Wisconsin Geological
and Natural History Survey
DIVISION OF EXTENSION
UNIVERSITY OF WISCONSIN–MADISON

Evaluation of Geology and Hydraulic Performance of Wisconsin Ground-Water Monitoring Wells

Final report to the Wisconsin Department of Natural Resources
DNR Project No. 135
July 1, 1997 to April 30, 1999

James M. Rauman[a], Bernard R. Ellefson[a], Alexander Zaporozec[b]

[a] U.S. Geological Survey

[b] Wisconsin Geological and Natural History Survey

Open-File Report 1999–08 | 1999

Evaluation of Geology and Hydraulic Performance of Wisconsin Ground-water Monitoring Wells

James M. Rauman, Bernard R. Ellefson, and Alexander Zaporozec
April 1999

Introduction

The Wisconsin Geological and Natural History Survey (WGNHS) in cooperation with the U.S. Geological Survey (USGS) has maintained a ground-water observation-well network since 1946 (Zaporozec, 1996). The purpose of the network is to relate short-term changes and long-term trends in ground-water levels to changes in storage of ground-water aquifers and provide data needed for ground-water research and effective management of ground water resources in Wisconsin.

Currently, water levels are measured in approximately 140 observation wells. Water-level measurements along with associated geologic and well construction data are stored in a computer database. These data are available to the public upon request. Representing regional areas of Wisconsin, 16 wells have been selected to have their water levels updated monthly on the World Wide Web (http://wwwdwimdn.er.usgs.gov/gw/). All of the wells in the ground-water network are updated at this web address annually. For more information call Bernie Ellefson, USGS, 608/821-3849; or Alex Zaporozec, WGNHS, 608/262-3385.

Interpretation of water-level measurements from approximately 30% of network wells is difficult because descriptions of geologic units and estimates of hydraulic conductivity are not available. Identification of the geologic units tapped and estimates of their hydraulic conductivity will increase the value of these measurements. In July 1994, WGNHS in cooperation with the USGS initiated a two-year study to obtain these data (Dunning and others, 1996). Accessible wells (wells that could be tested or logged) were identified from the ground-water observation-well network. The study obtained geophysical data and estimates of hydraulic conductivity on 37 observation wells based on their regional representation of the state. These data suggested that 30% of the selected wells had very slow to no response to the displacement/recovery tests and may have a poor connection with the aquifer. Results of this study warranted investigation of the remaining 16 accessible wells in the network. In July of 1996 the Wisconsin Department of Natural Resources (WDNR), WGNHS and USGS cooperatively funded a study to obtain data from the remaining accessible wells. Funding from the WDNR came from the ground water account of the Environmental Fund (DNR Project No 135).

Selection of Wells

Wells selected for this study included the remaining observation wells identified as accessible for testing during the previous project (1994-1996) and some additional network wells identified later. From the 19 wells included in the project proposal, three wells (BR-46, ML-148 and ON-22) could not be tested because they were found to be sealed. The 16 tested wells are listed in Table 1. One well, WS-8, which was tested in the previous project, was re-tested as part of the quality control of results. The tested wells range in depth from 13 to more than 350 feet. Most of them are in the sand and gravel aquifer (11 wells); one well is open to the Silurian dolomite aquifer, one to the Galena-Platteville dolomite and three to the sandstone aquifer (Table 1).

Site-Identification System

A local number based on the cadastral-survey system of the U.S. Government (well) identifies each network site. The number consists of an abbreviation of the county name, township, range, and section, and a unique four-digit number assigned to the well. For example, the well with the local number BN-24/20E/18-0013 is in Brown County (BN), township 24 north, range 20 east, section 18, and has sequence number 0013. The location of the 16 wells that are a part of this study are identified on Figure 1 using an abbreviated local well number, which includes only the county abbreviation and the well sequence number.

Methods

Geophysical logs - caliper, natural gamma, spontaneous potential, and single-point resistivity - were run in the wells, where it was possible, which could help interpret geologic units in a wellbore. A Mount Sopris MGX Digital Logger was used for geophysical logging. Methods of logging and interpretation are described in Keyes and MacCary (1971).

The hydraulic conductivity of geologic units tapped by the wells were estimated by displacement/recovery tests (slug tests). A slug test is conducted by displacing the static water level in a wellbore by quickly adding to, or removing from, the water a solid volume (the slug). The rate at which the water level returns to static is controlled by formation characteristics. Hydraulic conductivity was estimated from slug tests using the Hvorslev method (Hvorslev, 1951).

Results and Discussion

The data that have been collected or compiled during the course of this study are listed in Table 1. Geophysical logs were obtained from 9 of the 16 selected network wells, and are presented on single-page well reports in the appendix. Displacement/recovery tests were conducted in all 16 of the wells. Well construction information and the results of tests are listed in Table 1 and presented on the single-page well reports in the appendix. Displacement/recovery tests provided reliable data for estimation of hydraulic conductivity for 9 wells, 7 wells exhibited very slow recovery during the test. Slow recovery in well SK-3 is believed to be due to low formation conductivity, the other 6 are interpreted to have a poor hydraulic connection with the aquifer.

The 6 wells that exhibited very slow recovery due to poor hydraulic connection (indicated by an asterisk in Table 1 and included in Table 2) are open to sand and gravel units. Wells open to sand and gravel units would be expected to exhibit quick recovery during the tests, so these 6 are probably restricted due to encrustation of the well screen, plugging of the well screen by fines, or collapse of the well casing. These problems frequently occur with older wells. These 6 wells include some of the oldest wells in the network, 5 were constructed between 1937 and 1956. However, there are 6 other similarly aged wells for which reliable estimates of hydraulic conductivity was made, so well age is not necessarily the primary factor. Regardless, the usefulness of the 6 slow recovering wells for showing short-term changes in water level are doubtful, and their usefulness for reflecting long-term trends may be questionable.

Recommendations

Based on the findings of this project, the following recommendations are made.

Finding a high percentage (~ 30 %) of the tested wells that appear not to have a good hydraulic connection with the aquifer, these wells should be repaired or replaced with one of suitable size so that a good hydraulic connection is established between the well and the geologic unit it taps. This will improve the efficiency and quality of the network, and optimize the use of project funds.

Detailed interpretation of the geophysical logs should be made to provide additional useful information such as depths and thickness of geologic formations.

All accessible network wells should be tested on a regular basis (for example every five years) to ensure that they are in good hydraulic connection with the geologic unit.

Cited References

Dunning C. P., Ellefson B. R., and Zaporozec A., 1996, Collection of hydraulic and geologic data to improve the quality of the Wisconsin observation-well network: WGNHS/USGS report to Wisconsin DNR on project no. 118, 44 p.

Hvorslev M. J., 1951, Time lag and soil permeability in ground-water observations: U.S. Army Corps of Engineers, Waterways Experimental Station, Bulletin 36, 50 p.

Keyes W. S., and MacCary L. M., 1971, Application of borehole geophysics to water-resources investigations: Techniques of Water-Resources Investigations of the Unites States Geological Survey, Book 2, Chapter E1, 126 p.

Zaporozec A., 1996, Wisconsin ground-water observation-well network, 1946-95 : Wisconsin Geological and Natural History Survey Educational Series 40, 13 p.

Figure 1. Location and measurement frequency of the 16 tested observation wells. Well location in the county is indicated by the center of the letter representing measurement frequency.

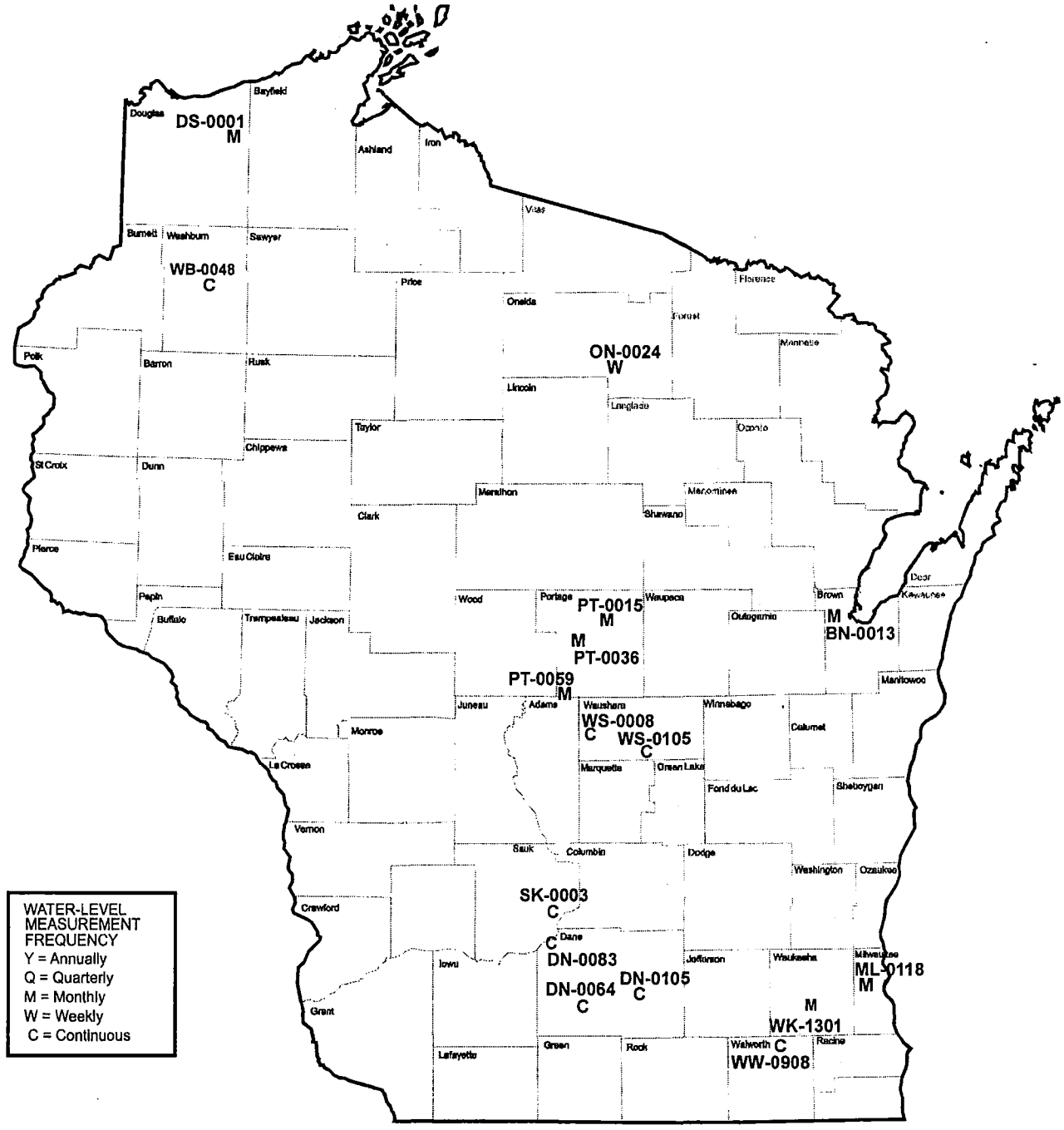


Table 1. Aquifer type, well construction information, and results from the displacement/recovery tests for the 16 observation wells.

