Information Circular 63
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ANALYSIS OF WATER-LEVEL FLUCTUATIONS IN WISCONSIN WELLS

By G. L. Patterson, U.S. Geological Survey, and
Alexander Zaporozec, Wisconsin Geological and Natural History Survey

PREPARED BY
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

IN COOPERATION WITH
UNIVERSITY OF WISCONSIN EXTENSION–
GEOLOGICAL AND NATURAL HISTORY SURVEY
M. E. Ostrom, Director and State Geologist
Madison, Wisconsin

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The Wisconsin Geological and Natural History Survey Water Resources Program includes: systematic collection, analysis, and cataloging of basic water data; impartial research and investigation of Wisconsin's water resources and water problems; publication of technical and popular reports and maps; and public service and information. This report for the Survey's Water Resources Program is accomplished through state-federal cooperative cost sharing with the U.S. Geological Survey, Water Resources Division.

This report is available at: Wisconsin Geological and Natural History Survey, 3817 Mineral Point Road, Madison, Wisconsin, 53705.

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CONVERSION TABLE

For readers who prefer to use metric (International System) units rather than the inch-pound units used in this report, conversion factors are listed below.

Multiply inch-pound unit	By	To obtain SI unit
inch (in)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)

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ABSTRACT

More than 60 percent of the residents of Wisconsin use ground water as their primary water source. Water supplies presently are abundant, but ground-water levels continually fluctuate in response to natural factors and human-related stresses. A better understanding of the magnitude, duration, and frequency of past fluctuations, and the factors controlling these fluctuations may help anticipate future changes in ground-water levels.

This report presents the results of statistical analyses of historical ground-water level fluctuations in Wisconsin. Short- and long-term fluctuations are discussed in terms of their relation to components of the hydrogeologic system.

Water-level measurements from 124 wells with at least 20 years of record each were used in the study. The mean, highest and lowest monthly mean, median, and selected quantiles were obtained using the SAS Proc Univariate procedure. The frequency values from the Univariate table were used to construct stage-duration graphs. Pearson Type III frequency analyses were used to obtain probabilities of exceedance of particular water levels. The data were divided into seasonal data sets for each well. The stage-duration and Pearson Type III analyses are based on past fluctuations but may be useful for estimating future water-level changes under similar conditions.

Multiple-regression analyses were run on data from groups of wells representing different ground-water districts. The SAS Proc Stepwise method was used. The regression model used average annual amplitude as the dependent variable and mean water level, mean annual precipitation, standard deviation of the seasonal mean precipitation, aquifer type, and topographic setting as the independent variables. This procedure produced different regression equations for each hydrogeologic district. Regression analyses also were done on data from groups of wells representing different aquifers. These regression models used average annual amplitude as the dependent variable and mean water level, topographic setting, and standard deviation of seasonal mean precipitation as the independent variables.

Because of the many factors influencing ground-water level fluctuations, it was difficult to obtain a regression model that accurately reproduced average annual amplitude. The results of the regression analyses are helpful in recognizing the important variables; however, the equations are not effective in predicting the amplitude of a particular well because local conditions were omitted in the regional analyses.

Hydrographs of average annual water level and frequency distribution analyses of annual maximum and minimum water levels were inspected for possible long-term trends. Analysis of annual maximum and minimum water levels indicates several periods in the annual cyclic fluctuations—two periods of recession (winter and summer), and two periods of rising levels (spring and fall). Usually, water levels are lowest in late winter and highest in spring for every annual cycle. The summer-fall minimum and the fall maximum are less distinct and do not occur every year.

A composite frequency analysis of extreme annual water levels on 71 of the wells shows that the lowest levels most frequently occur in December, February, or March. However, the record low usually occurs in August, September, or October during drought. Ground-water levels most often peak in May, April, or June. In the fall they may peak from September through December, depending upon complexities of meteorological, geomorphological, and geological factors.

The long-term cyclicity of ground-water level fluctuations is shown on hydrographs of wells Sw-7, Ln-25a, Mt-7, Ju-8, and Ju-98. Seasonal variations that tend to obscure the long-term trends are eliminated by plotting the average annual water levels. The hydrographs are similar even though the wells are 80 to 100 miles apart and constructed in different geologic materials. The long-term trends and the duration of the cycles apparently depend little on the location and

on the lithologic composition of the aquifers, but rather on precipitation. The hydrographs show several periods of well-defined peaks and lows. The ground-water levels reached peaks in 1946, 1952, 1960, 1966, 1973, 1979. The average interval between these peaks is 6.6 years. The low levels occurred in 1949, 1958–59, 1964, 1970, and 1977; average interval between the low levels is 7.0 years, which is similar to that for the high levels.

Long-term trends are apparent on hydrographs of wells Br-46, Mr-28, Pt-276, Ro-3, and Ve-8. The trend of average annual water levels has been generally increasing since the late 1950's and is in general agreement with the increasing trend of precipitation. Hydrographs of well Ve-8, which has the longest period of record in Wisconsin, indicate that the generally rising trend started even earlier at the end of an extensive drought period in the 1930's.

INTRODUCTION

Ground water is one of the major resources of Wisconsin; more than 60 percent of the residents use ground water as their primary water source. Water supplies throughout the State are presently abundant, but ground-water levels are almost constantly fluctuating. They decline and rise within a short time in response to natural factors (climate, topography, surface water, earthquakes) and to human-related stresses (pumping and dewatering, and changes in recharge and discharge conditions) on both local and regional scales. A better understanding of the duration, frequency, and amplitude of fluctuations is required to help make sound planning decisions in the future as new and greater stresses are imposed on the ground-water system.

Purpose and Scope

The purpose of this report is to present the results of statistical analyses of historical ground-water-level fluctuations in Wisconsin, and to discuss the relation of short- and long-term fluctuations to other components of the hydrogeologic system.

