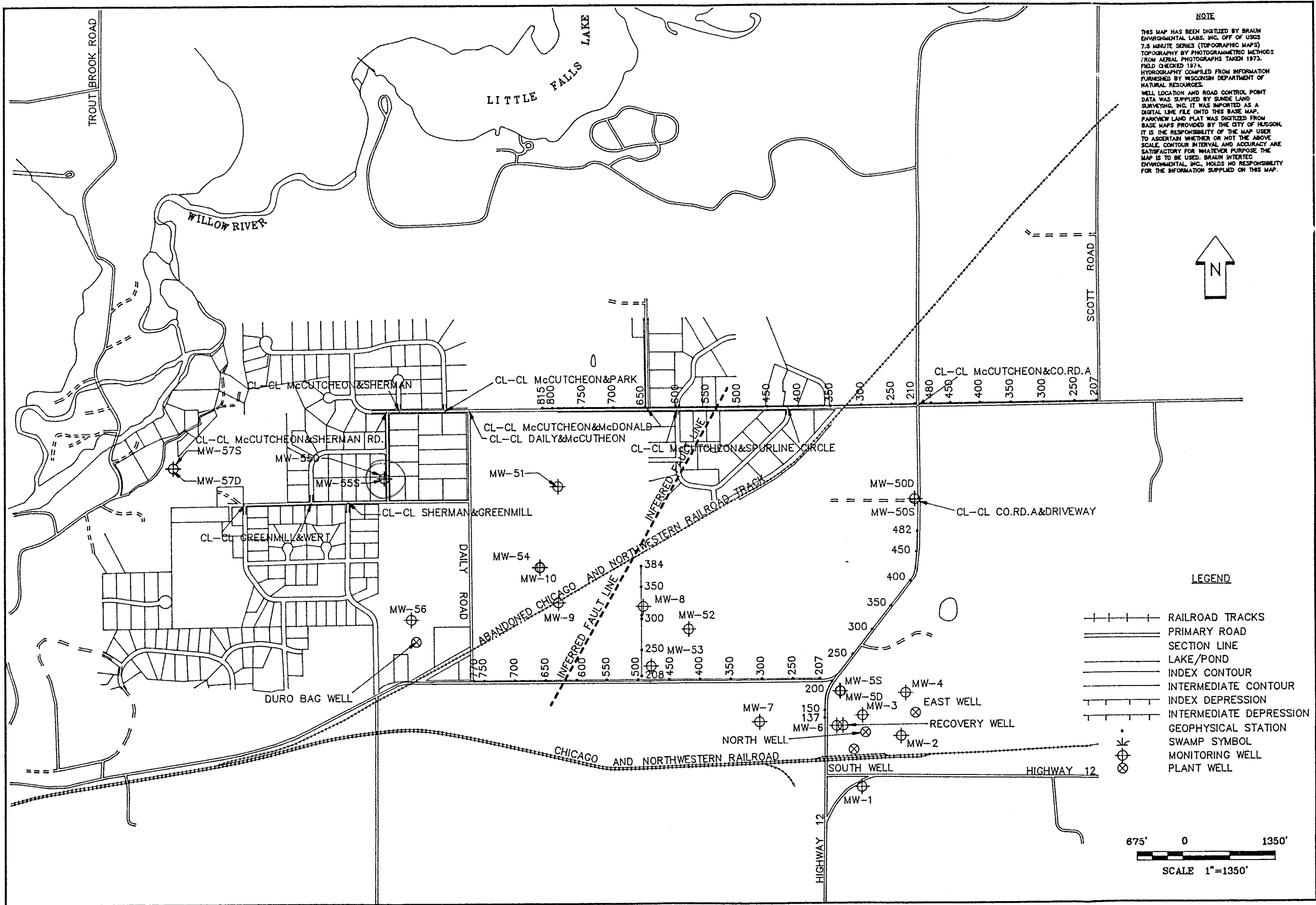


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PETREX SITE MAP  
(From Petrex Report March, 1992)  
Wisconsin Department of Natural Resources  
USGS Quads Northline/Somerset So.

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APP'D BY: LMH		OF
JOB No. CMKX-91-0118		14
DWG. No. MK10118	FIGURE #	
SCALE 1:24,000		4