County	Well ID	Aquifer Type	** Total Depth	Diameter of Riser	Diameter of: Screen/ Perfed/ Open Interval	Length of: Screen/Perfed/ Open Interval	Geophysical Logs	Hvorslev Time Lag T_0	Horizontal Hydraulic Conductivity	Comments
			ft	ft	ft	ft	yes/no	seconds	ft/day	
Brown	BN-24/20E/18-0013	Galena-Plattville	76.2	0.25	0.25	?	yes	n/a	n/a	Open interval unknown due to inconsistencies between geophysical data and drill logs
Dane	DN-07/09E/19-0064	Sandstone	300.0	0.333	0.333	150	yes	3.5	52	Insufficient test data, test was ended prematurely
Dane	DN-09/06E/29-0083	Sand & Gravel	136.9	0.25	0.208	6.9	yes	10.75	90	
Dane	DN-07/10E/09-0105	Sandstone	354.2	0.5	0.75	264.2	yes	9.25	26	
Douglas	DS-47/10W/23-0001	Sand & Gravel	36.0	0.333	0.333	3	yes	*	*	
Milwaukee	ML-08/21E/35-0118	Silurian	104.5	0.25	0.25	12 ?	yes	90.75	10	Open interval unknown due to inconsistencies between geophysical data and drill logs, used driller reported interval for K calculation
Oneida	ON-36/09E/09-0024	Sand & Gravel	22.0	0.052	0.052	?	no	*	*	Open interval unknown, no geophysical logs due to small well diameter
Portage	PT-24/10E/28-0015	Sand & Gravel	49.8	0.083	0.083	?	no	*	*	Open interval unknown, no geophysical logs due to small well diameter
Portage	PT-21/08E/10-0036	Sand & Gravel	13.2	0.052	0.052	2	no	14.25	15	
Portage	PT-21/07E/31-0059	Sand & Gravel	21.0	0.052	0.052	2	no	5	43	
Sauk	SK-10/06E/02-0003	Sandstone	445.0	0.5	0.5	295	yes	254.5	1	Low formation conductivity
Walworth	WW-04/17E/02-0908	Sand & Gravel	82.3	0.333	0.333	13.3	yes	n/a	n/a	Transmissivity estimated with Van Der Kamp Method est. 25,600 ft2/day , Oscillatory Response w/Storativity est. .0001
Washburn	WB-41/12W/26-0048	Sand & Gravel	85.0	0.25	0.208	1.5	yes	146	24	
Waukesha	WK-06/19E/31-1301	Sand & Gravel	238.0	0.083	0.083	?	no	*	*	Open interval unknown due to inconsistencies between geophysical data and drill logs
Waushara	WS-19/08E/15-0008	Sand & Gravel	27.0	0.125	0.125	?	no	*	*	Open interval unknown, no geophysical logs due to the lack of open interval in the well
Waushara	WS-198/10E/01-0105	Sand & Gravel	13.4	0.125	0.125	?	no	*	*	Open interval unknown, no geophysical logs due to the lack of open interval in the well

* Well may not have a good connection with the aquifer

** Current measurments, may be different than construction logs due to well condition

Table 2. Observation wells exhibiting poor connection with the aquifer.

Well ID	Year Drilled	Aquifer Type	Casing Diameter In.	Screened Interval ft	Well Depth Measured ft
DS-1	1937	Sand & Gravel	8	37-40	36.0
ON-24	1944	Sand & Gravel	1.25	31-33	22.0
PT-15	1950?	Sand & Gravel	2	50-52	49.8
WK-1301	1988	Sand & Gravel	2	195-210	238.0
WS-8	1951	Sand & Gravel	4	Open end	18.0
WS105	1956	Sand & Gravel	4	Open end	13.4

Horizontal conductivity not calculated; slug tests were not interpretable.

Appendix

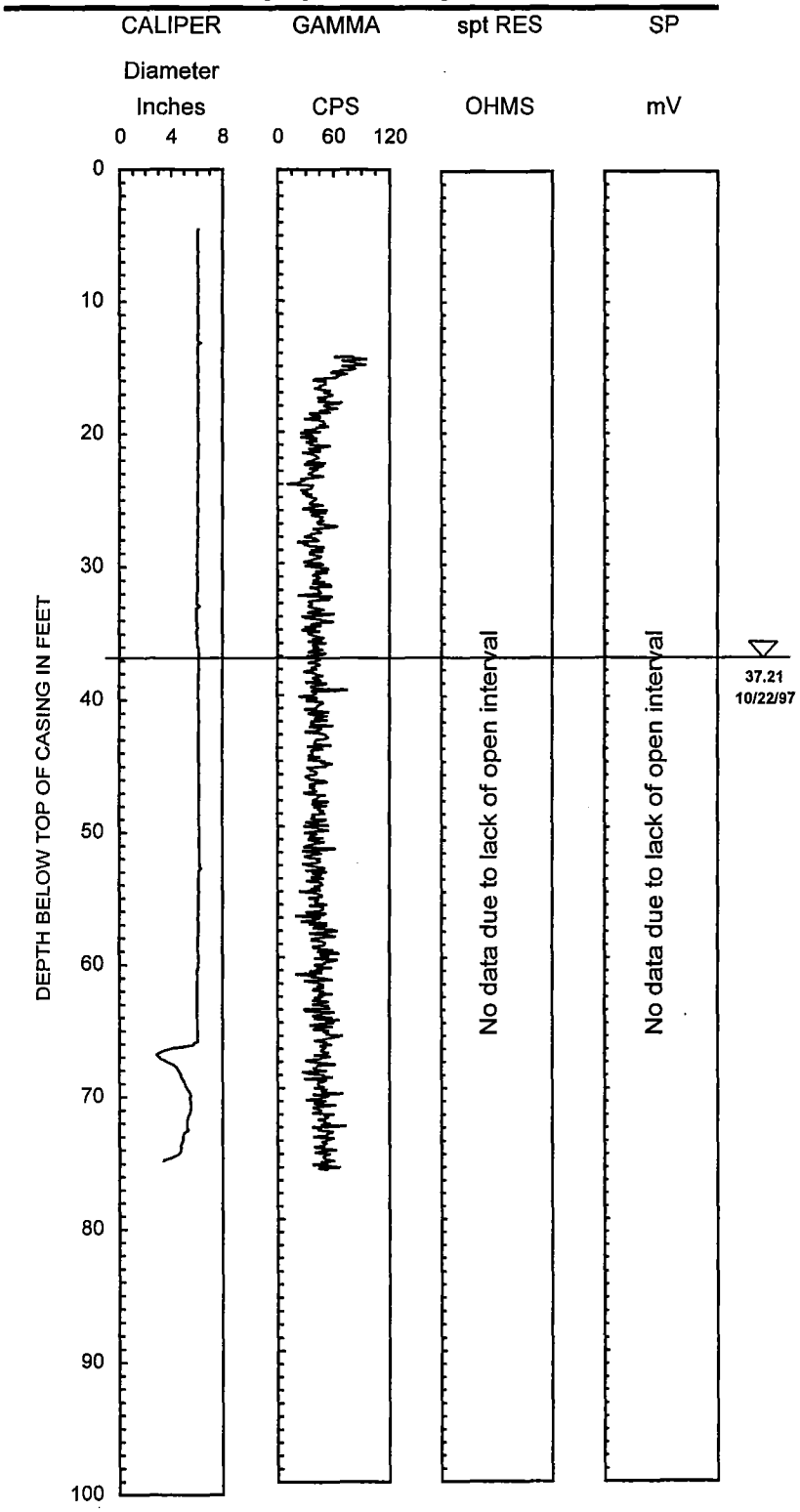
Single Page Well Reports for Selected Wells in the
Wisconsin Ground-water Observation Well Network

Brown County

BN-24/20E/18-0013

GALENA-PLATTVILLE AQUIFER

Geophysical Logs



Well Information

Est. MSL 690 feet

Total Depth 76.2 feet

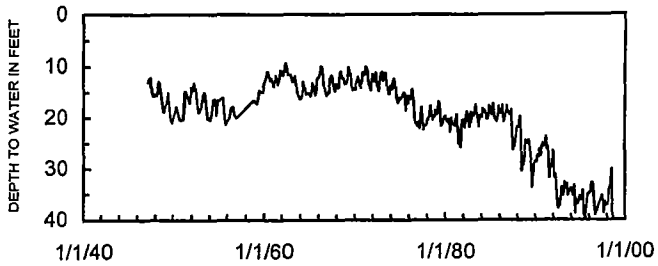
Cased Depth 90 feet*

Casing Diameter 6 inches

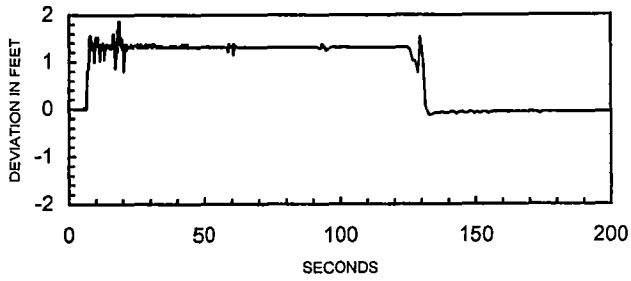
Use Of Well Monitor

* Picked from drilling logs

Depth of Water Below Land Surface for Period of Record

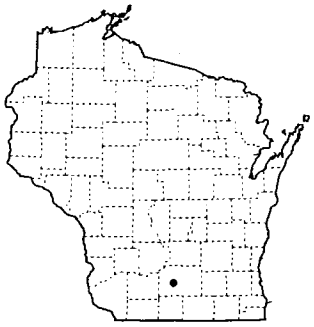


Deviation From Static Water Level During Displacement/Recovery Test



Hydraulic Conductivity

Open interval unknown due to inconsistencies between geophysical data and drill logs
Insufficient test data, test was ended prematurely