Water-level measurements from 124 wells with at least 20 years of record each were selected for study. These measurements were then divided into subsets to approximate normal distribution and reduce serial correlation. The subsets were analyzed for various common statistical values such as mean, median, and range. Precipitation data from the nearest weather station to each well were similarly analyzed. These statistical values were subsequently used in the frequency, duration, and regression analyses to correlate them with factors such as topographic setting, aquifer type, and hydrogeologic district.

In addition to the statistical methods, graphical methods using average annual water level, annual precipitation, and cumulative departure from normal precipitation were used to describe long-term trends and responses of various wells to precipitation.

Objectives of Ground-Water-Level Monitoring

The purpose of systematic observations of ground-water levels is to provide information needed for water- and land-use planning, resource management, and environmental protection. Representative ground-water level data are needed for a continuing evaluation of the response of major hydrogeologic units to natural and human-related stresses. The primary objectives of the water-level measurement program are to (1) determine water-level fluctuations and their causes, the range of fluctuations, and the trend in water levels; (2) study the natural regime of ground water under different hydrogeologic conditions and to estimate changes in the regime caused by manmade factors (especially in the areas influenced by major pumping centers); (3) measure changes in gradient that may lead to changes in water quality; and (4) establish regional characteristics of the regime, interactions of ground water and other components of the hydrologic cycle, and interactions between aquifers.

Wisconsin Observation-Well Network

Ground-water-level measurements in Wisconsin began more than 50 years ago. Periodic measurements of ground-water levels began on June 15, 1934, when 13 observation wells were put into service in the Coon Creek area in southwestern Wisconsin by the U.S. Soil Conservation Service as a part of the National Soil Conservation Program (Zaporozec, 1982). All but three of these 13 wells (Mo-2, Mo-10, and Ve-8) have since been discontinued. During the years 1935–37, 10 more wells were added to the observation-well program, which brought the total number to 23. One well was added in the Coon Creek area and nine wells were installed by the Wisconsin Conservation Department (now the Wisconsin Department of Natural Resources) in each of its Forest Protection Districts in northern and central Wisconsin as part of the shallow ground-water resource investigation. Seven of the 10 wells (Ad-2, Bt-2, Ds-1, La-118, Pr-6, Sw-7, and Vi-3) have been in operation ever since. The number of observation wells remained less than 30 through 1945.

The beginnings of a statewide ground-water observation network can be traced back to 1946 when the Wisconsin Geological and Natural History Survey (WGS), directed by the State Legislature, began a program to measure ground-water levels in cooperation with the U.S. Geological Survey. During the period 1946–50, 217 wells were added to the observation network (fig. 1). By 1954, the network had reached its peak of 270 wells in 55 counties. After a revision in 1956, 34 wells were dropped from the program. By 1957 coverage was extended to 64 counties, although the number of wells had dropped to 208. Since 1958 the number of observation wells has stabilized at about 200. In 1965, measurements were made in 196 wells in 66 counties.

In 1982, measurements were made in 196 wells in 69 counties; wells in Iron, Menominee, and Washington Coun-

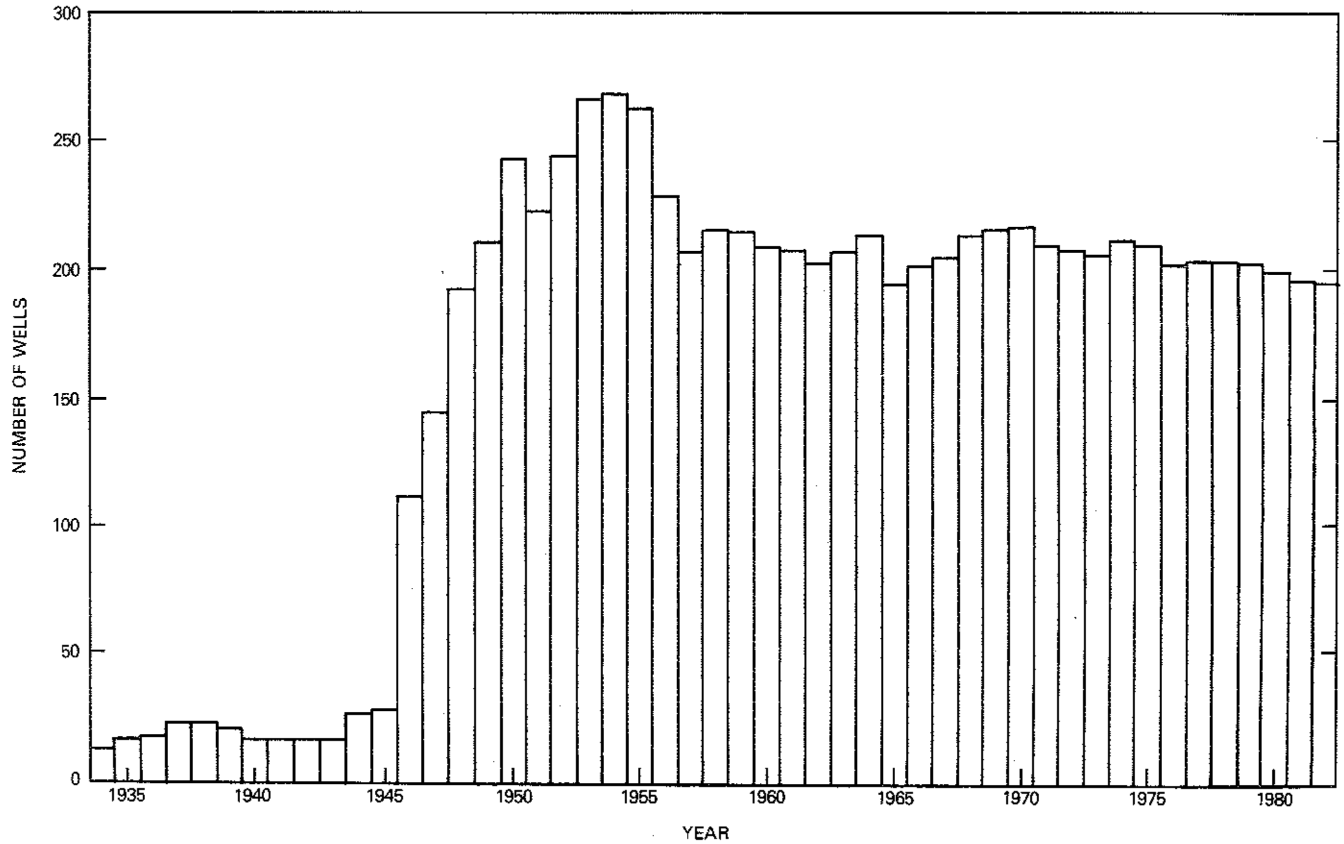


Figure 1. Number of observation wells in Wisconsin, by year.