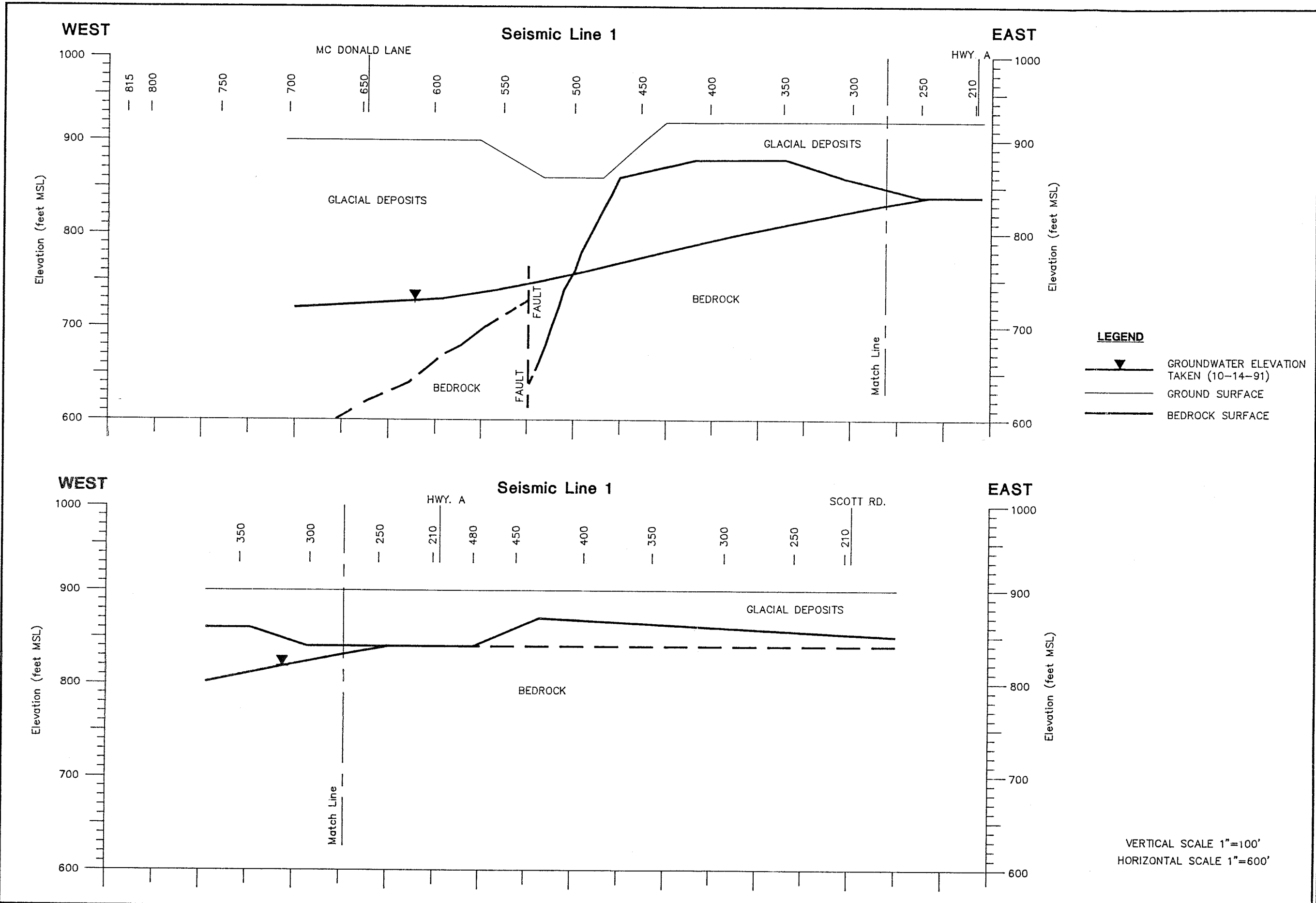




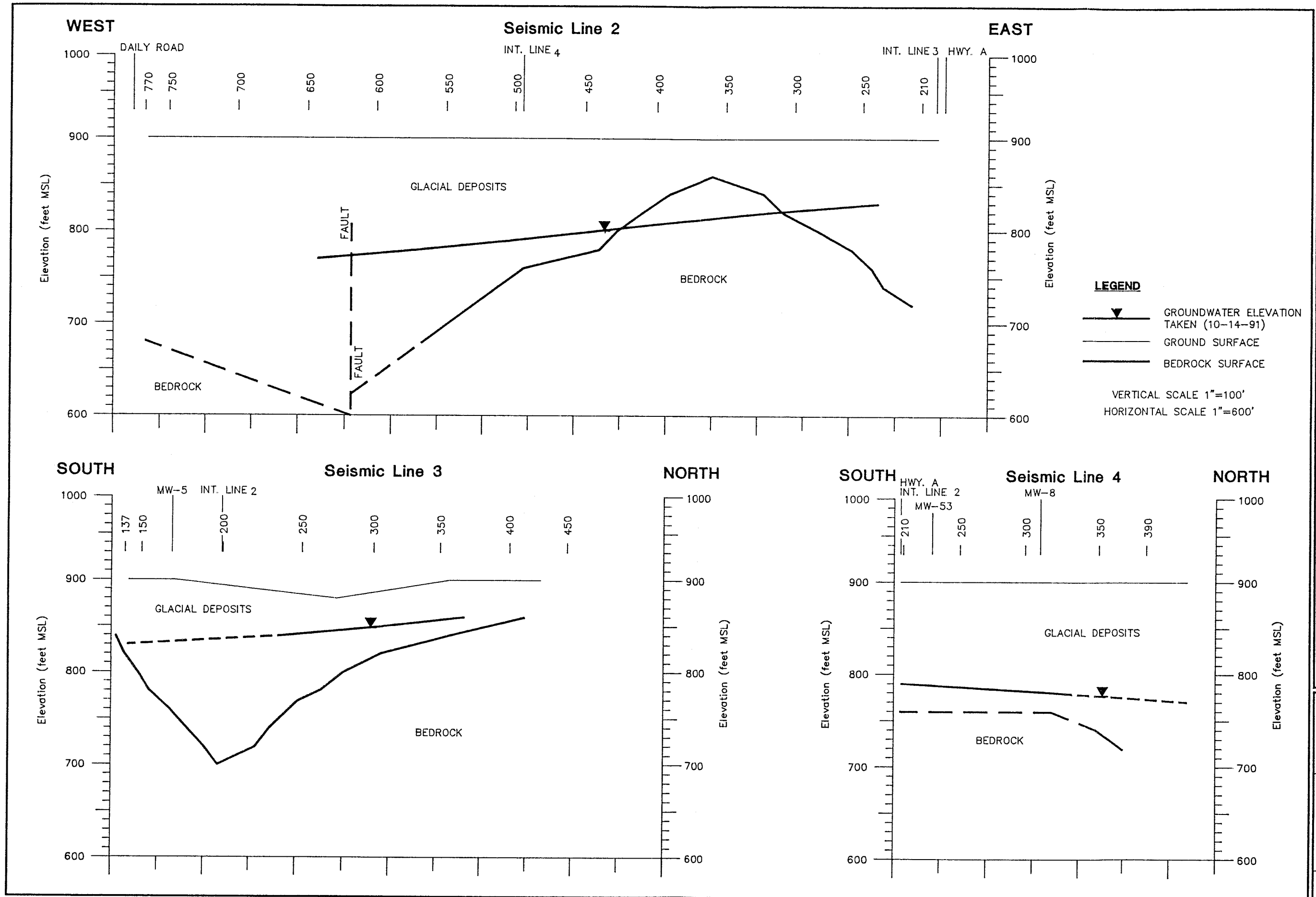
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GEOPHYSICAL LINES  
In-Field Conditions Report  
Wisconsin Department of Natural Resources  
USGS Quadrangles Northline & Somerset South

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INT	DATE
DRAWN BY: KMR	4-1-92
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DWG.No. MK10118T	SHEET OF
SCALE AS SHOWN	6 14

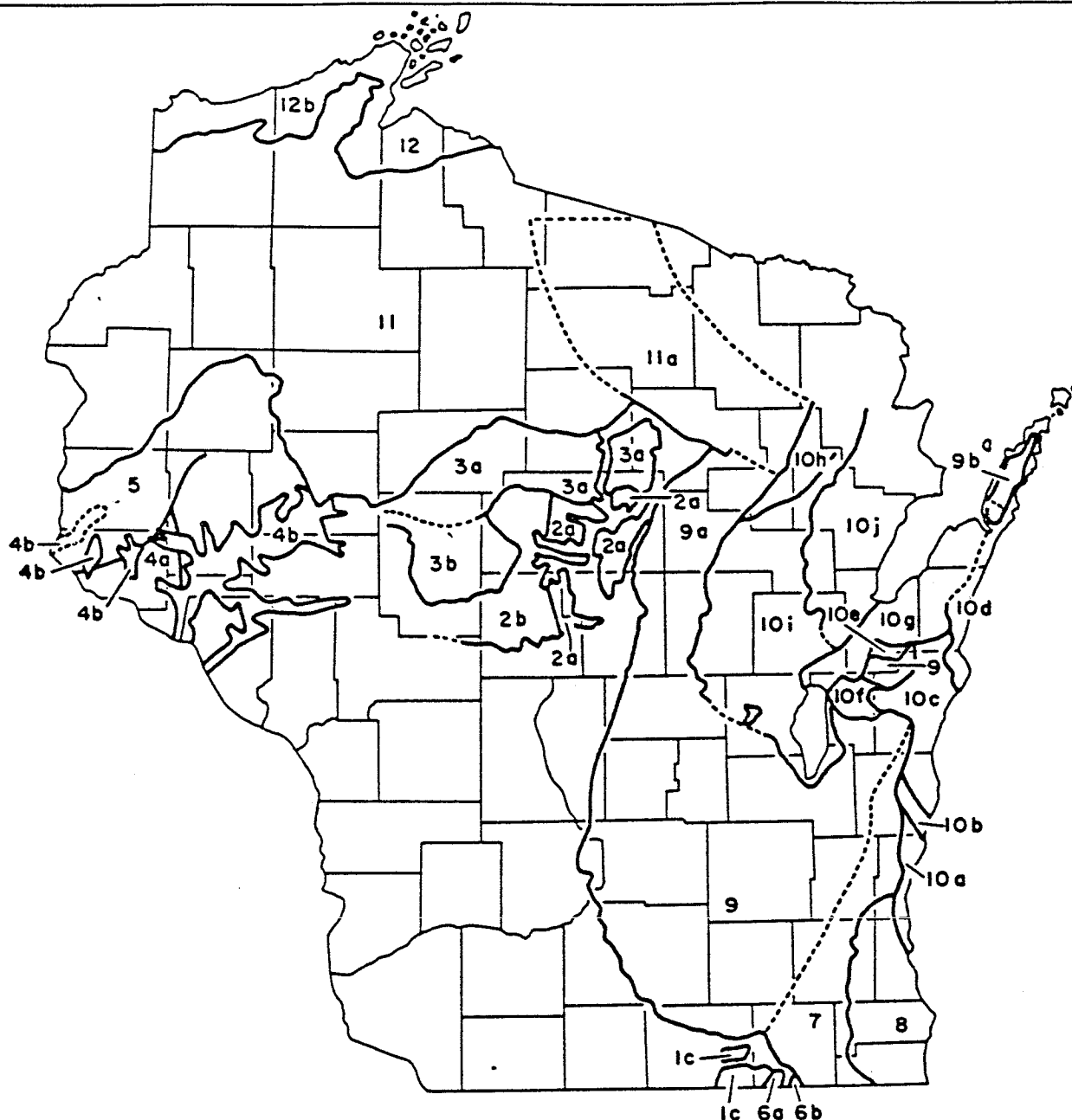


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SEISMIC LINES 2, 3 & 4 (BEDROCK BASED ON WELL LOG DATA)  
In-Field Conditions Report  
Wisconsin Department of Natural Resources  
USGS Quadrangle Somerset/Northline, Wisconsin

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JOB No. CMXX-91-0118	
DWG.No. MK10118T	SHEET OF
SCALE AS SHOWN	7 14

FIGURE # 7



Map of Wisconsin showing the surface distribution of named lithostratigraphic units. Number and letter designations used here correspond with appendix designations for named lithostratigraphic units. (1) Walworth Formation, 1c: Clinton Member; (2) Marathon Formation, 2a: Wausau Member, 2b: Edgar Member; (3) Lincoln Formation, 3a: Merrill Member, 3b: Bakerville Member; (4) Pierce Formation, 4a: Hersey Member, 4b: Kinnickinnic Member; (5) River Falls Formation; (6) Zenda Formation, 6a: Capron Member, 6b: Tiskilwa Member; (7) New Berlin Formation; (8) Oak Creek Formation; (9) Horicon Formation, 9a: Mapleview Member, 9b: Liberty Grove Member; (10) Kewaunee Formation, 10a: Ozaukee Member, 10b: Haven Members, 10c: Valders Member, 10d: Two Rivers Member, 10e: Branch River Member, 10f: Chilton Member, 10g: Glenmore Member, 10h: Silver Cliff Member, 10i: Kirby Lake Member, 10j: Middle Inlet Member; (11) Copper Falls Formation, 11a: Nashville Member; (12) Miller Creek Formation, 12a: Hanson Creek Member, 12b: Douglas Member.