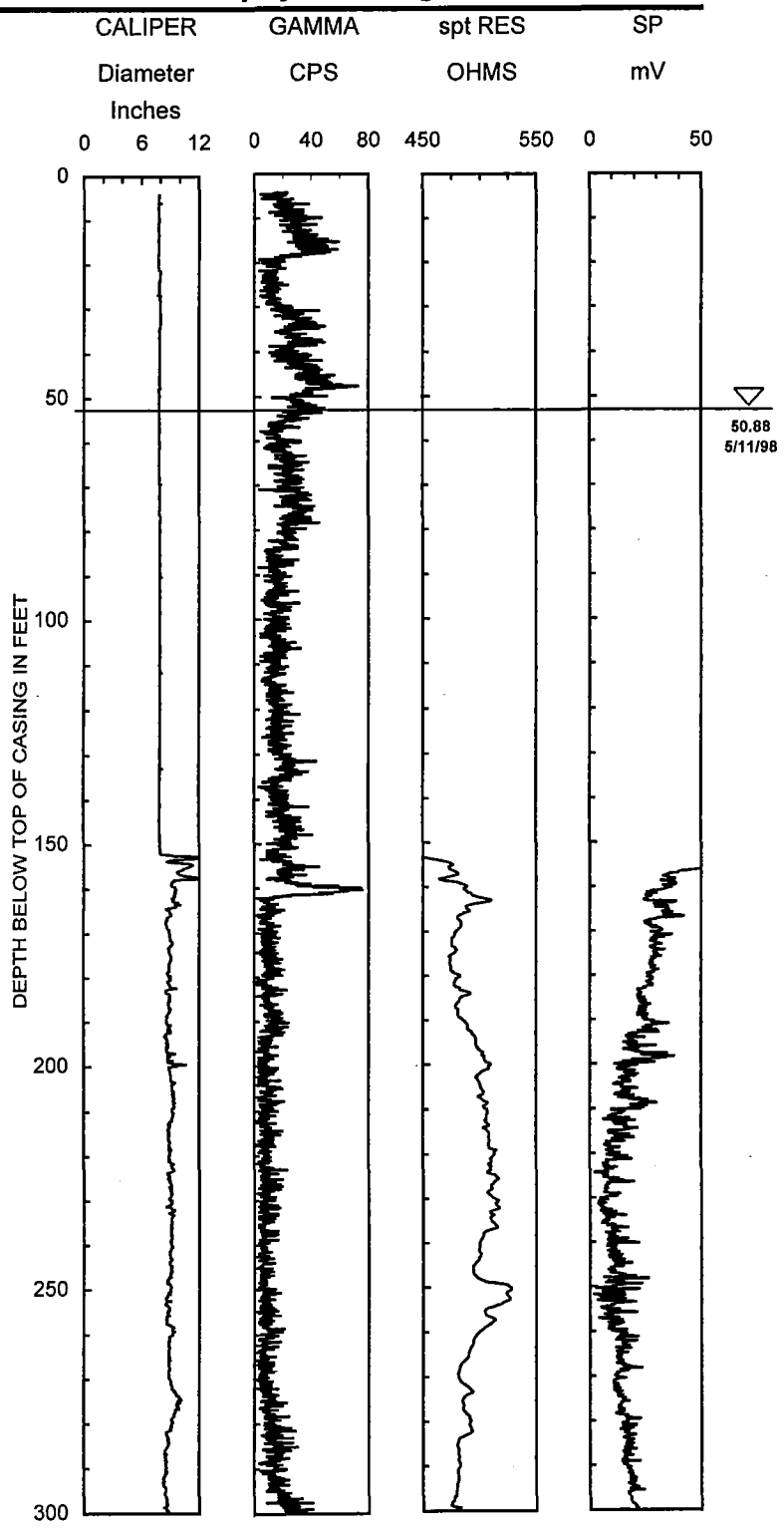


Dane County

DN-07/09E/19-0064

SANDSTONE AQUIFER

Geophysical Logs



Well Information

Est. MSL 921 feet

Total Depth 300 feet

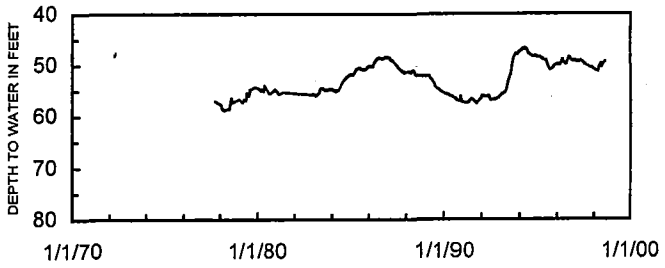
Cased Depth 150 feet*

Casing Diameter 8 inches

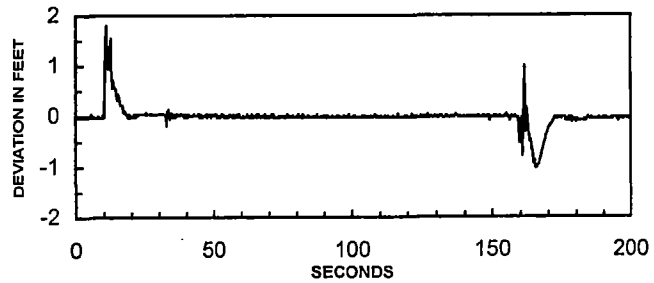
Use Of Well Monitor

* Picked from geophysical logs

Depth of Water Below Land Surface for Period of Record



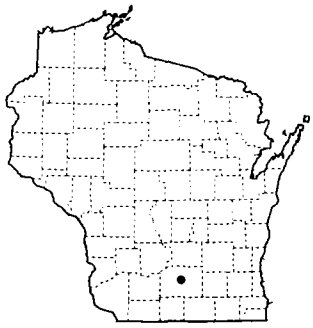
Deviation From Static Water Level During Displacement/Recovery Test