ties were not measured (Zaporozec, 1983). Twenty-four of these wells were equipped with continuous recording gages, 39 were measured weekly, and 133 were measured monthly (table 1).

The observation-well network is constantly reevaluated and revised as necessary. A committee of representatives of the U.S. Geological Survey and WGS meet regularly to evaluate the network. Hydrographs for observation wells are periodically published (Audini and others, 1959; Devaul, 1967; Erickson, 1972; Erickson and Cotter, 1983).

The observation wells represent ground-water conditions in all four major aquifers in Wisconsin: the sand-and-gravel aquifer of Pleistocene age; the Silurian dolomite aquifer of Silurian and Devonian age; the upper sandstone aquifer including the Galena Dolomite, Decorah and Platteville Formations (Galena-Platteville aquifer), St. Peter Sandstone, Prairie du Chien Group, all of Ordovician age, and Cambrian Jordan Sandstone; and the lower sandstone aquifer including Cambrian sandstones of the Tunnel City and Elk Mound Groups (following the usage of the Wisconsin Geological and Natural History Survey—see Ostrom, 1967). The upper and lower sandstone aquifers are separated by the St. Lawrence Formation of Cambrian age. Locally, Precambrian rocks are minor aquifers that are used where other aquifers are absent or yield poor-quality water.

General Ground-Water Fluctuations

Fluctuations in ground-water levels indicate changes in actual quantity of water stored in aquifers and movement of ground water. Water levels generally decline when discharge exceeds recharge and rise when recharge is greater than discharge.

The character of water-level fluctuations depends in part on the character of the aquifers. Water levels in confined aquifers under natural conditions generally fluctuate to a much greater extent than water levels in unconfined (water-table) aquifers. However, under water-table conditions the actual amount of water taken from or added to storage per unit change is generally many times larger than under artesian conditions.

Table 2 summarizes the causes of ground-water fluctuations. Water-level fluctuations can be classified into several types on the basis of either time or cause. Three types of fluctuations are recognized according to the duration of variations in water levels: (1) short-term fluctuations that last from a few minutes to several days; (2) seasonal fluctuations that last from a few weeks to several months, depending upon the quantities of water recharged and discharged during the year; and (3) long-term fluctuations that extend over periods of several years (Zaporozec, 1980). Water-level fluctuations may be caused by (1) changes in ground-water storage (S);

Table 1. Period of record and frequency of measurement of observation wells in Wisconsin as of December 31, 1982

[— indicates data not available]

Years of continuous record	Number of wells	Frequency of measurement: Monthly	Weekly	Recording
46 or more	7	2	5	—
41-45	2	1	1	—
31-40	57	31	15	11
21-30	24	17	3	4
11-20	65	53	8	4
10 or less	41	29	7	5
TOTAL	**196**	**133**	**39**	**24**

Table 2. Classification of causes of fluctuations of ground-water levels

(Modified from Zaporozec, 1980. Origin of causes: S—changes in storage, L—deformation of aquifer[1], M—meteorological phenomena, D—disturbances within well)

Duration	Natural: Periodic	Natural: Nonperiodic	Human induced: Mostly nonperiodic
SHORT TERM (minutes, hours, days)	Geyser effects (S) Diurnal (daily): Evapotranspiration Changes in atmospheric pressure Temperature changes (M) Ocean tides (L) Earth tides (L)	Air entrapment during ground-water recharge (S) Floods (S) External load of surface water (L) Earthquakes (L) Bubbling gas (D) Animals falling into well (D) Water cascading from overlying formation (D)	Pumping (S) External load: Construction blasting (L) Earth-moving machinery (L) Passing trains (L) Water cascading from pipes in well casing (D) Objects dropped into well (D)
SEASONAL (weeks, months)	Recharge from precipitation (S) Variations of surface-water stages (S) Bank storage effects (S) Recharge from springs (S) Evapotranspiration and phreatophytic losses (M)		Seasonal pumping (S) (irrigation, seasonal industry)
LONG TERM (SECULAR) (years)	Recharge from precipitation (S) Discharge of springs and streams (S)		Heavy pumping (S) Artificial recharge Drainage (S) Seepage from dams (S) Deep-well injection[1] (S) Infiltration galleries (S) Changes in land use (S)

[1] Applies predominantly to confined aquifers.

(2) meteorological phenomena (atmospheric pressure, wind) (M); (3) deformation of aquifers (external loading, earthquakes) (L); and (4) disturbances within the well such as leaking pipes, objects falling into wells, or gas bubbles (D).

The majority of water-level fluctuations are caused by changes in ground-water storage. Storage changes can be periodic or nonperiodic and can be caused by natural or man-made artificial factors. Natural changes of storage, such as those caused by recharge from precipitation or from rivers, spring flow, and evapotranspiration losses, generally cause rather gradual changes in water levels. Near river channels, however, the increase in storage may be rather abrupt in response to flood flow. Artificial changes of storage caused by pumping, for example, are responsible for rapid fluctuations of water levels. However, artificially caused changes of storage can also be gradual. Examples of gradual storage change are those caused by changes in land use that result in changes of recharge characteristics or by gradual depletion of aquifers in areas of heavy pumping. Nonperiodic fluctuations are usually caused by factors other than changes in storage and are readily discernible.