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SURFICIAL LITHOSTATIGRAPHIC UNITS  
In-Field Conditions Report  
Wisconsin Department of Natural Resources  
USGS Quads Northline/Somerset So.

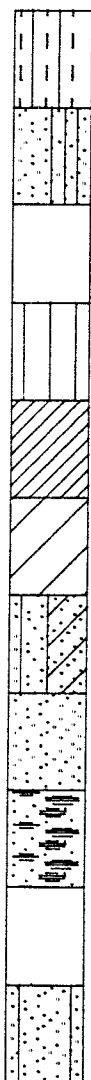
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APP'D BY: LMH		OF
JOB No. CMKX-91-0118		14
DWG. No. MK10118	FIGURE #	
SCALE 1:24,000		8

# Soil Column

# Abbreviation

# Description



OL

ORGANIC CLAY

SP-SM

POORLY GRADED SAND WITH SILT

GW-GM

WELL GRADED GRAVEL WITH SILT

ML

SILT

DOLOMITE

CL

LEAN CLAY WITH SAND

SC-SM

GRAVEL

SP

POORLY GRADED SAND

GW

WELL GRADED GRAVEL

GP-GM

POORLY GRADED GRAVEL WITH SILT

SM

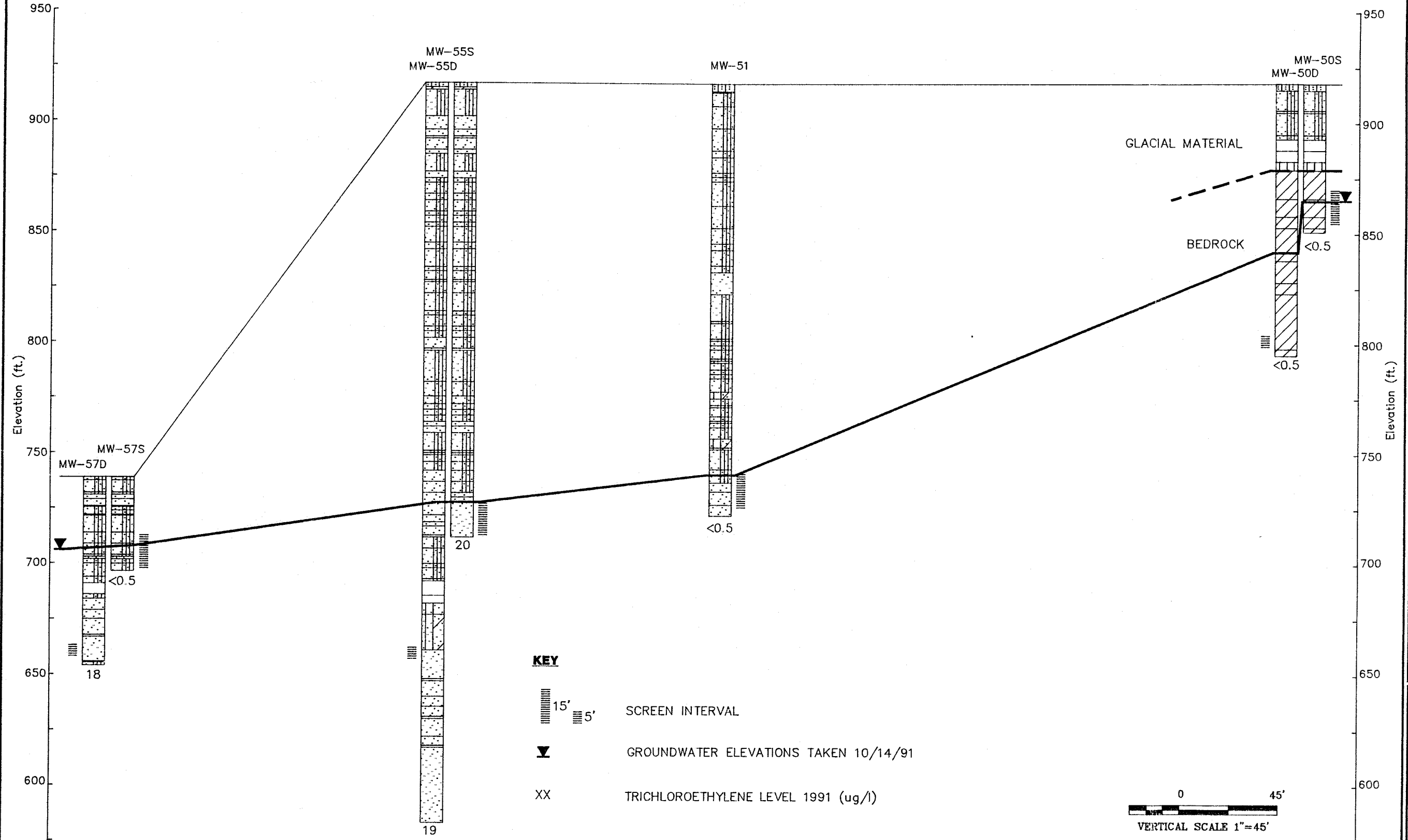
SILTY SAND

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WELL LOG SOIL CLASSIFICATIONS  
In-Field Conditions Report  
Wisconsin Department of Natural Resources  
USGS Quadrangles Northline & Somerset South

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DWG. No. MK10118I	FIGURE #	
SCALE NONE		9A

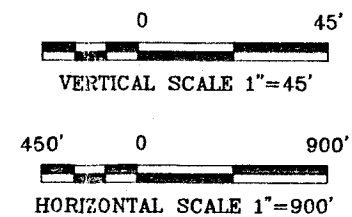
# GEOLOGICAL CROSS-SECTION A-A'



## KEY

- 15' 5' SCREEN INTERVAL
- ▽ GROUNDWATER ELEVATIONS TAKEN 10/14/91
- XX TRICHLOROETHYLENE LEVEL 1991 (ug/l)

NOTE: DETAILED BORING DESCRIPTIONS ARE FOUND IN APPENDIX 12.  
ALSO SEE FIGURE 9A SOIL CLASSIFICATION LEGEND.



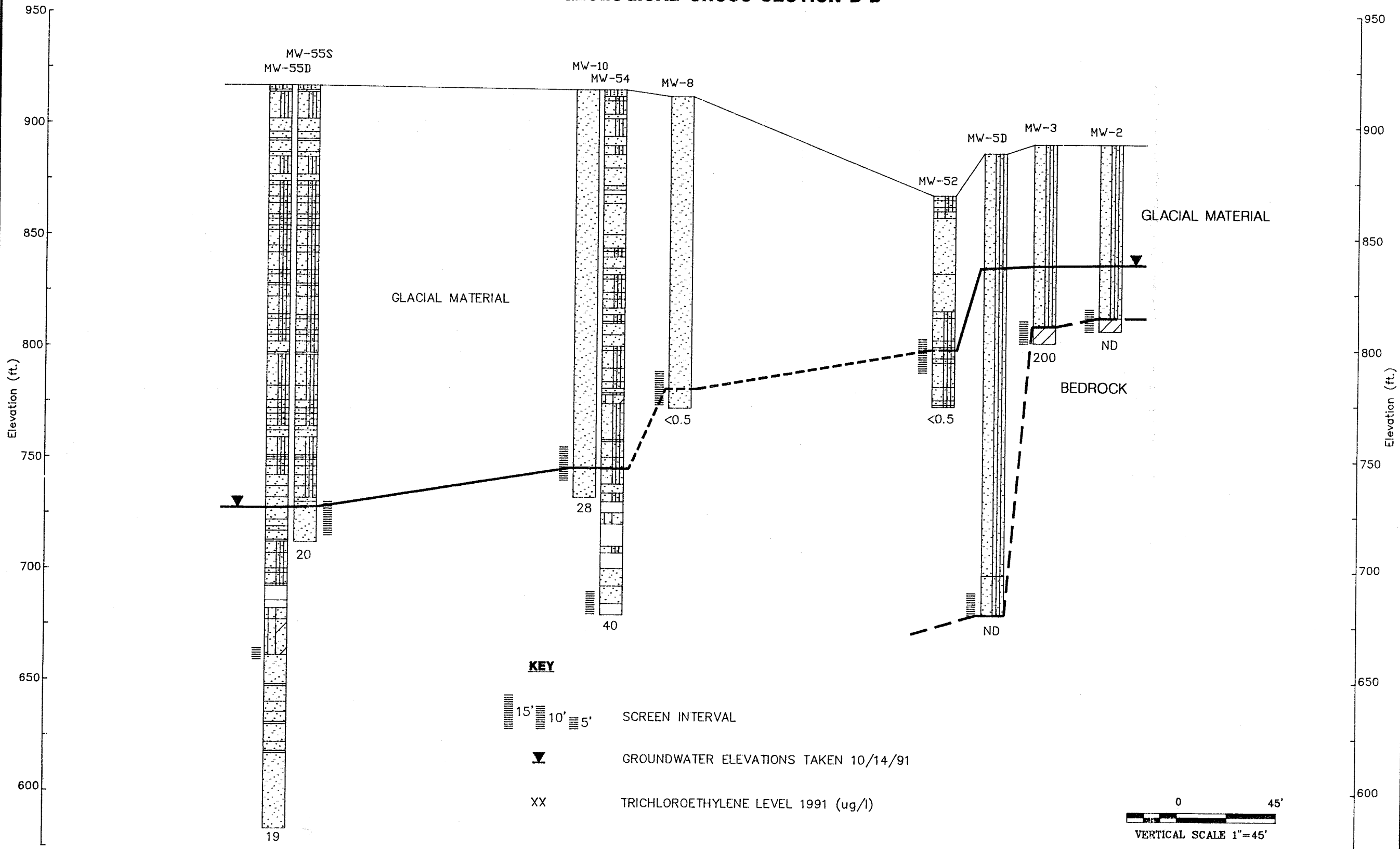
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GEOLOGICAL CROSS-SECTION A-A'  
In-Field Conditions Report  
Wisconsin Department of Natural Resources  
USGS Quadrangle Somerset/Northline, Wisconsin