Hydraulic Conductivity

K = Hvorslev Method

K = 52 ft/day

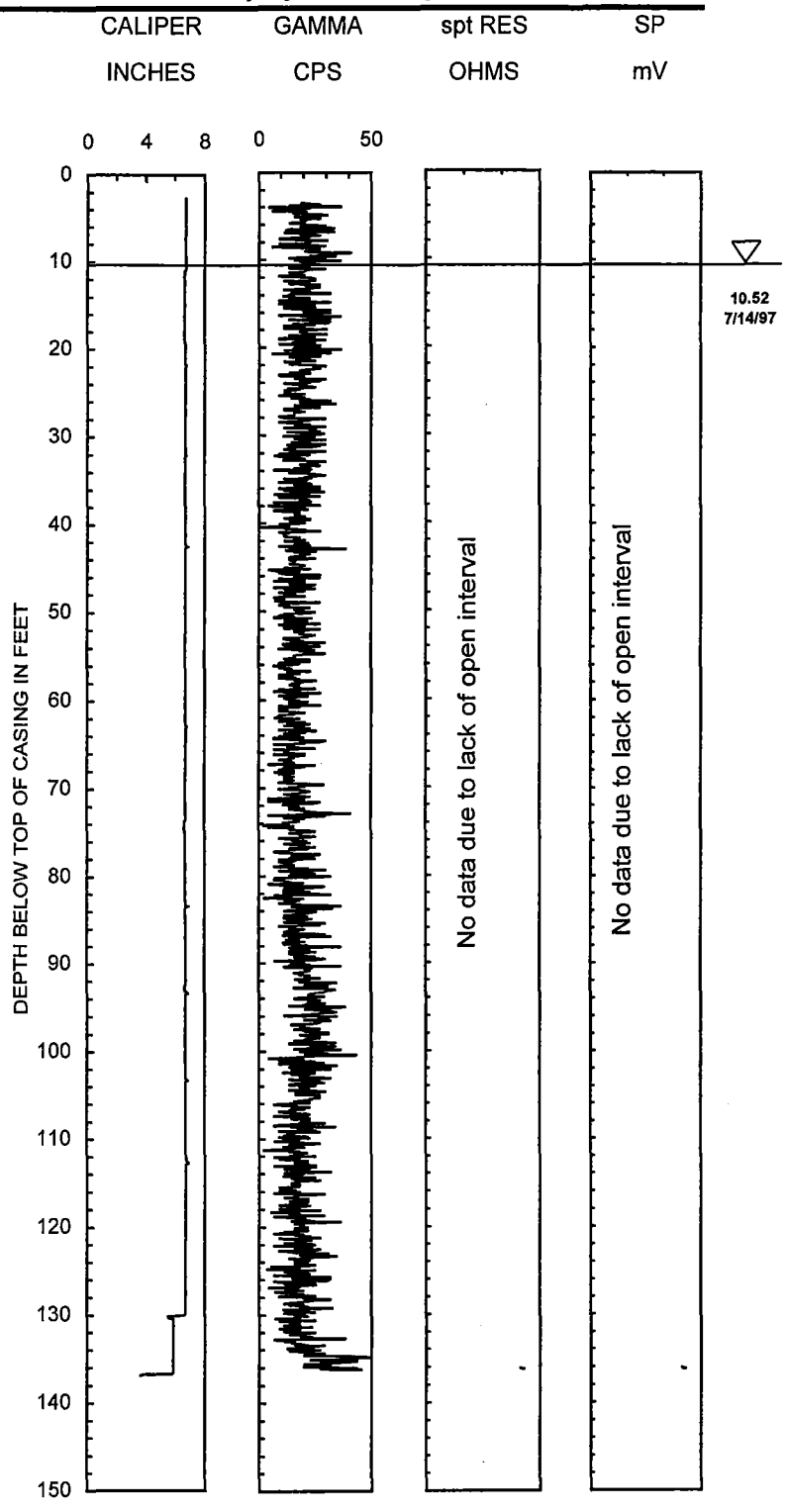


Dane County

DN-09/06E/29-0083

SAND & GRAVEL AQUIFER

Geophysical Logs



Well Information

Est. MSL 740 feet

Total Depth 136.9 feet

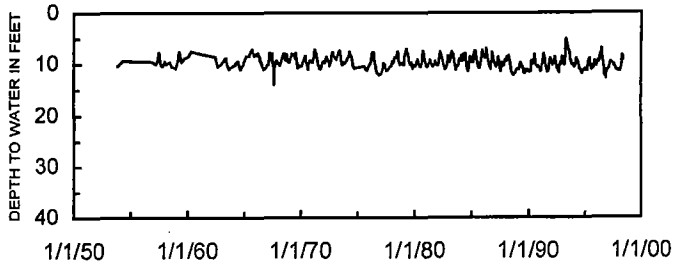
Cased Depth 136 feet*

Casing Diameter 6 inches

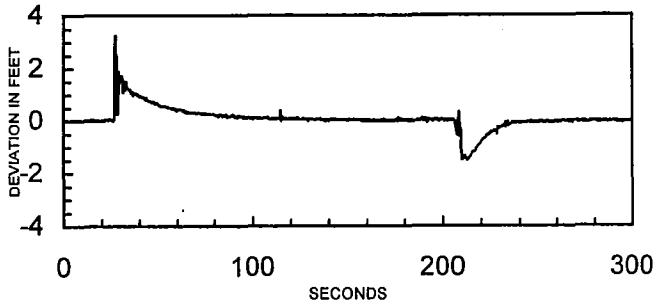
Use Of Well Non pumping

* Picked from drilling logs

Depth of Water Below Land Surface for Period of Record



Deviation From Static Water Level During Displacement/Recovery Test



Hydraulic Conductivity

K = Hvorslev Method ~ 90 ft/day

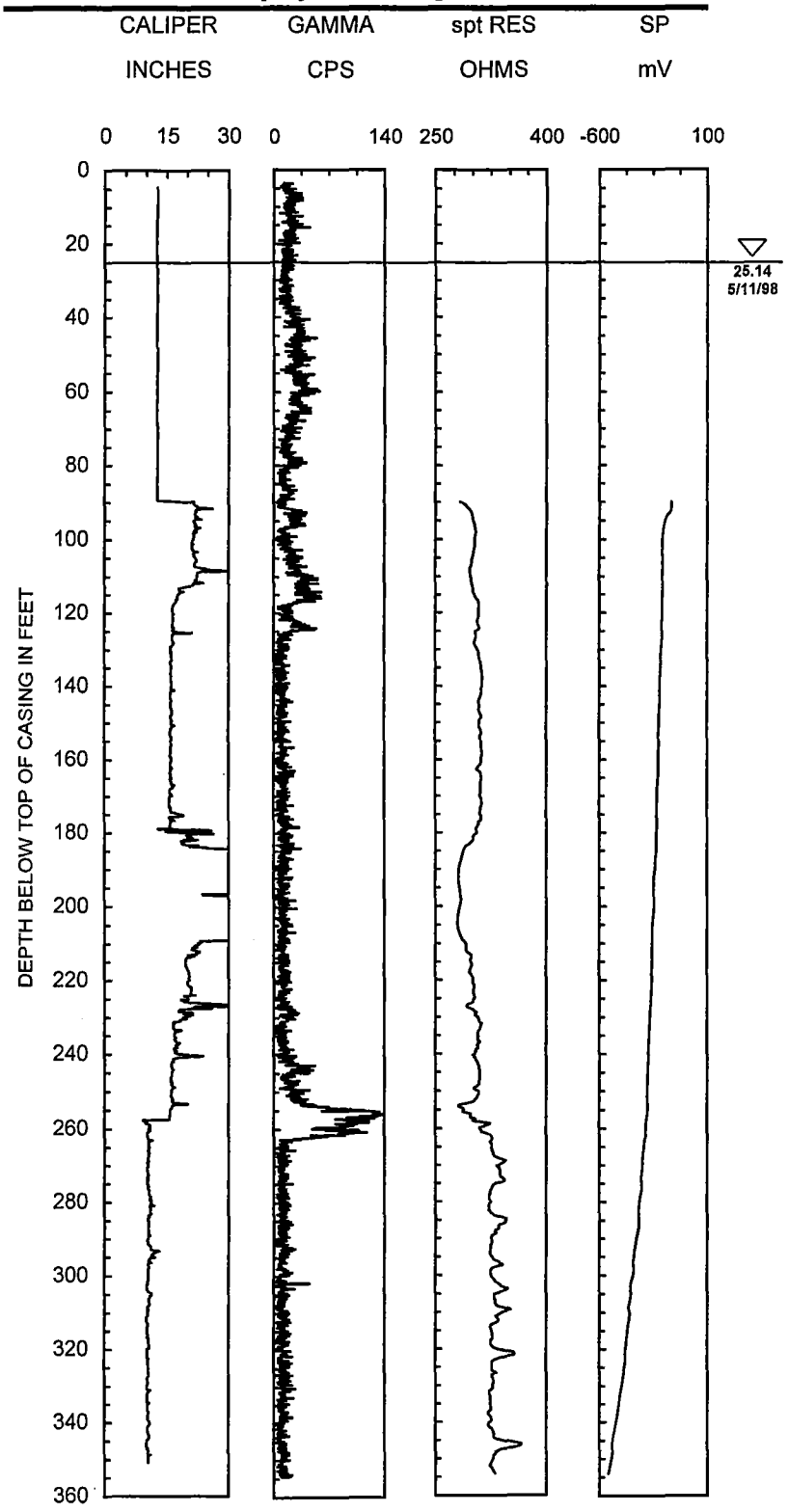
Indeterminant screened interval due to collapse of the casing and screen

Dane County

DN-07/10E/09-0105

SANDSTONE

Geophysical Logs



Well Information

Est. MSL 869 feet

Total Depth 354.2 feet

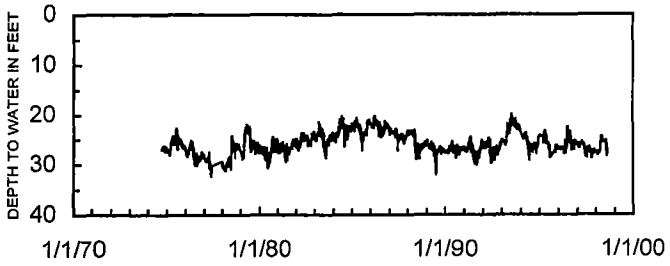
Cased Depth 90 feet*

Casing Diameter 10 inches

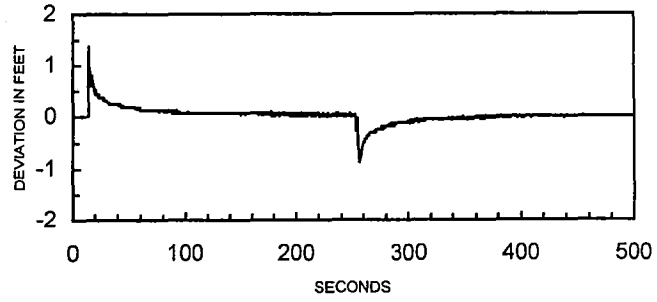
Use Of Well Non pumping

* Picked from geophysical logs

Depth of Water Below Land Surface for Period of Record



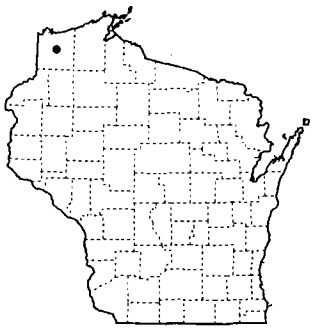
Deviation From Static Water Level During Displacement/Recovery Test