METHODS OF ANALYSES

Wells Selected for Analysis

One hundred and twenty-four wells with at least 20 years of measurement and no lengthy intervals of missing record were selected for analysis. The locations of the analyzed wells are shown in figure 2. The historical water levels for each well were inspected for length of record and frequency and length of missing intervals upon retrieval from the Ground-Water Site Inventory (GWSI) data base. Estimated values were used to complete the data set where short intervals of missing measurements occurred. Although the frequency of measurement for various wells ranged from daily to monthly, the monthly mean was used in the analyses to create equally weighted data sets and to reduce the original data to a more manageable size.

Pertinent information, such as period of record, depth, aquifer type, and hydrogeologic district for the wells selected for analysis in this report, is shown in table 3 (p. 24–25). The wells are listed alphabetically by county and consecutively by serial number within each county.

A local well number, consisting of a system of letters and numbers, is used to identify individual wells. The prefix indicating the county name consists of a two-letter abbreviation. It is followed by the location designation within the county consisting of the township, range, and section numbers. This is followed by a sequential number assigned to each well within the county. For example, well Mr-27/09E/31–28 is in Marathon County, township 27 north, range 9 east, section 31, and was the 28th well inventoried in the county. An abbreviated version of this identification number consisting of the two-letter county abbreviation and the sequence number is used in the text. The above example would be referenced to as Mr-28.

Statistical Analyses

The following procedures, as presented by example well Wk-50, were used for all analyzed wells. Results for all wells are available at the Wisconsin District office of U.S. Geological Survey, Water Resources Division. These results are represented in this report by the fluctuability index in tables 7 through 13 and the probabilities of exceedance in table 6 (tables 6–13 are found on pages 26–38). The fluctuability index represents the range of water-level fluctuations and is used similarly to average annual amplitude in the discussions of individual districts.

The mean, highest and lowest monthly mean, median, particular quantiles and tests for normal distribution were obtained using the SAS[1] Proc Univariate procedure (SAS Institute, Inc., 1982a). The SAS Proc Univariate procedure utilizes the entire set of monthly mean water levels. The stage duration analyses were also obtained by plotting values from the frequency table of the univariate analysis. Table 4 shows the results of a typical Proc Univariate analyses. These data are not normally distributed, as shown by the Prob >D value of 0.125, even though the stem leaf and normal probability plots suggest normal distribution.

The fluctuability index is the difference between the ground-water levels exceeded by 10 percent ($H_{10\%}$) and by 90 percent ($H_{90\%}$) of days per year, determined from the frequency distribution curves (Zaporozec, 1980). The difference between these two levels is a much better indicator of the capacity of water level to fluctuate (hence the term fluctuability index) than its amplitude (the difference between the maximum and minimum recorded level). By using the values exceeded by 10 percent and 90 percent we eliminate the extreme end values of the set, which usually are very rare. The advantage of using the fluctuability index instead of the amplitude is clearly shown on well Bt-2, where the maximum fluctuation (amplitude) is 6.72 ft, whereas the more realistic range of fluctuations (fluctuability) is 2.07 ft.

Duration Analysis

The frequency values shown in table 4 were plotted on probability graphs for the stage (water-level) duration analyses. Figure 3 shows the duration plot for Wk-50. This plot indicates, for example, that 10 percent of the time the water level in Wk-50 has been more than 16.37 ft below land surface. It also shows that 10 percent of the time the water level has been less than 90.46 ft below land surface. Any percentile can be selected and the water level associated with that duration can be read off the curve. This type of analysis, although not predictive, can be used to examine how a well has fluctuated in the past and, barring any changes in stress on the hydrologic system, how it might fluctuate in the future.

[1] Use of the trade name in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