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APP'D BY: LMH					
JOB No. CMKX-91-0118					
DWG.No. MK10118G					

FIGURE # 9

GEOLOGICAL CROSS-SECTION B-B'



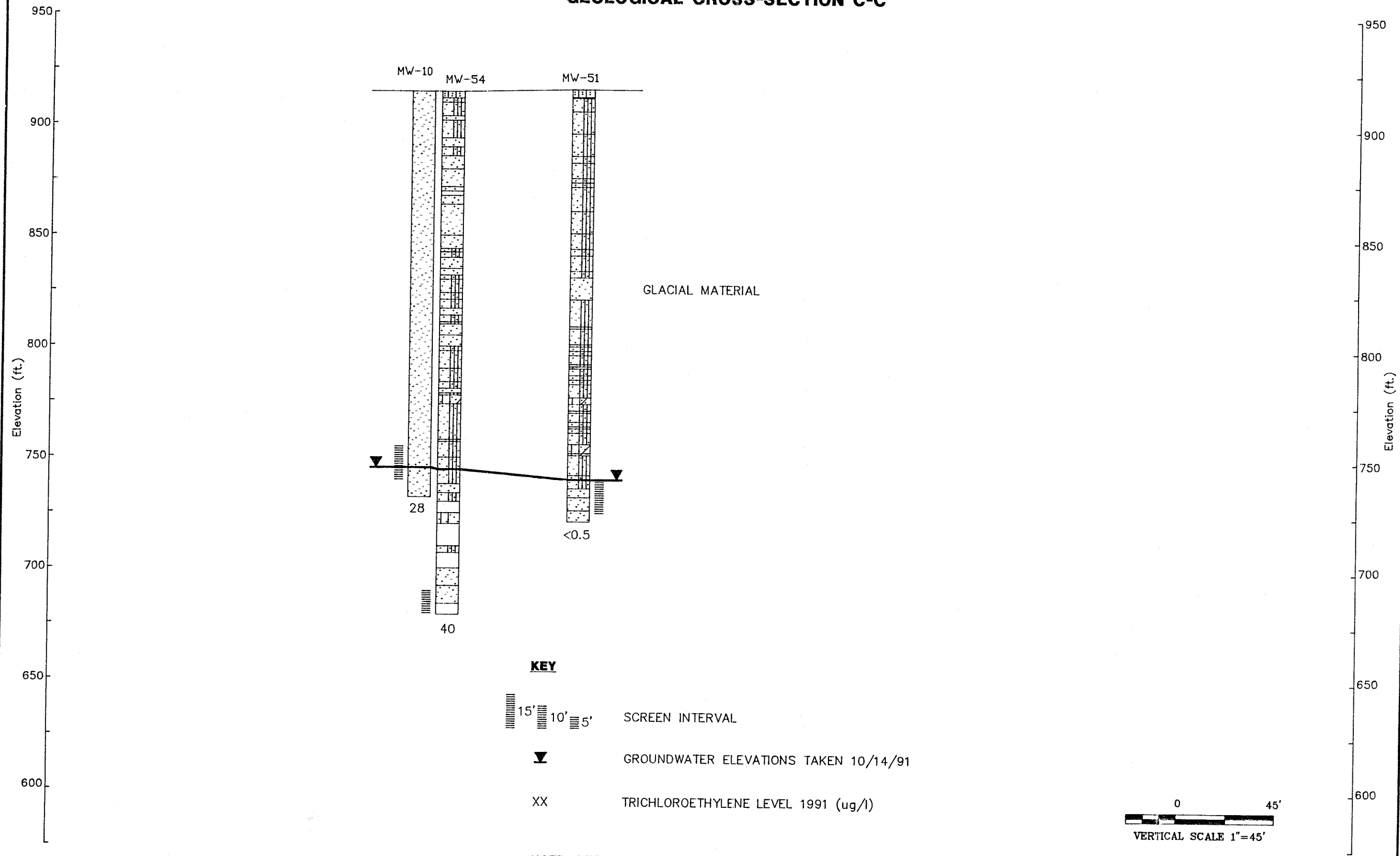
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GEOLOGICAL CROSS-SECTION B-B'  
In-Field Conditions Report  
Wisconsin Department of Natural Resources  
USGS Quadrangle Somerset/Northline, Wisconsin

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APP'D BY: LMH	
JOB No. CMXX-91-0118	
DWG.No. MK10118G	SHEET OF 14
SCALE AS SHOWN	10

FIGURE # 10

# GEOLOGICAL CROSS-SECTION C-C'



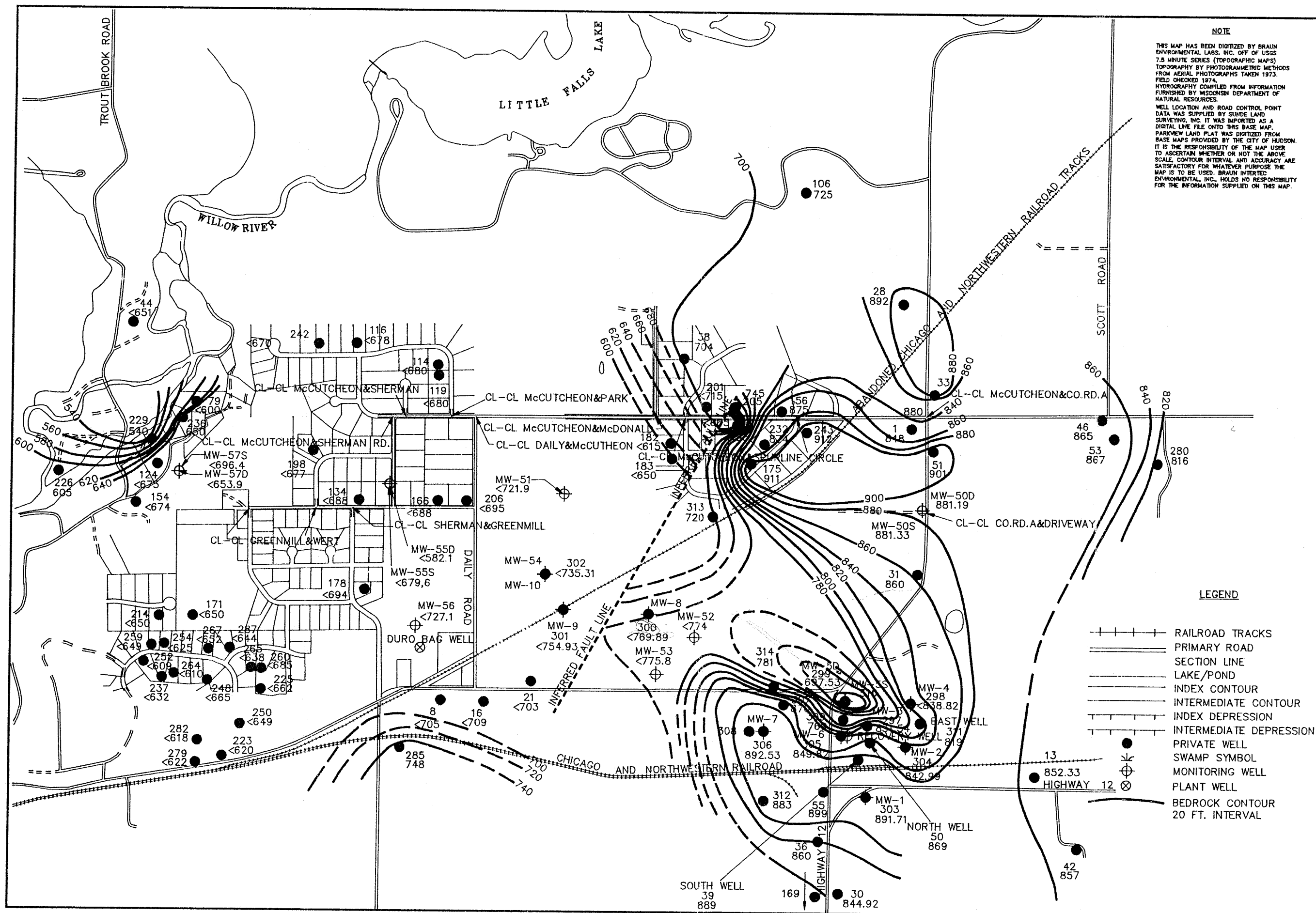
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GEOLOGICAL CROSS-SECTION C-C'  
In-Field Conditions Report  
Wisconsin Department of Natural Resources  
USGS Quadrangle Somerset/Northline, Wisconsin