Hydraulic Conductivity

K = Hvorslev Method

K = 26 ft/day

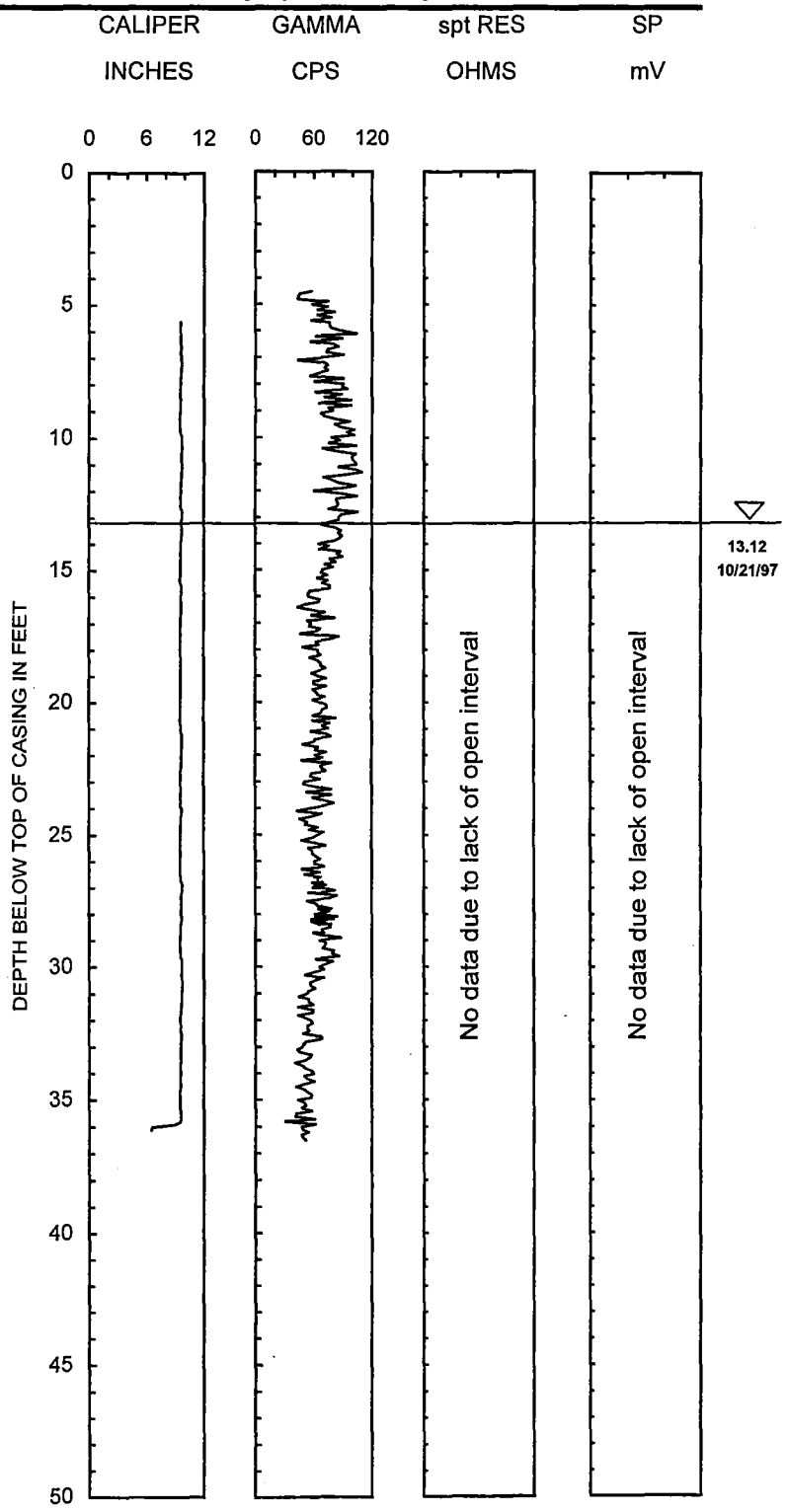


Douglas County

DS-47/10W/23-0001

SAND & GRAVEL

Geophysical Logs



Well Information

Est. MSL 1019 feet

Total Depth 36 feet

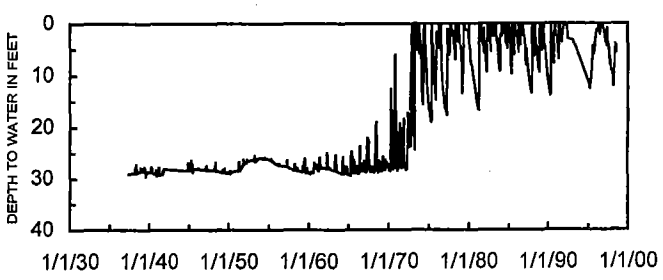
Cased Depth 37 feet*

Casing Diameter 8 inches

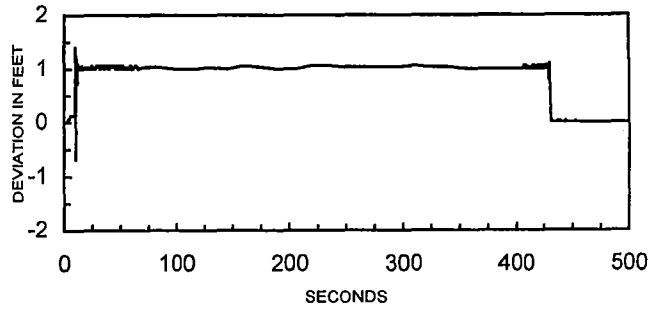
Use Of Well Non pumping

* Picked from drilling logs

Depth of Water Below Land Surface for Period of Record



Deviation From Static Water Level During Displacement/Recovery Test



Hydraulic Conductivity

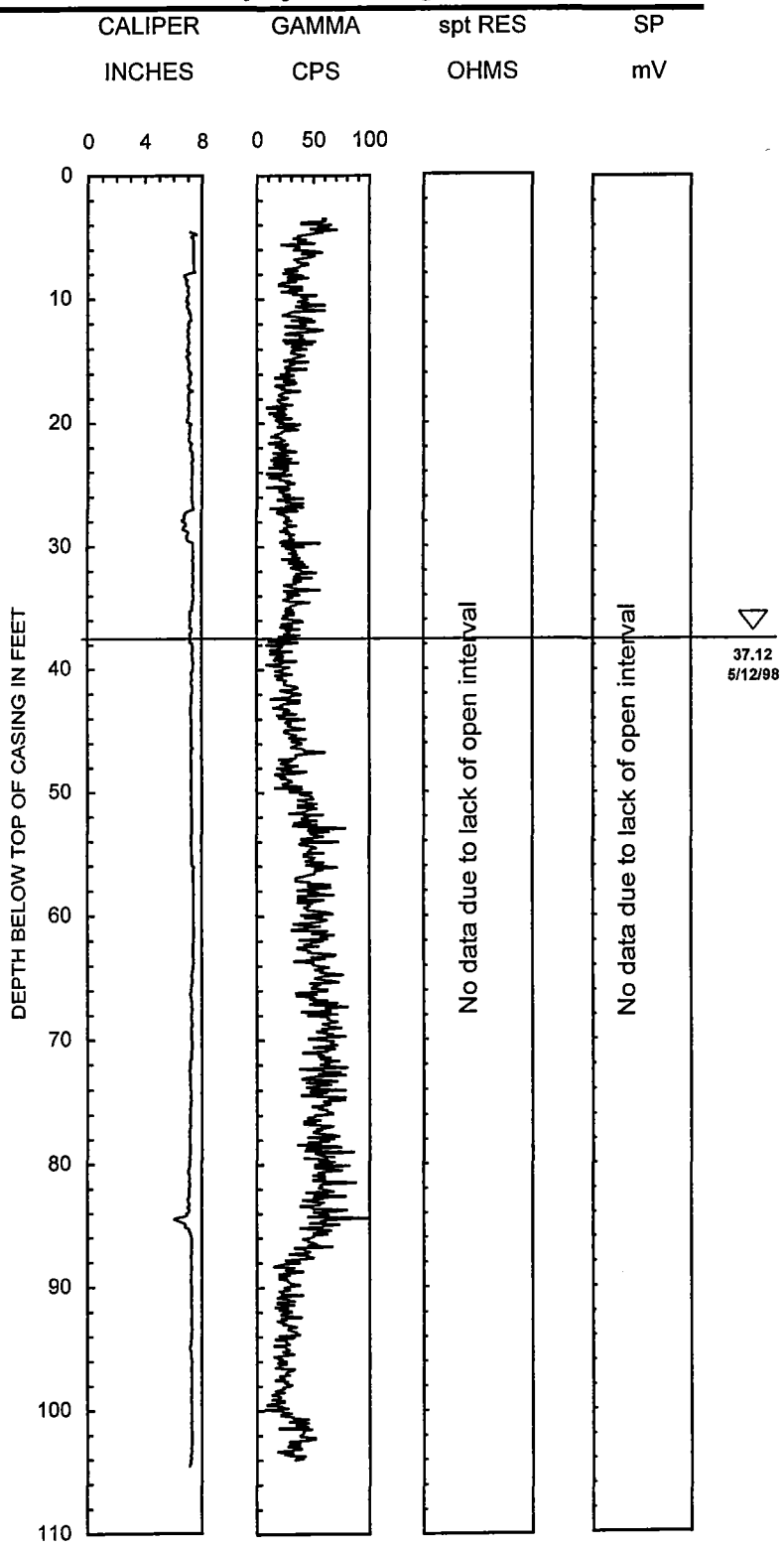
The data suggest that the well may not have a good connection with the aquifer

Milwaukee County

ML-08/21E/35-0118

SILURIAN

Geophysical Logs



Well Information

Est. MSL 679.25 feet

Total Depth 104.5 feet

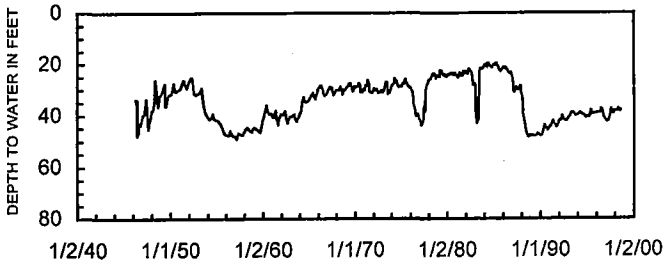
Cased Depth 124 feet*

Casing Diameter 6 inches

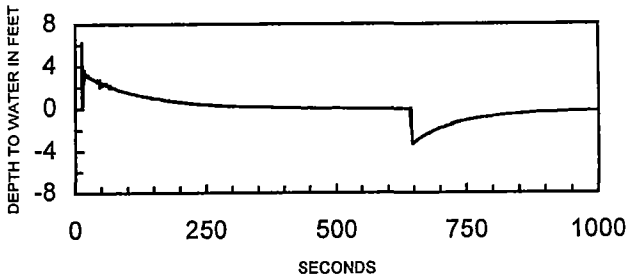
Use Of Well Non pumping

* Picked from drilling logs

Depth of Water Below Land Surface for Period of Record



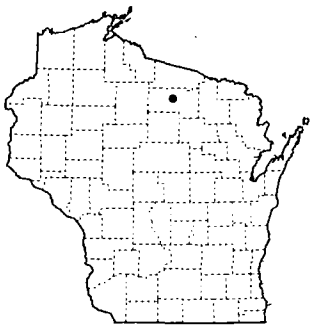
Deviation From Static Water Level During Displacement/Recovery Test