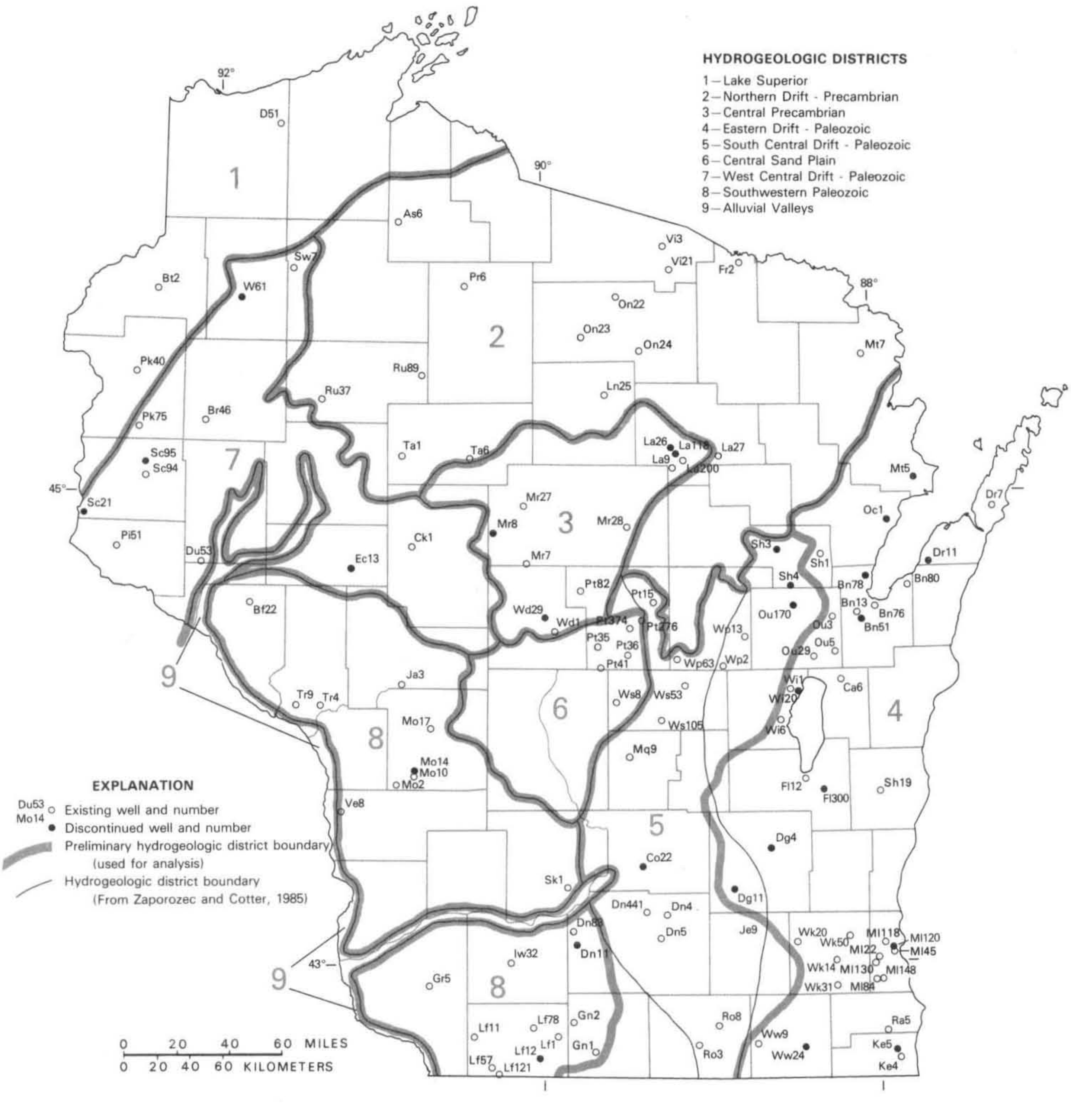


Figure 2. Hydrogeologic districts of Wisconsin and the location of observation wells used for analysis.

Table 4. Proc Univariate analyses of well Wk-50 water levels

UNIVARIATE

(Water levels in feet below land surface)

MOMENTS

NUMBER OF OBSERVATIONS	336	SUM OF WEIGHTS OF OBSERVATION	336
MEAN	13.6062	SUM	4571.68
STANDARD DEVIATION	2.1494	VARIANCE	4.61993
SKEWNESS	0.329597	KURTOSIS	-0.348462
UNCORRECTED SUM OF SQUARES	63750.8	CORRECTED SUM OF SQUARES	1547.68
COEFFICIENT OF VARIATION	15.7972	STANDARD MEAN	0.11726
NUMBER OF NONZERO OBSERVATIONS	336		
KOLOMOGOROV D STATISTIC	0.0433634	KOLOMOGOROV D TEST FOR NORMAL DISTRIBUTION	0.125
t-TEST FOR MEAN=0	116.035	PROBABILITY THAT ABSOLUTE VALUE FOR t IS GREATER THAN REPORTED	0.0001
CENTERED SIGN RANK STATISTIC TEST FOR MEAN=0	28308	PROBABILITY THAT ABSOLUTE VALUE FOR CENTERED SIGN RANK STATISTIC IS GREATER THAN REPORTED	0.0001

QUANTILES (DEF=4)

100% MAXIMUM	19.66	99%	19.0278
75% Q3 (3RD QUARTILE)	15.1775	95%	17.2325
50% MEDIAN	13.57	90%	16.517
25% Q1 (1ST QUARTILE)	11.945	10%	10.745
0% MINIMUM	9.23	5%	10.3185
		1%	9.6859

RANGE	10.43
Q3-Q1	3.2325
MODE	13.79

EXTREMES

LOWEST	HIGHEST
9.23	18.86
9.48	18.99
9.66	19.05
9.73	19.14
9.76	19.66

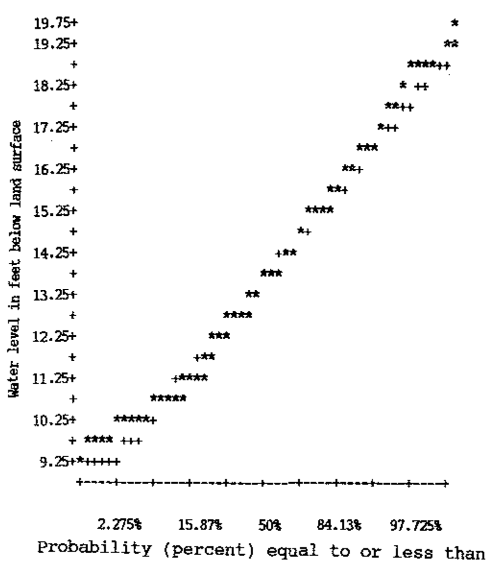
```
STEM LEAF ANALYSIS                                  #      BOXPLOT

19 7                                                1         &
19 001                                              3         &
18 7789                                             4         &
18 224                                              3         &
17 789                                              3         &
17 0001244                                          7         &
16 55666778888999                                  14         &
16 001122334444                                    12         &
15 55556667777889999                               17         &
15 000111222222222222334444444                     27      +-----+
14 55566667777777778899                            20      &     &
14 00001111222223333334444444                      26      &     &
13 55555555666666666777777788888888899999999       41      *--+--*
13 0001111112222233334444                          22      &     &
12 55555555566666777778888899999                   29      &     &
12 00111222222233333444444                         23      &     &
11 555566777788889999                              18      +-----+
11 01222223333333344444444                         23         &
10 5555566666778889999999                          22         &
10 02223333333444                                  14         &
 9 577899                                           6         &
 9 2                                                1         &
   ----+----+----+----+----+----+----+----+-

          NUMBER OF OCCURRENCES
```

Water level in feet below land surface (number indicates decimal value)