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DRAWN BY: KMR	12-6-91
APP'D BY: LMH	
JOB No. CMKX-91-0118	
DWG.No. MK10118G	SHEET OF
SCALE AS SHOWN	11 14

FIGURE # 11





# NOTE

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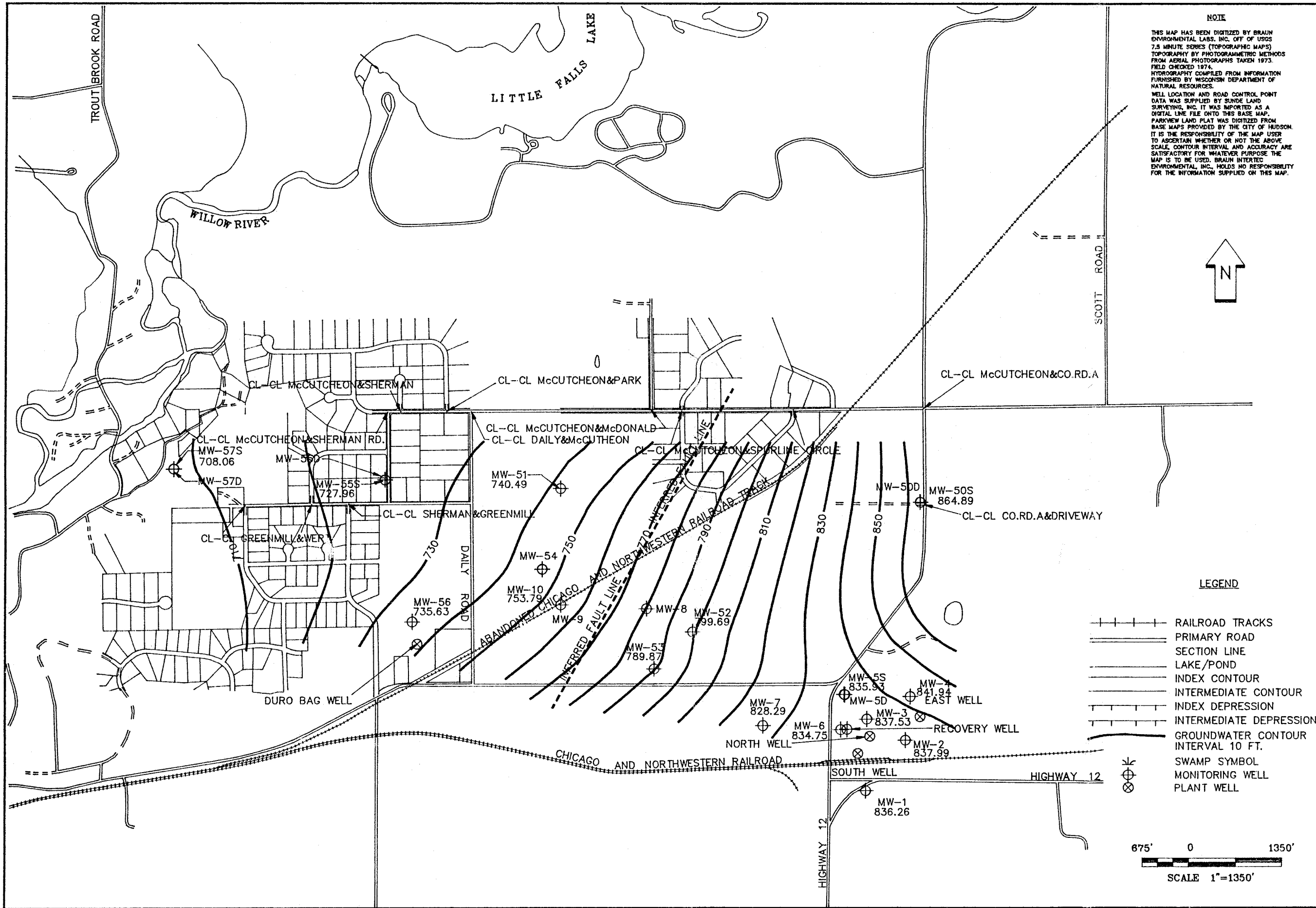
# LEGEND

- RAILROAD TRACKS
- PRIMARY ROAD
- SECTION LINE
- LAKE/POND
- INDEX CONTOUR
- INTERMEDIATE CONTOUR
- INDEX DEPRESSION
- INTERMEDIATE DEPRESSION
- PRIVATE WELL
- SWAMP SYMBOL
- MONITORING WELL
- PLANT WELL
- BEDROCK CONTOUR 20 FT. INTERVAL

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INFERRED BEDROCK ELEVATIONS (BASED ON WELL LOG DATA)  
In-Field Conditions Report  
Wisconsin Department of Natural Resources  
USGS Quadrangles Northline & Somerset South

INT	DATE	FIGURE #
DRAWN BY: KMR	4-3-92	12
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JOB No. CMKX-91-0118		
DWG.No. MK10118B		
SCALE 1"=1350'		



**NOTE**

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WELL LOCATION AND ROAD CONTROL POINT DATA WAS SUPPLIED BY SUNDE LAND SURVEYING, INC. IT WAS IMPORTED AS A DIGITAL LINE FILE ONTO THIS BASE MAP. PARKVIEW LAND PLAT WAS DIGITIZED FROM BASE MAPS PROVIDED BY THE CITY OF HUDSON. IT IS THE RESPONSIBILITY OF THE MAP USER TO ASCERTAIN WHETHER OR NOT THE ABOVE SCALE, CONTOUR INTERVAL AND ACCURACY ARE SATISFACTORY FOR WHATEVER PURPOSE THE MAP IS TO BE USED. BRAUN INTERTEC ENVIRONMENTAL, INC. HOLDS NO RESPONSIBILITY FOR THE INFORMATION SUPPLIED ON THIS MAP.



- LEGEND**
- RAILROAD TRACKS
  - PRIMARY ROAD
  - SECTION LINE
  - LAKE/POND
  - INDEX CONTOUR
  - INTERMEDIATE CONTOUR
  - INDEX DEPRESSION
  - INTERMEDIATE DEPRESSION
  - GROUNDWATER CONTOUR INTERVAL 10 FT.
  - SWAMP SYMBOL
  - MONITORING WELL
  - PLANT WELL

675' 0 1350'

SCALE 1"=1350'

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WATER TABLE ELEVATION (10-14-91)  
In-Field Conditions Report  
Wisconsin Department of Natural Resources  
USGS Quadrangles Northline & Somerset South

INT	DATE	FIGURE #
DRAWN BY: KMR	4-3-92	13
APP'D BY: LMH		14
JOB No. CMKX-91-0118		
DWG.No. MK10118B		
SCALE 1"=1350'		

# OSPHERE MIDWEST

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Seismic Reflection Survey Results  
Troutbrook/Parkview Estates Project  
North Hudson, Wisconsin

---

Prepared for  
Braun-Intertec Environmental, Inc.  
and  
Wisconsin Department of Natural Resources

December 3, 1991

### STATEMENT OF PURPOSE

The contents of this report are for use by the clients, Braun-Intertec Environmental, Inc. and Wisconsin Department of Natural Resources. The data contained herein, as well as all interpretations, inferences, and conclusions drawn, reflect Geosphere Midwest's commitment to the highest professional standards. Interpretations are not facts, however, and may be subject to ambiguities in some circumstances. Consequently, any decisions made on the basis of these data must allow for these inherent uncertainties.

All data, including this document, are the property of the clients, and may be used in the normal conduct of their business. However, publication of any of this material in professional journals, presentations, or any other public forum, must receive prior written authorization from Geosphere Midwest.