Hydraulic Conductivity

K = Hvorslev Method ~ 10 ft/day

Indeterminant screened interval due to collapse of the casing and screen



Oneida County

ON-36/09E/09-0024

SAND & GRAVEL

Geophysical Logs

CALIPER	GAMMA	spt RES	SP
INCHES	CPS	OHMS	mV

No Geophysical Logs Run
Due To Small Well Diameter

Well Information

Est. MSL 1560 feet

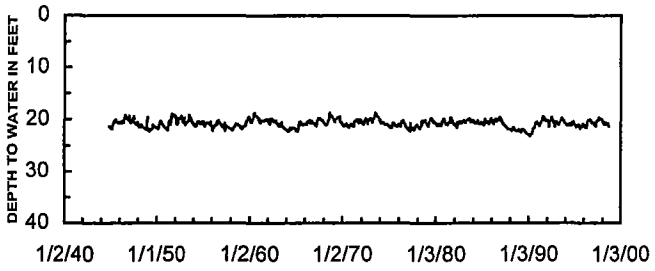
Total Depth 22 feet

Cased Depth N/A feet*

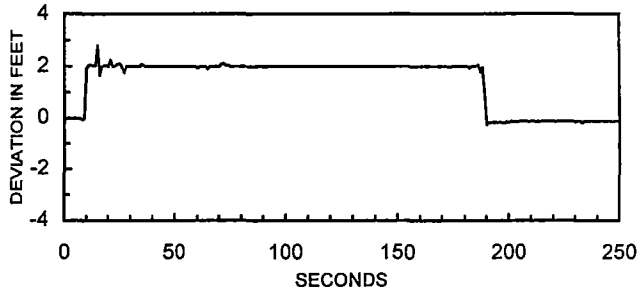
Casing Diameter 1.25 inches

Use Of Well Non pumping

Depth of Water Below Land Surface for Period of Record



Deviation From Static Water Level During Displacement/Recovery Test



Hydraulic Conductivity

The data suggest that the well may not have a good connection with the aquifer

*Indeterminant screened interval due to collapse of the casing and screen

Portage County

PT-24/10E/28-0015

SAND & GRAVEL

Geophysical Logs

CALIPER	GAMMA	spt RES	SP
INCHES	CPS	OHMS	mV

No Geophysical Logs Run
Due To Small Well Diameter

Well Information

Est. MSL 1133 feet

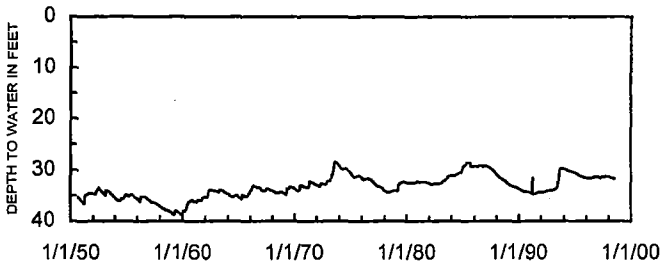
Total Depth 49.8 feet

Cased Depth N/A feet *

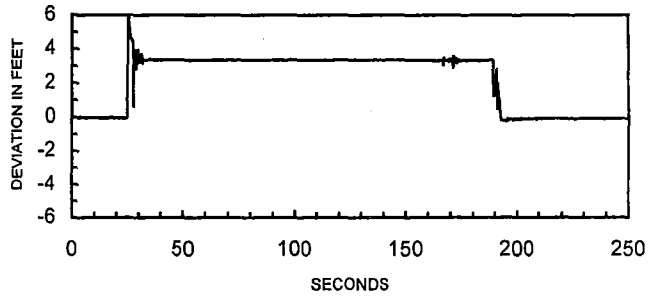
Casing Diameter 2 inches

Use Of Well Non pumping

Depth of Water Below Land Surface for Period of Record



Deviation From Static Water Level During Displacement/Recovery Test



Hydraulic Conductivity

The data suggest that the well may not have a good connection with the aquifer

* Indeterminant screened interval due to collapse of the casing and screen

Portage County

PT-21/08E/10-0036

SAND & GRAVEL

Geophysical Logs

CALIPER	GAMMA	spt RES	SP
INCHES	CPS	OHMS	mV

No Geophysical Logs Run
Due To Small Well Diameter

Well Information

Est. MSL 1074.3 feet

Total Depth 13.2 feet

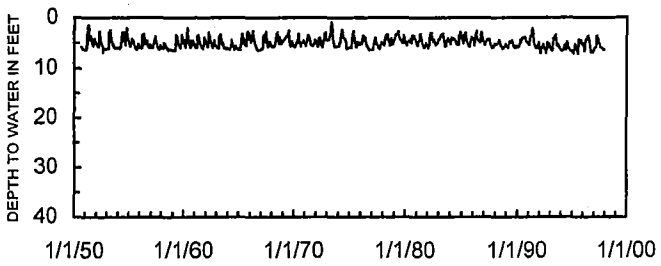
Cased Depth 11.2 feet*

Casing Diameter 1.25 inches

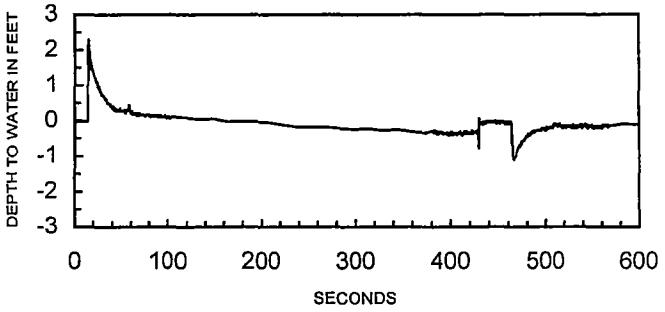
Use Of Well Non pumping

* Picked from drilling log

Depth of Water Below Land Surface for Period of Record



Deviation From Static Water Level During Displacement/Recovery Test



Hydraulic Conductivity

K = Hvorslev Method
K = 15 ft/day

Portage County

PT-21/07E/31-0059

SAND & GRAVEL

Geophysical Logs

CALIPER	GAMMA	spt RES	SP
INCHES	CPS	OHMS	mV

No Geophysical Logs Run
Due To Small Well Diameter

Well Information

Est. MSL 1034 feet

Total Depth 21 feet

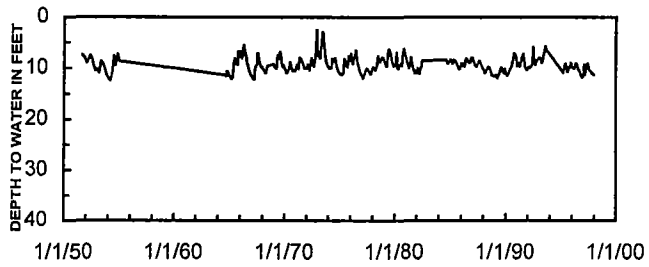
Cased Depth 19 feet*

Casing Diameter 1.25 inches

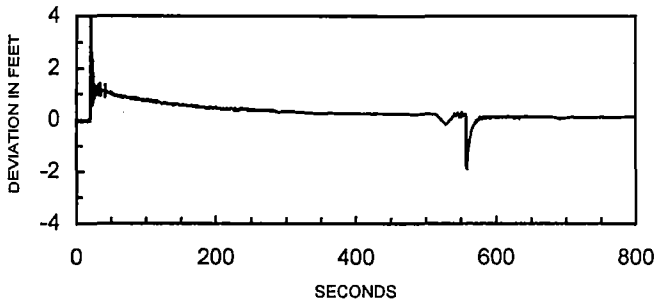
Use Of Well Non pumping

* Picked from drilling logs

Depth of Water Below Land Surface for Period of Record



Deviation From Static Water Level During Displacement/Recovery Test



Hydraulic Conductivity

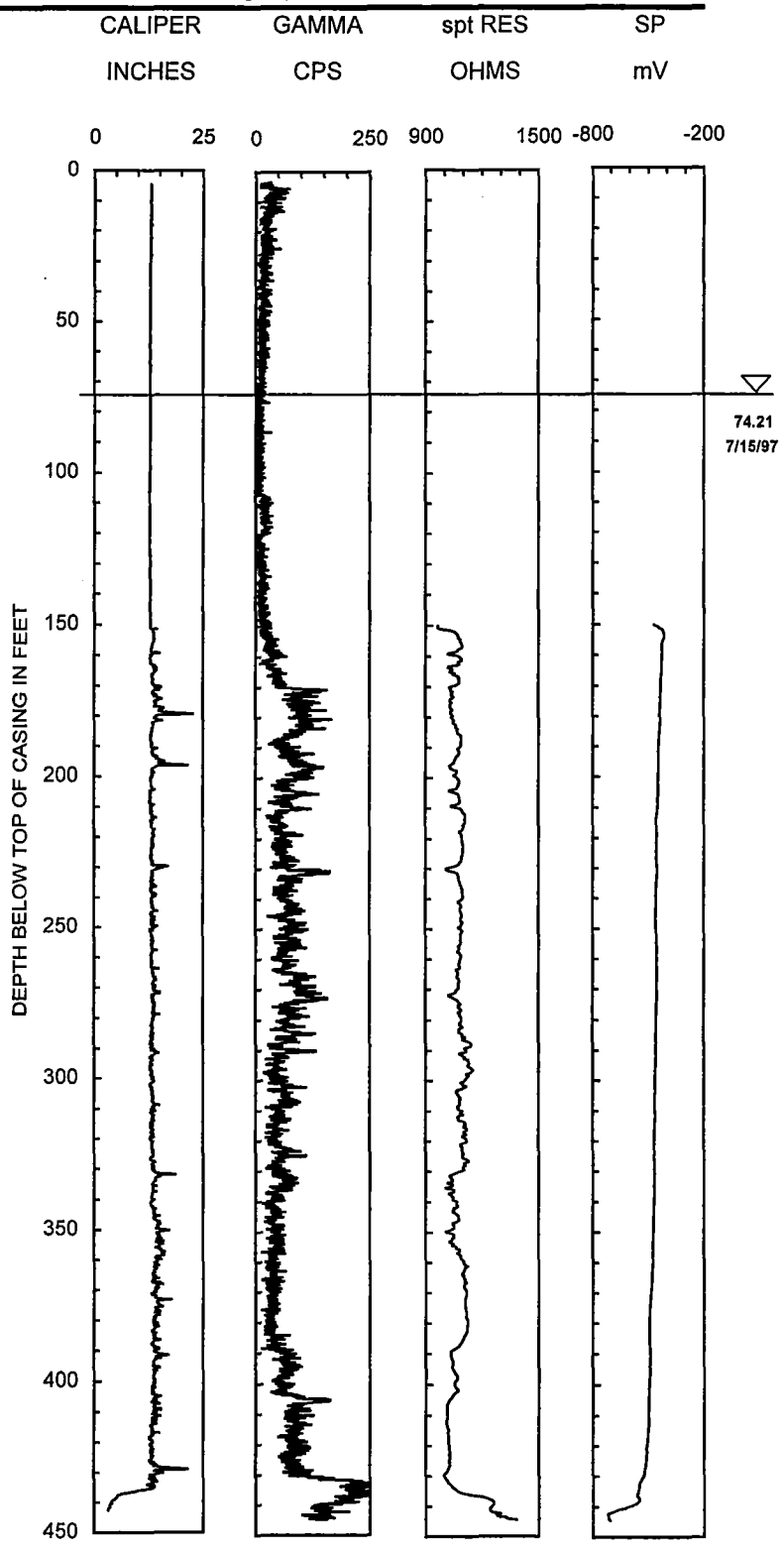
K = Hvorslev Method
K = 43 ft/day

Sauk County

SK-10/06E/02-0003

SANDSTONE

Geophysical Logs



Well Information

Est. MSL 884 feet

Total Depth 445 feet

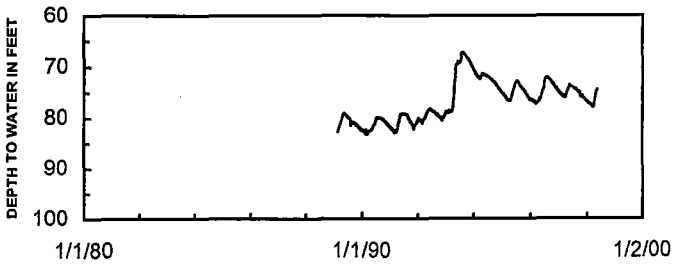
Cased Depth 150 feet*

Casing Diameter 12 inches

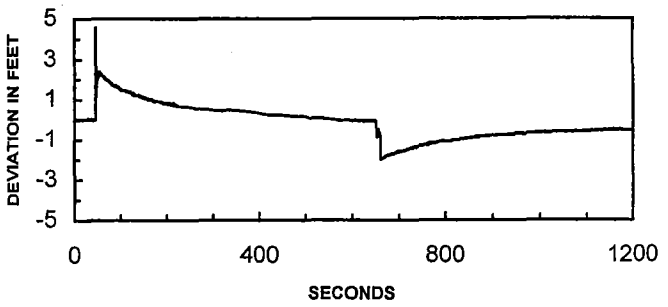
Use Of Well Non pumping

* Picked from geophysical logs

Depth of Water Below Land Surface for Period of Record



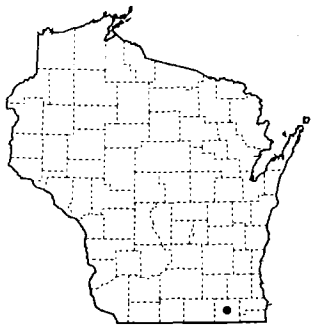
Deviation From Static Water Level During Displacement/Recovery Test