NORMAL PROBABILITY PLOT



UNIVARIATE

FREQUENCY TABLE

VALUE	COUNT	PERCENTS CELL	PERCENTS CUM	VALUE	COUNT	PERCENTS CELL	PERCENTS CUM	VALUE	COUNT	PERCENTS CELL	PERCENTS CUM	VALUE	COUNT	PERCENTS CELL	PERCENTS CUM
9.23	1	0.3	0.3	10.27	1	0.3	3.6	14.68	2	0.6	69.9	18.2	1	0.3	97.0
9.48	1	0.3	0.6	12.54	2	0.6	33.9	14.71	3	0.9	70.8	18.25	1	0.3	97.3
9.66	1	0.3	0.9	12.55	2	0.6	34.5	14.73	1	0.3	71.1	18.38	1	0.3	97.6
9.73	1	0.3	1.2	12.56	1	0.3	34.8	14.77	1	0.3	72.0	18.67	1	0.3	97.9
9.76	1	0.3	1.5	12.57	1	0.3	35.1	14.81	1	0.3	72.3	18.69	1	0.3	98.2
9.88	1	0.3	1.8	12.59	2	0.6	35.7	14.87	1	0.3	72.6	18.84	1	0.3	98.5
9.95	1	0.3	2.1	12.66	1	0.3	36.0	14.89	1	0.3	72.9	18.86	1	0.3	98.8
10.04	1	0.3	2.4	12.68	3	0.9	36.9	14.99	1	0.3	73.2	18.99	1	0.3	99.1
10.19	1	0.3	2.7	12.7	1	0.3	37.2	15	1	0.3	73.5	19.05	1	0.3	99.4
10.2	1	0.3	3.0	12.81	1	0.3	38.4	15.05	1	0.3	73.8	19.14	1	0.3	99.7
10.22	1	0.3	3.3	12.83	1	0.3	38.7	15.07	2	0.6	74.4	19.66	1	0.3	100.0

Probability Analysis

Pearson Type III frequency analysis was used to obtain probability of exceedance of values of the Pearson variable (in this case water levels). The monthly mean water levels were subdivided into four seasonal data sets for each well, with March through May representing spring, June through August representing summer, September through November representing fall, and December through February representing winter. These data sets better approximate a normal distribution and also reduce the serial correlation. Four separate Pearson Type III analyses—one for each season—were run for each well. Figure 4 shows the four Pearson Type III analyses for well Wk-50 and table 5 shows the values corresponding to the 98, 90, 80, 20, 10, and 2 percent probabilities of exceedance of water levels. Table 6 shows the seasonal probability of exceedance values for all wells analyzed in the report.

These analyses indicate, for example in well Wk-50, that during the spring there is a 90 percent chance that the water level will be more than 10.5 ft and a 10 percent chance that the water level will be more than 15 ft below land surface (table 5). During the fall there is a 90 percent chance that the water level will be more than 12 ft and a 10 percent chance that the water level will be more than 17 ft below land surface. Like the duration analyses, any probability can be selected off the horizontal scale and the corresponding water level read from the plot. Unlike the duration analysis, which provides a description of a well's past fluctuations, the Pearson Type III analysis has been used as a tool, based on past fluctuations, to predict extremely high or low water levels.

Extreme care must be taken in using the information gained from either the duration or the Pearson Type III analyses because both are based on past hydrogeologic conditions and any major changes in the system could alter the water-level fluctuations. One example is the case of a well affected by pumping where the water level fluctuates sporadically based on the pumping schedule and rate. Both types of analysis would be meaningless for random fluctuations.

Multiple Regression

In an attempt to relate water-level fluctuations to other factors in the hydrogeologic system, multiple-regression analyses were run on data from groups of wells representing various hydrogeologic districts. The SAS Proc Stepwise