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## SUMMARY

A seismic reflection survey was conducted near the Troutbrook/Parkview Estates in North Hudson, Wisconsin by Geosphere Midwest, Inc. for Braun-Intertec Environmental, Inc. and the Wisconsin Department of Natural Resources. Field work for the project took place between November 27 and December 8, 1990. The purpose of the survey was to locate and define a suspected bedrock fault or any other geologic anomalies which might affect the migration of ground water contaminants in the area. Line locations are shown in Figure 1, along with contours of interpreted bedrock elevation.

Seismic reflection was selected for its unique ability to map structural and stratigraphic variations in near-surface geology. Data were recorded with a Bison Instruments 8024 "GeoPro" 24-channel seismograph, using a Bison Instruments "Elastic Wave Generator" to generate the source pulse. Data were processed on a microcomputer using software developed by the Kansas Geological Survey, supplemented by Geosphere Midwest software.

Figures 2 and 3 show the interpreted seismic time sections. The thicker line marks the interpreted top of bedrock, which appears on all four profiles. The thinner line on profiles 2 and 3 correlates fairly well with a dense glacial outwash unit encountered in well MW-5. The most prominent structural feature evident on the seismic profiles is the fault on lines 1A and 2, which was picked on the basis of a pronounced character change. Because of a very thick low-velocity layer we were unable to obtain a clear reflection event to the west of the fault, so the bedrock surface in this area is not certain. The pronounced flexure on line 1A near station 450 may be an expression of a second fault below the bedrock surface.

Line 2 shows an apparent channel centered at about station 450. The edges of the channel are indicated by a break in the bedrock reflector, but its sides and bottom cannot be accurately defined due to the narrowness of the feature. A similar feature has been interpreted on line 4, but the evidence on this line is much weaker. A somewhat broader channel appears on the eastern end of line 2 and on line 3. Additional evidence for this feature is the anomalous bedrock depth encountered in MW-5. This may be a buried alluvial channel flowing northwest toward the St. Croix drainage.

Figures 4 and 5 show the interpreted depth sections. Depth conversions were based on a velocity model derived from well data. These elevations are contoured in Figure 1. Because most of the contoured area is some distance from seismic or well control, much of the surface is not well constrained. Additional control, either seismic or drilling, would be necessary to better define the bedrock surface, especially the apparent buried channels.

Both the fault and the buried channels could have a bearing on the migration of ground water contaminants. While the location of the fault is fairly certain, the meandering nature of alluvial channels makes it difficult to discern their pattern any distance from the seismic lines. If these channels prove to have a significant effect on contaminant migration, their extent could be better defined with additional geophysical work.

## INTRODUCTION

A geophysical survey, consisting of four high-resolution seismic reflection profiles, was conducted near the Troutbrook/Parkview Estates in North Hudson, Wisconsin. The seismic data were acquired, processed, and interpreted by Geosphere Midwest, Inc. for Braun-Intertec Environmental, Inc. and the Wisconsin Department of Natural Resources. Field work for the project took place between November 27 and December 8, 1990.

### Goals

The purpose of the geophysical survey was to locate and define a suspected fault in the bedrock beneath the site, or any other geologic anomalies which might affect the migration of ground water contaminants in the area.

### Survey Design

Seismic reflection was selected for this project for its unique ability to map structural and stratigraphic variations in near-surface geology. Seismic line locations (see Figure 1) were determined on the basis of discussions between Phil Davis of Geosphere Midwest and LeeAnn Hammerbeck of Braun-Intertec.

### Method

A discussion of seismic methods is contained in Appendix A. Briefly, seismic reflection uses measurements of sound waves to determine subsurface structure, in a manner analogous to sonar. The time it takes for an echo from a subsurface layer to reach a surface receiver, when compensated for acoustic velocity and offset distance, gives an estimate of the depth to that layer. The recognition of very shallow layers is limited by the frequency bandwidth of the source signal, together with the complexities caused by large variations in near-surface seismic velocity. Generally, seismic reflection can map reflectors at depths of 30 to 50 feet or greater.

### Equipment

Data were recorded with a Bison Instruments 8024 "GeoPro" 24-channel seismograph. Input to the seismograph came from 24 Mark Products 40-hertz geophones, linked via two 12-channel electrical cables. The source pulse was generated with a Bison Instruments "Elastic Wave Generator" (EWG), a trailer-mounted mechanical hammer. Data were processed on an IBM-compatible microcomputer using software developed by the Kansas Geological Survey, supplemented by Geosphere Midwest software.



DATA ACQUISITION

The Geosphere Midwest field crew, consisting of James Traen and Steven Varberg, began collecting data on November 27, 1990. All four lines were along roads or driveways, so access was good. A certain amount of background noise was present, due to traffic along the roadways.

The survey began with a series of field tests to determine the optimum parameters for the site. The initial parameters chosen were:

Shot spacing: 18 feet  
Geophone spacing: 18 feet  
Minimum offset: 63 feet  
Maximum offset: 477 feet  
Sample rate: 0.5 millisecond

Lines 1 and 1A were acquired using these parameters. Because of the much deeper bedrock encountered toward the west end of line 1A, the offset distances were increased for the remainder of the lines. The following parameters were used for lines 2, 3, and 4:

Shot spacing: 18 feet  
Geophone spacing: 18 feet  
Minimum offset: 135 feet  
Maximum offset: 549 feet  
Sample rate: 0.5 millisecond

The field portion of the project was completed on December 8, 1990. A summary of data production for the survey follows:

<u>Line #</u>	<u># Records</u>	<u>Footage</u>
1	132	2,160
1A	298	5,148
2	276	4,752
3	168	2,808
4	<u>84</u>	<u>1,296</u>
	958	16,164

### DATA PROCESSING

Processing of shallow seismic reflection data requires reflected events to be separated from various types of non-reflections. Each 24-channel field record consists of the recorded ground motion from 24 geophones, at increasing distances from the seismic source. The travel time from source to geophone increases with distance, with the rate of increase determined by the velocity of the earth along the travel path. The goal of seismic reflection processing is to convert these field records into a cross-section format, where each seismic trace represents the acoustic response of the earth at a given surface location.

Five processes form the core of the seismic reflection processing sequence:

- sorting,
- muting,
- gain correction,
- normal moveout (NMO) correction, and
- stacking.

Sorting involves reordering the individual seismic traces from field records into common midpoint groups. Traces from different shots with common source-receiver midpoints are assumed to represent the same subsurface location. Each common midpoint (CMP) gather consists of traces with varying offsets, each from a different shot-receiver pair. (The term "common depth point", or CDP, is widely used in the seismic industry. Since depth points are dependent on subsurface structure as well as source-receiver configuration, the term "common midpoint" is more accurate, and is gaining in recognition and usage. The two are otherwise synonymous.)

Muting of non-usable portions of the data is critical to the success of shallow reflection processing. Many non-reflections are stronger than reflections, and would swamp the desired data were they not removed by proper muting. Excessive muting can be even worse, as reflections can be lost by injudicious application of this numerical cleaver.

Gain correction compensates for the decrease in amplitude of events with travel time. Methods vary, but the most common involves some kind of automatic gain control (AGC), where event amplitudes are increased or decreased to fall within a prescribed range.

Normal moveout correction compensates for the increase in travel time with horizontal offset. Using input velocities, a correction can be determined which brings a given event up in time to a point equivalent to a vertical travel path. If the correction is properly applied, a given event will occur at the same travel time on all traces within a CMP gather, and will appear "flat". Other events, such as multiple reflections, diffractions, and coherent and random noise, will not be corrected to a flat event, and will be attenuated in the stacking process.

"Stacking" is simply the summing of all traces within a CMP gather into a single trace. Events which have been corrected to "flat" will be significantly enhanced, while others will be reduced in relative amplitude. The final seismic section is simply a series of such summed traces from adjacent CMP locations. Each trace on the time sections shown in Figures 2 and 3 represents the sum of six individual field traces, yielding 6-fold CMP data.

In practice, seismic processing can be extremely tricky. It requires experience to correctly identify reflectors, analyze velocities, and subsequently interpret the resulting seismic section. Shallow reflection is even more difficult than deep reflection, and requires even more "hands on" processing. When properly done, however, a seismic section provides a wealth of information not available from any other method.

## INTERPRETATION

### General Aspects of Reflection Interpretation

In principle, a seismic reflection section is a series of vertical graphs of ground motion. Each graph, or seismic trace, represents the ground motion over some time following the source impact. (The black bands result from the filling in of half the graph, to aid interpretation.) When the seismic wave traveling downward from the source encounters a change in layers, part of that energy echoes back to the surface. On the seismic trace, this is recognizable as a strong kick on the graph, which will appear on the overall section as a continuous black band. Since the vertical scale is time (in milliseconds) the actual depth to the interface depends on the distribution of sound velocities in the overlying layers, which can be fairly complex. In the present survey, data from water wells, monitoring wells, and soil borings were used to convert travel time to depth.