Hydraulic Conductivity

K = Hvorslev Method

K = 1 ft/day

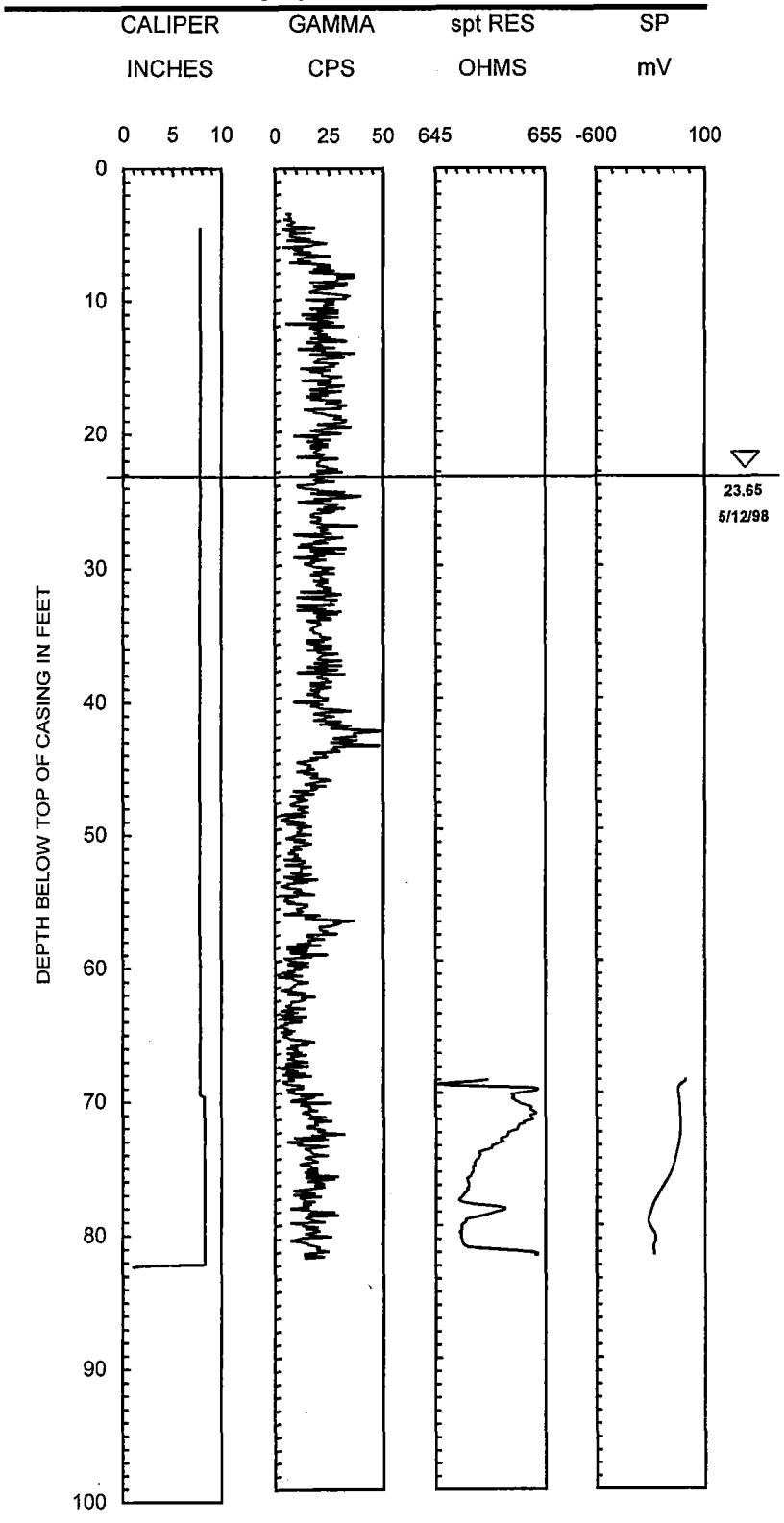


Walworth County

WW-04/17E/02-0908

SAND & GRAVEL

Geophysical Logs



Well Information

Est. MSL 845 feet

Total Depth 82.3 feet

Cased Depth 69 feet*

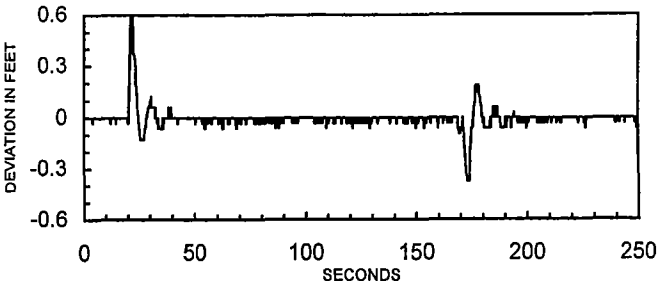
Casing Diameter 8 inches

Use Of Well Non pumping

* Picked from geophysical logs

Depth of Water Below Land Surface for Period of Record

Deviation From Static Water Level During Displacement/Recovery Test



Oscillatory Response to Slug Test

T = Van Der Kamp Method

Transmissivity (T) = 25,617 ft^2/day

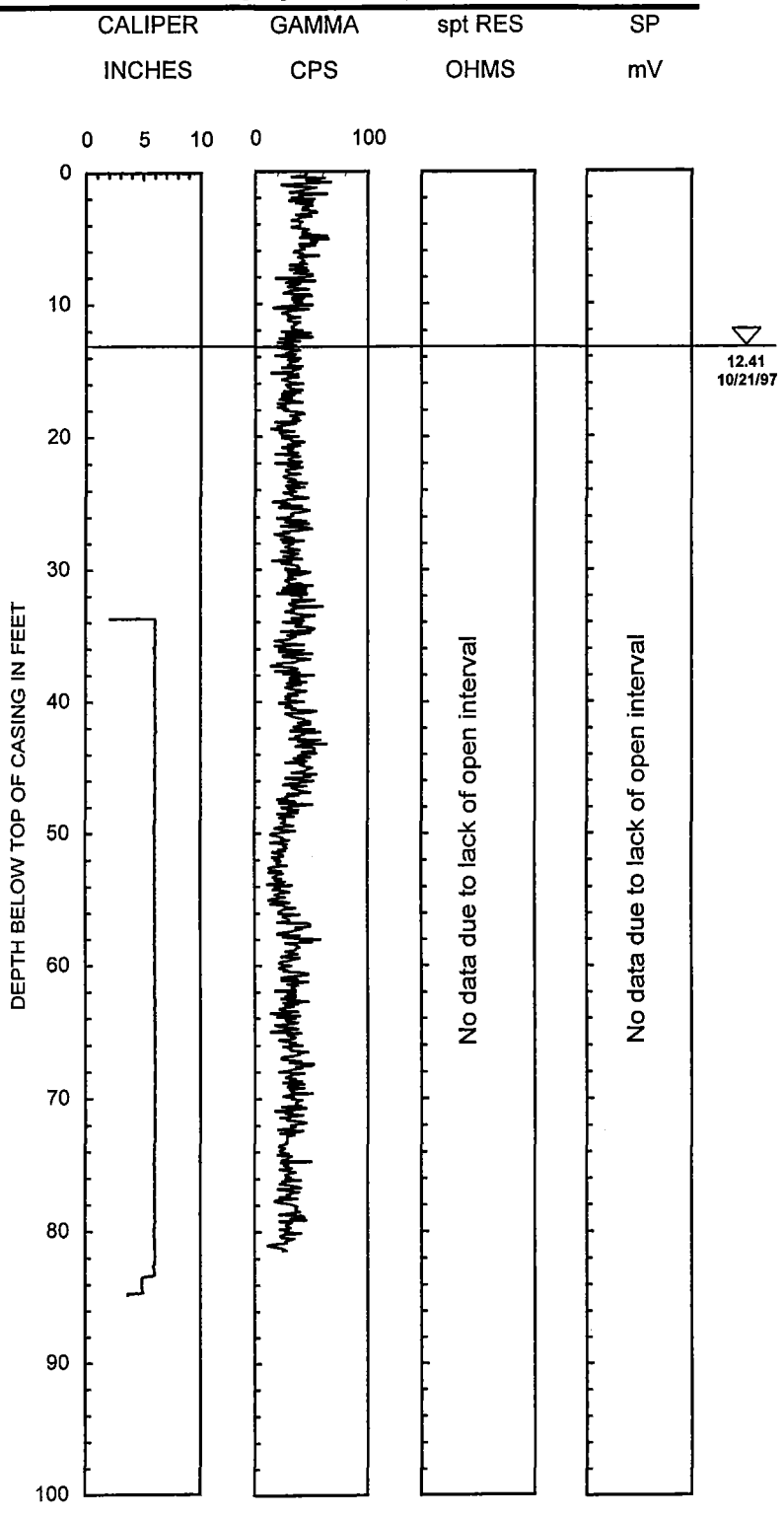
Storativity (S) = .0001

Washburn County

WB-41/12W/26-0048

SAND & GRAVEL

Geophysical Logs



Well Information

Est. MSL 1078 feet

Total Depth 85 feet

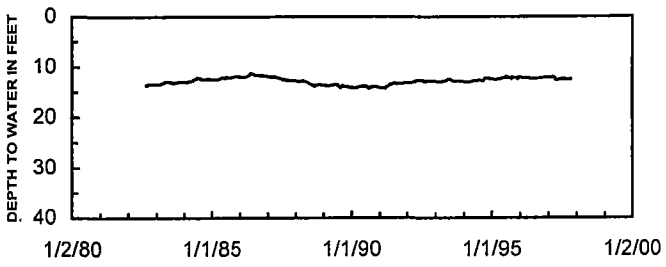
Cased Depth 82 feet*

Casing Diameter 6 inches

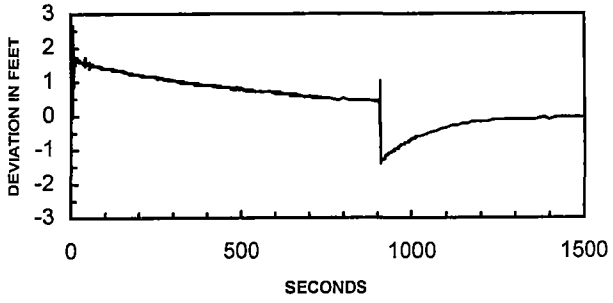
Use Of Well Non pumping

* Picked from geophysical logs

Depth of Water Below Land Surface for Period of Record



Deviation From Static Water Level During Displacement/Recovery Test



Hydraulic Conductivity

K = Hvorslev Method

K = 24 ft/day

Waukesha County

WK-06/19E/31-1301

SAND & GRAVEL

Geophysical Logs

CALIPER	GAMMA	spt RES	SP
INCHES	CPS	OHMS	mV

No Geophysical Logs Run
Due To Small Well Diameter

Well Information

Est. MSL 788 feet

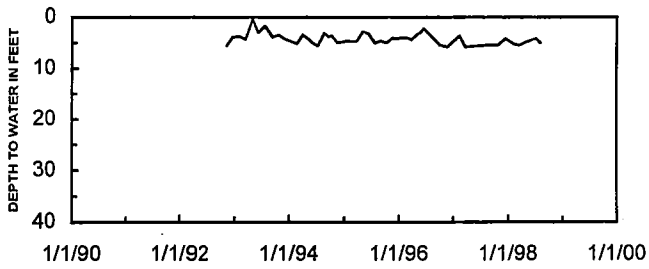
Total Depth 238 feet

Cased Depth N/A feet*

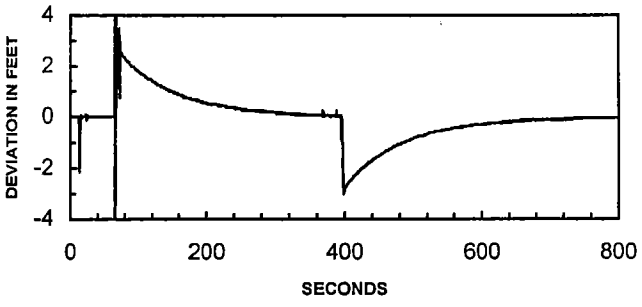
Casing Diameter 2 inches

Use Of Well Non pumping

Depth of Water Below Land Surface for Period of Record



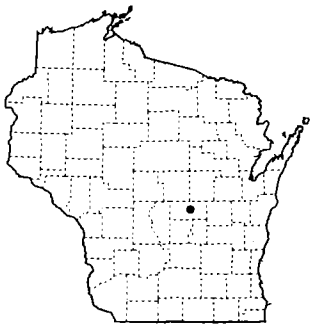
Deviation From Static Water Level During Displacement/Recovery Test



Hydraulic Conductivity

The data suggest that the well may not have a good connection with the aquifer

* Indeterminant screened interval due to collapse of the casing and screen



Waushara County

WS-19/08E/15-0008

SAND & GRAVEL

Geophysical Logs

CALIPER	GAMMA	spt RES	SP
INCHES	CPS	OHMS	mV

Geophysical Logs Run During the Previous Project (Dunning and others, 1996)

Well Information

Est. MSL 1080 feet

Total Depth 27 feet

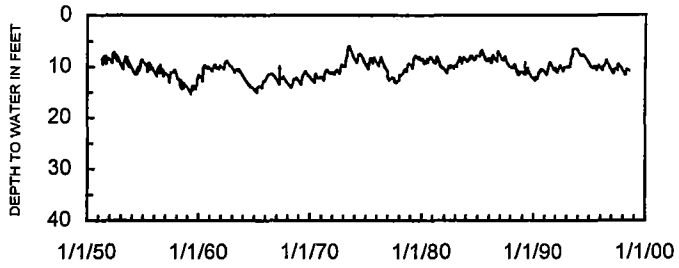
Cased Depth 25 feet*

Casing Diameter 3 inches

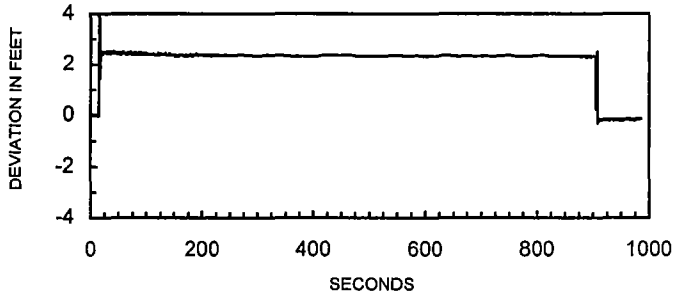
Use Of Well Non pumping

* Picked from drilling logs

Depth of Water Below Land Surface for Period of Record

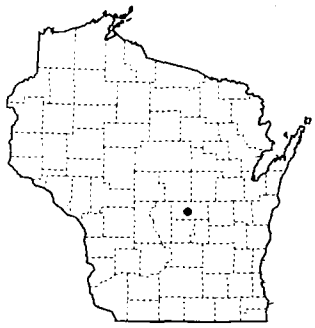


Deviation From Static Water Level During Displacement/Recovery Test



Hydraulic Conductivity

The data suggest that the well may not have a good connection with the aquifer



Waushara County

WS-198/10E/01-0105

SAND & GRAVEL

Geophysical Logs

CALIPER	GAMMA	spt RES	SP
INCHES	CPS	OHMS	mV

No Geophysical Logs Run
Due To Small Well Diameter

Well Information

Est. MSL 873 feet

Total Depth 13.4 feet

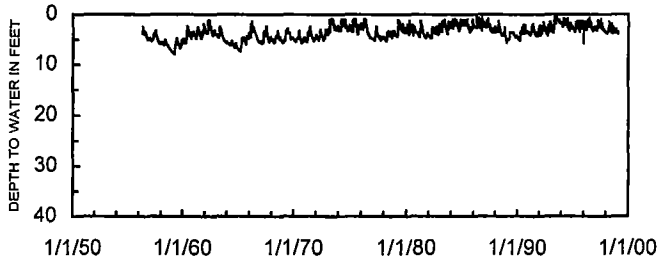
Cased Depth 12.4 feet*

Casing Diameter 3 inches

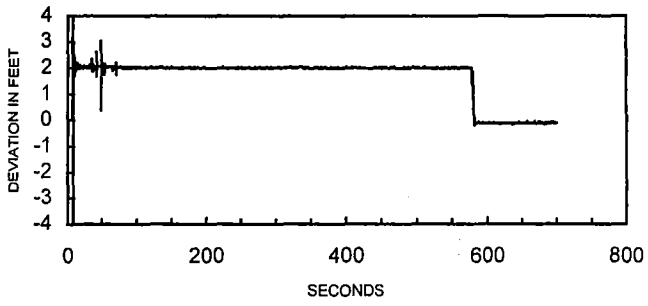
Use Of Well Non pumping

* Picked from drilling logs

Depth of Water Below Land Surface for Period of Record



Deviation From Static Water Level During Displacement/Recovery Test



Hydraulic Conductivity

The data suggest that the well may not have a good connection with the aquifer