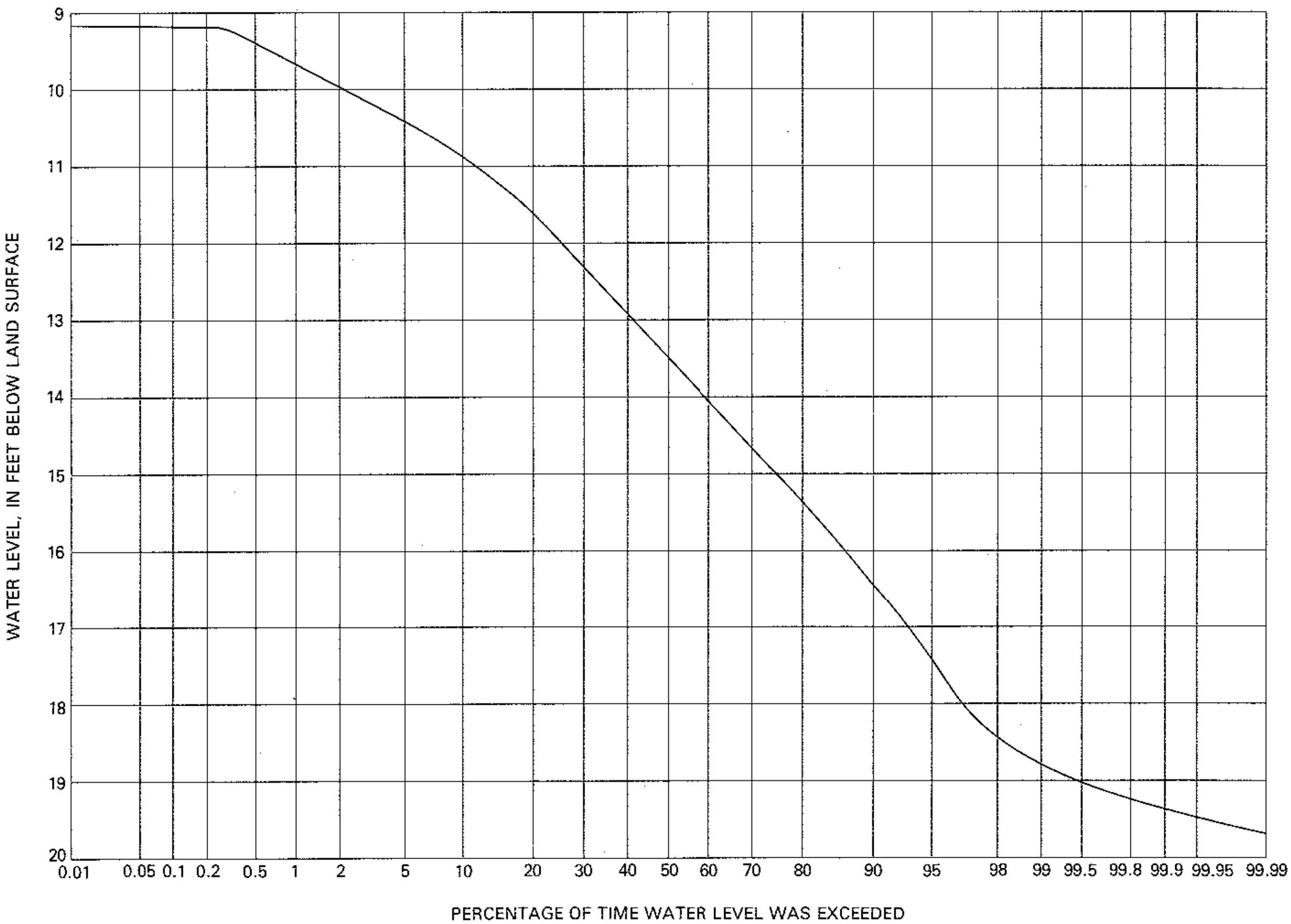


Figure 3. Water-level-duration plot for well Wk-50.

Table 5. Selected probabilities of exceedance for seasonal water levels in well Wk-50, in feet below land surface

Season	Probability of exceedance					
	98 percent	90 percent	80 percent	20 percent	10 percent	2 percent
Spring	9.5	10.5	11.0	14.0	15.0	16.5
Summer	10.0	11.5	12.5	15.0	15.5	16.6
Fall	10.5	12.0	13.0	16.0	17.0	18.5
Winter	10.5	11.5	12.5	16.0	17.0	19.5

(SAS Institute, Inc., 1982b) method was used. The model used average annual amplitude as the dependent variable and mean water level, mean annual precipitation, standard deviation of the seasonal mean precipitation, aquifer type (represented by an average transmissivity), and topographic setting (represented by land-surface slope) as the independent variables. This procedure produced different regression equations for each district and identified the principal factors (of those included in the model) involved in controlling fluctuations in each district. The results of these analyses are discussed in the district summaries. It should be noted, however, that because many factors control ground-water fluctuations it is difficult to obtain a model that accurately represents amplitude as a function of a single equation. The results of the regression analyses are helpful in recognizing some of the important factors. However, the equations are not effective in predicting the amplitude of a particular well because local conditions are of extreme importance and regional analysis does not consider the local factors at an individual well.

CHARACTERISTICS OF HYDROGEOLOGIC DISTRICTS AND ANALYTICAL RESULTS

Each geographic area of Wisconsin has a unique soil-rock-water relation, because geology, topography, and climate differ regionally. These three factors ultimately determine the amount of available ground water and the character of water-level fluctuations. On the basis of these three factors, the State has been divided into three hydrogeologic provinces (Meinzer, 1923), which have recently been further subdivided by Zaporozec and Cotter (1984) into nine hydrogeologic districts (fig. 2). For the purpose of this report, wells from Districts 1 and 2 were combined, and wells from Districts 8 and 9 were combined because the number of observation wells in Districts 1 and 9 were insufficient for statistical analysis.

Hydrogeologic Districts 1 and 2

These districts are a part of the Superior Uplands Province (Martin, 1932), a large hydrogeologic unit extending into northern Wisconsin from Minnesota and Michigan (fig. 2). This province is underlain by the southernmost part of the Canadian shield, which is mainly composed of metamorphic and igneous rocks of Precambrian age more than 600 million years old. For practical purposes, the Precambrian rocks may be considered impermeable and they form the lower limit of ground-water movement even though limited amounts of water can be obtained from fractures or weathered zones at the Precambrian surface.

The Precambrian is covered by thin unconsolidated material deposited during the Pleistocene glaciation. These deposits consist of loose material irregularly deposited by glaciers over the Precambrian surface, either in the form of extended sheets (ground moraine) or as end moraine ridges piled up at the margins of the ice sheets. This material is composed of unsorted and unstratified clay, silt, sand, gravel, and boulders, called till. Some sediments were deposited in postglacial, intraglacial, and glacial lakes in stratified layers of clay, silt, and sand. As the ice melted, the material brought by the glacier was reworked by meltwaters and deposited in extensive plains beyond active glacier ice. This material, called outwash, consists of sorted and stratified sand and gravel.

This area is a gently arched highland. Its surface is moderately hilly and gently rolling. Streams have accomplished very little in draining this area due to the relatively recent retreat of the last continental glacier (about 10,000 years ago). The area is characterized by poorly developed drainage systems, lakes and swamps, thin unconsolidated material, and shallow ground-water systems.

Table 7 summarizes hydrologic information on the 15 wells in Districts 1 and 2. All 15 wells are in the sand-and-gravel aquifer. The mean water levels are shallow and range from 2.27 to 33.86 ft below land surface, with the exception of La-27, which is located on a hilltop more than 70 ft above the water table. The average annual amplitudes are all less than 5 ft and, with the exception of Ta-6, so are the fluctuability indexes.