### Depth Conversion

The reliability of seismic depth estimates depends entirely on the quality of seismic velocity information. While velocity estimates can be derived from the seismic data, these are not as reliable as those obtained by correlation with wells or other independent geologic control. For this reason, the finalization of this report was deferred, at the request of Braun-Intertec, until the 1991 drilling program was completed, to allow the incorporation of new data into the interpretation. Data from the new wells (MW-A through MW-H), previously drilled monitoring wells, and a number of residential water wells were provided by Braun-Intertec personnel. Also provided were the results of a seismic refraction survey conducted in 1986 by Bison Instruments.

The refraction velocity data fall into three distinct groups. The top layer velocity varies from about 900 to 1500 feet/second. This velocity is typical of dry, unconsolidated sand or soil. A second layer, with a velocity ranging from 1700 to 2400 feet/second, occurs at a depth of between 15 and 50 feet. This would be a slightly more compacted, but still

dry, unconsolidated unit. The third layer velocity varies between 6000 and 8800 feet/second, and probably represents bedrock. A water table is noted in nearby wells, but is probably too close to bedrock to be recognizable on the refraction data.

Well data were used to obtain estimates of water table elevation, and to correlate the top of bedrock with the seismic reflection data. While a few wells on the east side of the survey area hit bedrock, there were no usable bedrock elevations toward the west. Consequently, the depth conversions of the western half of lines 1A and 2 are somewhat speculative.

Based on the refraction and well data, we obtained the following velocity model:

<u>Depth</u>	<u>Velocity</u>
0' - 30'	1200 ft/sec
30' - WT	2000 ft/sec
WT - LU	6000 ft/sec
LU - BR	8000 ft/sec (where present)

WT = water table elevation indicated by wells

LU = lower unconsolidated unit identified on lines 2 and 3

BR = bedrock surface defined by seismic reflection profiles

The depth model above was inverted to two-way seismic travel time to allow conversion of the seismic reflection events to depth.

### Survey Interpretation

Figures 2 and 3 show the interpreted seismic time sections. The depth scale on the right is a generalized version of the velocity model given above, but does not account for variations in the water table or lower unconsolidated unit. The thicker line represents the interpreted top of bedrock, which appears on all four profiles. The thinner line on profiles 2 and 3 correlates fairly well with a dense glacial outwash unit identified in well MW-5. Because MW-5 does not coincide perfectly with the seismic lines, the velocity of this unit is speculative.

The major structural feature is the fault identified on lines 1A and 2. The fault was picked on the basis of a pronounced character change on both lines at the interpreted fault position. Because of a very thick low-velocity layer (100 to 150 feet or more) we were unable to obtain a clear reflection event to the west of the fault, so the interpretation of the bedrock surface in this area is not particularly reliable. The pronounced flexure on line 1A at about station 450 may be an expression of a second fault below the bedrock surface.

Line 2 shows a pronounced trough or channel centered at about station 450. The edges of the channel are indicated by a break in the bedrock reflector, but its sides and bottom cannot be accurately defined due to the narrowness of the feature. A similar feature

has been interpreted on line 4, but the evidence on this line is much weaker. The bedrock reflector is less coherent on line 4, suggesting a somewhat broken or undulating surface. This may be due to the proximity of the fault.

A somewhat broader channel appears on the eastern end of line 2 and toward the southern end of line 3. Additional evidence for this feature is the anomalous bedrock depth encountered in MW-5. The northwest trend of this feature seems well defined in this area, but it is unclear whether this trend continues further northwest. This may be a buried alluvial channel flowing northwest toward the St. Croix drainage.

Figures 4 and 5 show the interpreted depth sections. Lines 1 and 2 are reversed from the time sections, to follow conventional cross-section presentation. (Our seismic data plotting software does not permit reversing the display direction for the time sections.) Elevation control was based on a topographic base map provided by Braun-Intertec. The water table was inferred from well data. Depth conversions were made every 10 stations, using the velocity model described above.

The bedrock elevations displayed in Figures 4 and 5 are contoured in Figure 1. Because most of the contoured area is some distance from seismic or well control, much of the surface is not well constrained. Additional control, either seismic or drilling, would be necessary to better define the bedrock surface, and in particular the apparent channels evident on lines 2 and 3.

### CONCLUSIONS AND RECOMMENDATIONS

Two significant structural features were identified by the seismic reflection profiles, both of which could have a bearing on the migration of ground water contamination. First, the northeast-southwest trending fault is a major disruption in the bedrock surface, with corresponding effects noticeable in the water table. Second, two apparent buried channels were identified, which would have a major impact on the flow of any heavier contaminants.

While the location of the fault is fairly certain, the meandering nature of alluvial channels makes it difficult to discern their pattern any distance from the seismic lines. If these channels prove to have a significant effect on contaminant migration, it would be important to better define their extent. This might involve additional seismic reflection, drilling, or perhaps other geophysical techniques.

# GEOSPHERE MIDWEST

8 | 9  
17 | 16

9 | 10  
16 | 15

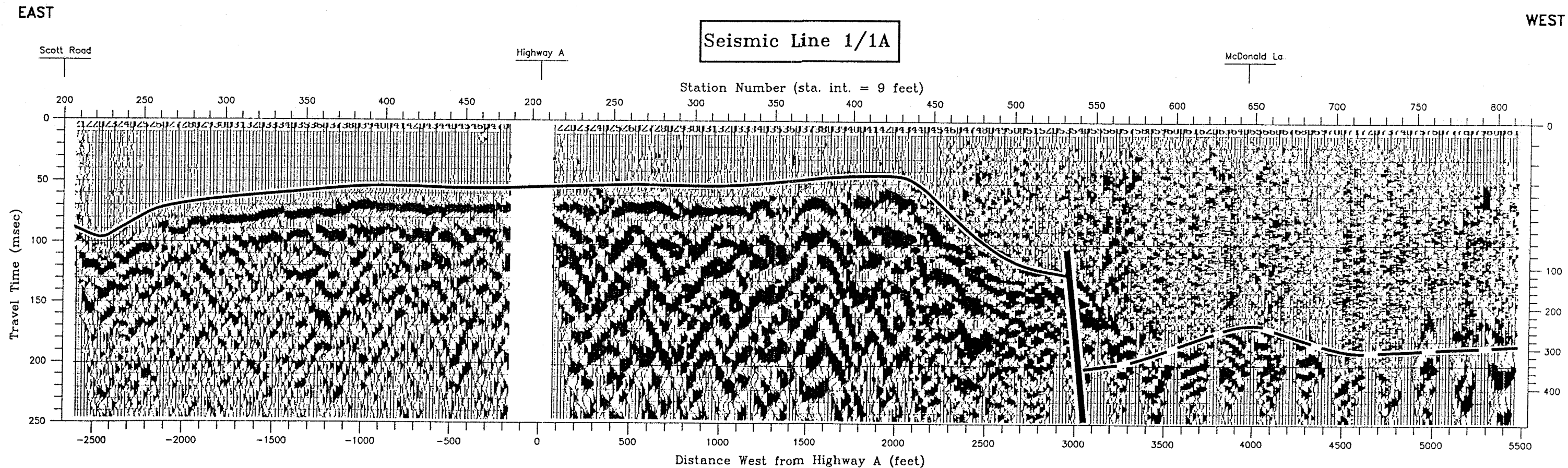
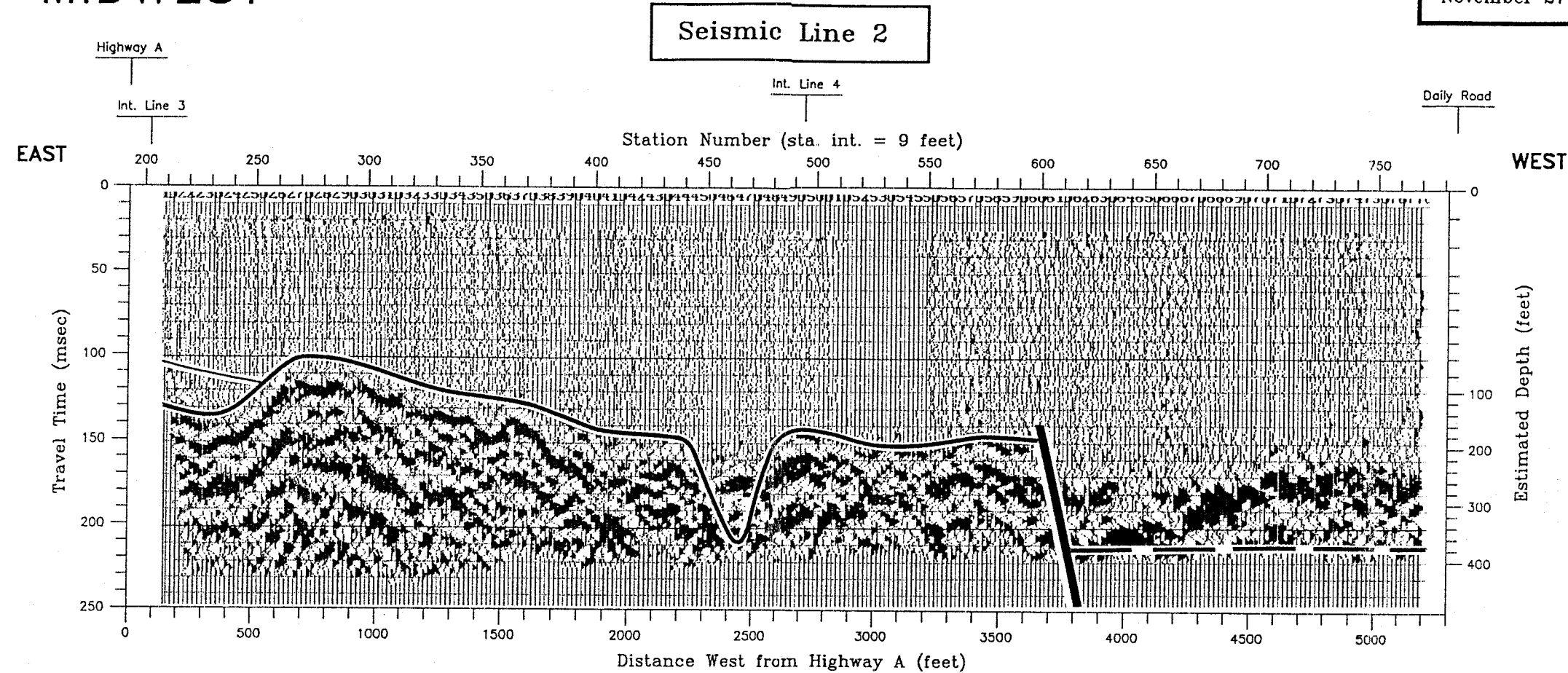