Title: **Evaluation of geology and hydraulic performance of Wisconsin ground-water monitoring wells**

Project I.D.: DNR Project No. 135

Investigators: Alexander Zaporozec, Senior Hydrogeologist, WGNHS, P.I.
James Rauman, Hydrologist, U.S. Geological Survey
Bernard Ellefson, Hydrologist, U.S. Geological Survey

Period of Contract: July 1, 1997 - April 30, 1999

Background/Need: Reliable ground-water level measurements are needed for ground-water research and effective management of ground-water resources in Wisconsin. Results of a similar study from 1994-1996 (DNR Project No. 118) indicated that a significant number of observation wells had poor hydraulic connection with aquifers. Geophysical logging and slug testing of the remaining accessible wells in the observation network will increase the quality of water-level measurements.

Objectives: The main objective is to improve the quality of the Wisconsin ground-water monitoring network, which in turn will contribute to the improvement of a ground-water level data base needed for the management of ground-water resources in Wisconsin.

Methods: Sixteen observation wells were identified as suitable for testing. Geophysical logs - caliper, natural gamma, spontaneous potential, and single-point resistivity - were run in the wells, where it was possible. A Mount Sopris MGX Digital Logger was used for geophysical logging. The hydraulic conductivity of geologic units tapped by the wells were estimated by displacement/recovery tests (slug tests).

Results and Discussion: The tested wells range in depth from 13 to more than 350 ft. Most of them are in the sand and gravel aquifer (11 wells); one well is open to the Silurian dolomite aquifer, one to the Galena-Platteville dolomite, and three to the sandstone aquifer.

Geophysical logs were obtained from 9 of the 16 selected network wells. Displacement/recovery tests were conducted in all 16 of the wells. The Hvorslev method was used to calculate hydraulic conductivity, which ranged from 1 to 90 ft/day. The tests provided reliable data for estimation of hydraulic conductivity of 9 wells, 7 wells exhibited very slow recovery during the test. Slow recovery in 1 well is believed to be due to low formation conductivity, the other 6 are interpreted to have a poor hydraulic connection with the aquifer.

Conclusions/ Implications/ Recommendations: The results suggest that a significant portion of the tested wells, 38%, had very slow or no response to the slug tests, and therefore, a poor hydraulic connection with aquifers. Most of these (5 out of 6)

were wells older than 40 years. This proportion and a similar proportion from the 1994-96 study, 31%, indicates the need for regular testing of wells in the Wisconsin monitoring network, especially those that are older than 35-40 years. In this way, the efficiency and quality of the network could be maintained and the use of limited funds for monitoring optimized.

Key Words: Hydraulic conductivity, geophysical logs, Wisconsin observation-well network.

Funding: DNR

Final Report: A final report containing more detailed information on this project is available for loan at the Water Resources Center, University of Wisconsin - Madison, 1975 Willow Drive, Madison, Wisconsin 53706 (608) 262-3069.