Figure 1: Seismic Reflection Line Location Map  
with Bedrock Surface Elevation Contours  
Contour Interval 20 feet MSL  
North Hudson, Wisconsin, 11/27 - 12/8, 1990

2534

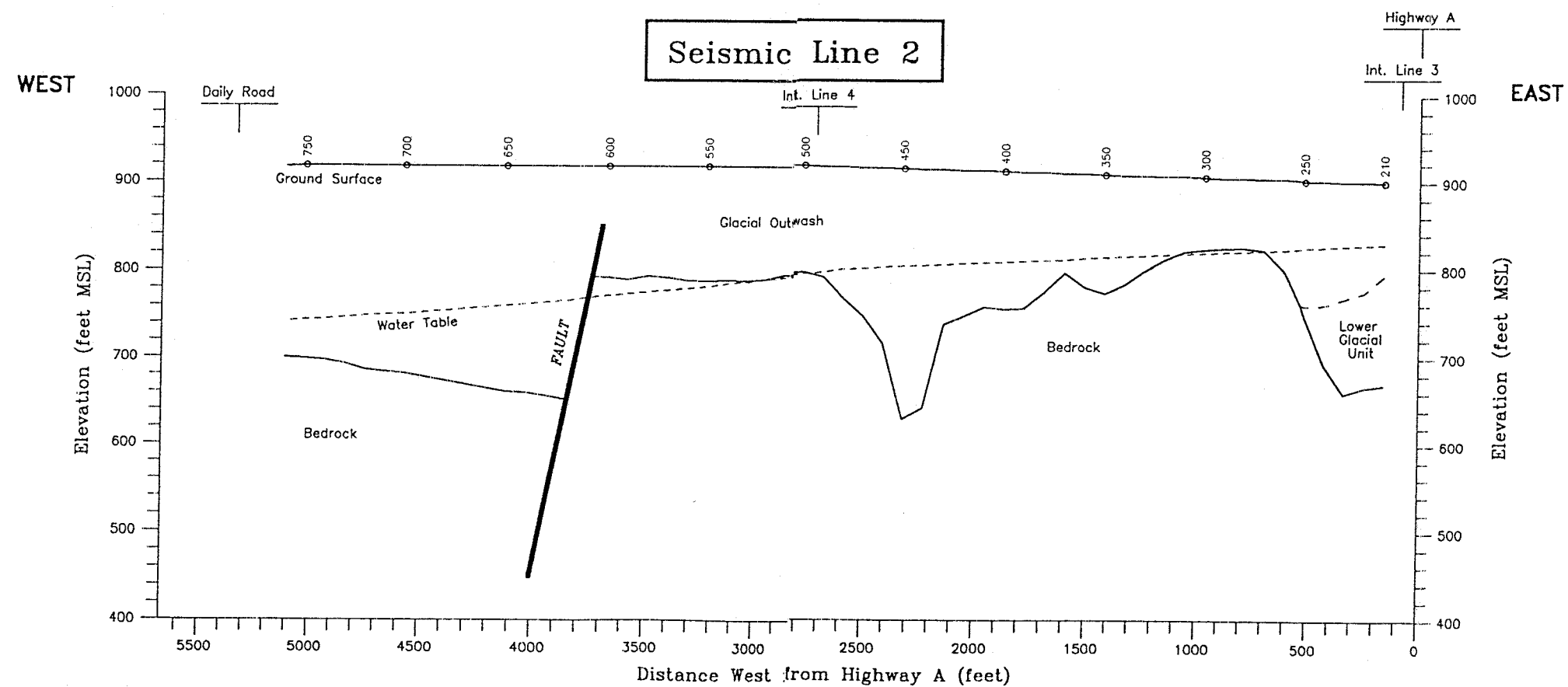
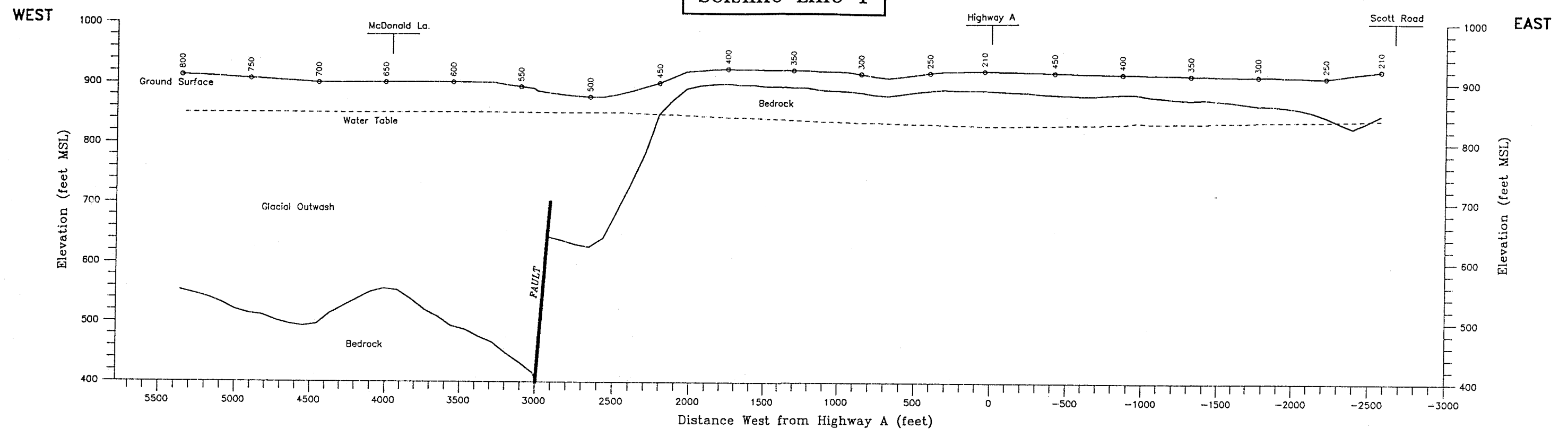
GEOSPHERE MIDWEST

Figure 2: Seismic Time Sections 1 and 2  
North Hudson Seismic Reflection Survey  
November 27 - December 8, 1990



# GEOSPHERE MIDWEST

Figure 4: Interpreted Depth Sections 1 and 2  
North Hudson Seismic Reflection Survey  
November 27 - December 8, 1990





# GEOSPHERE MIDWEST

Figure 5: Interpreted Depth Sections 3 and 4  
North Hudson Seismic Reflection Survey  
November 27 - December 8, 1990