Hydrogeologic District 3

This district has the same geologic and geomorphologic characteristics as Districts 1 and 2, except that the Precambrian rocks are exposed or near the surface and are covered by thin unconsolidated materials that supply small amounts of water to wells. Moderate to large supplies of water can be obtained from sand-and-gravel deposits in bedrock chan-

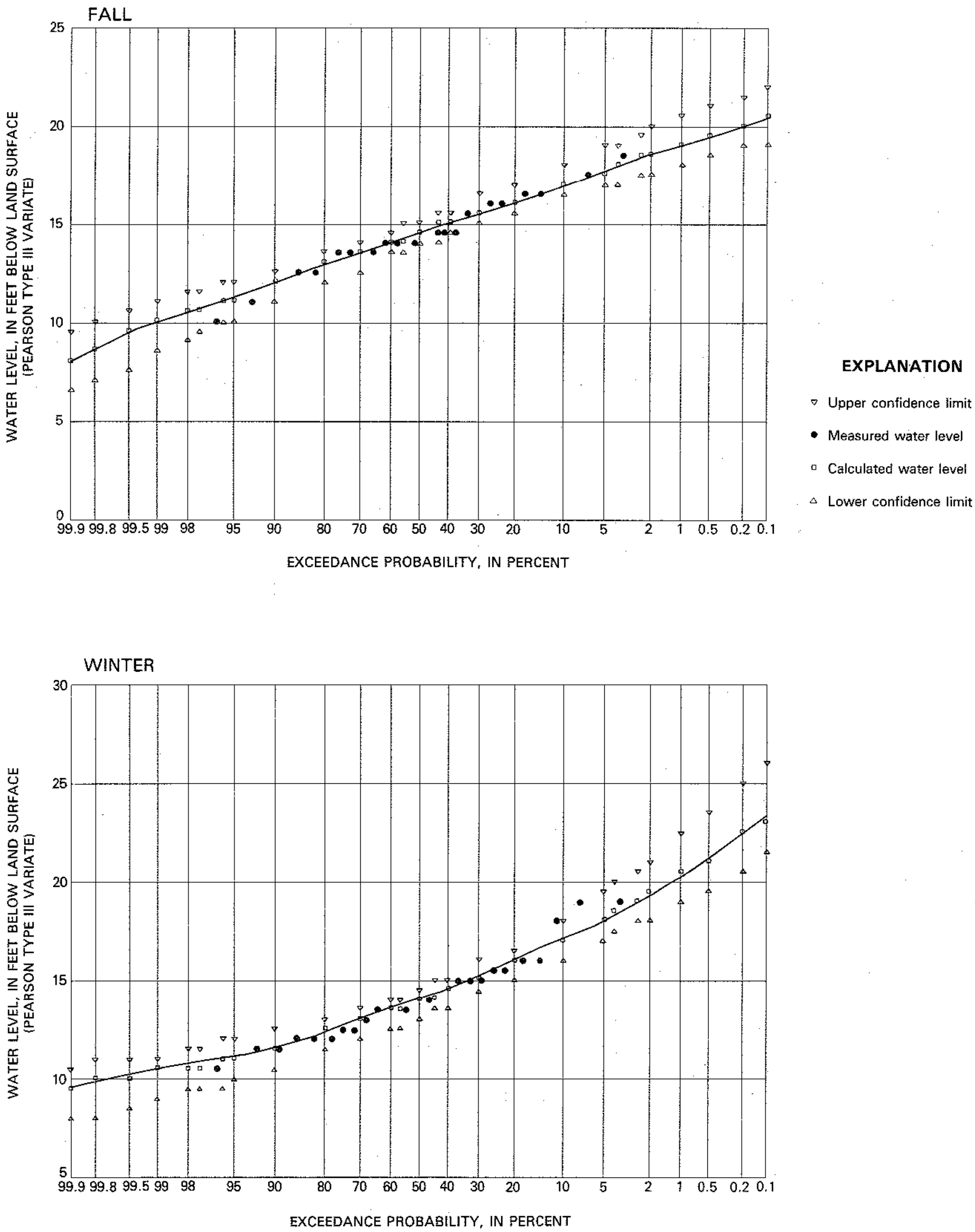
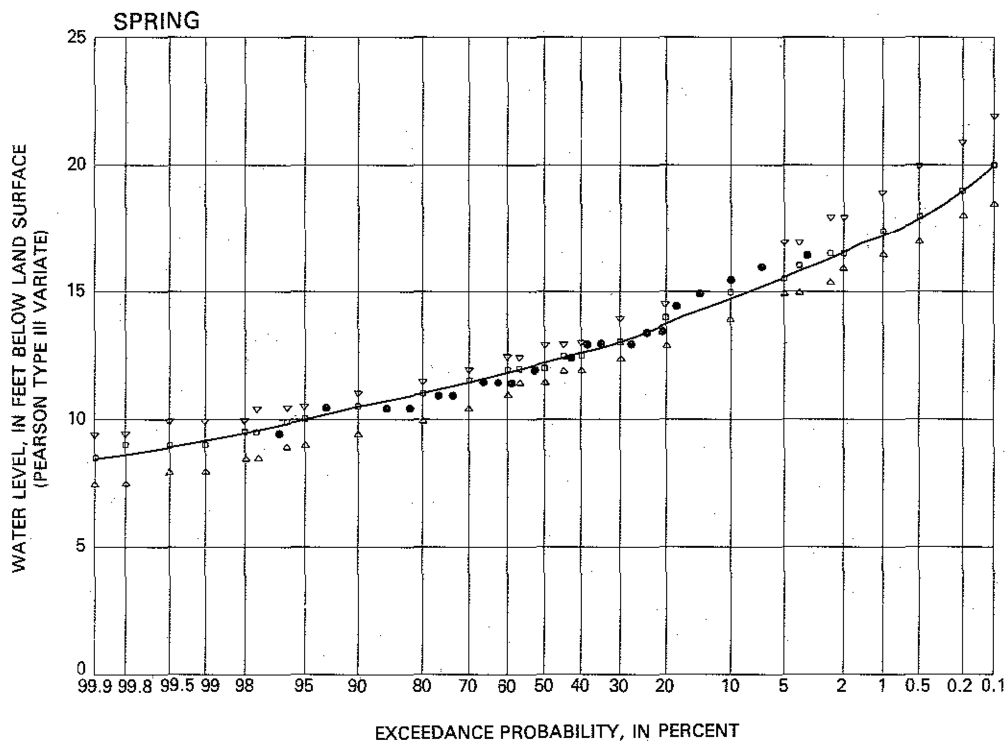


Figure 4. Pearson Type III analyses for well Wk-50 water levels.



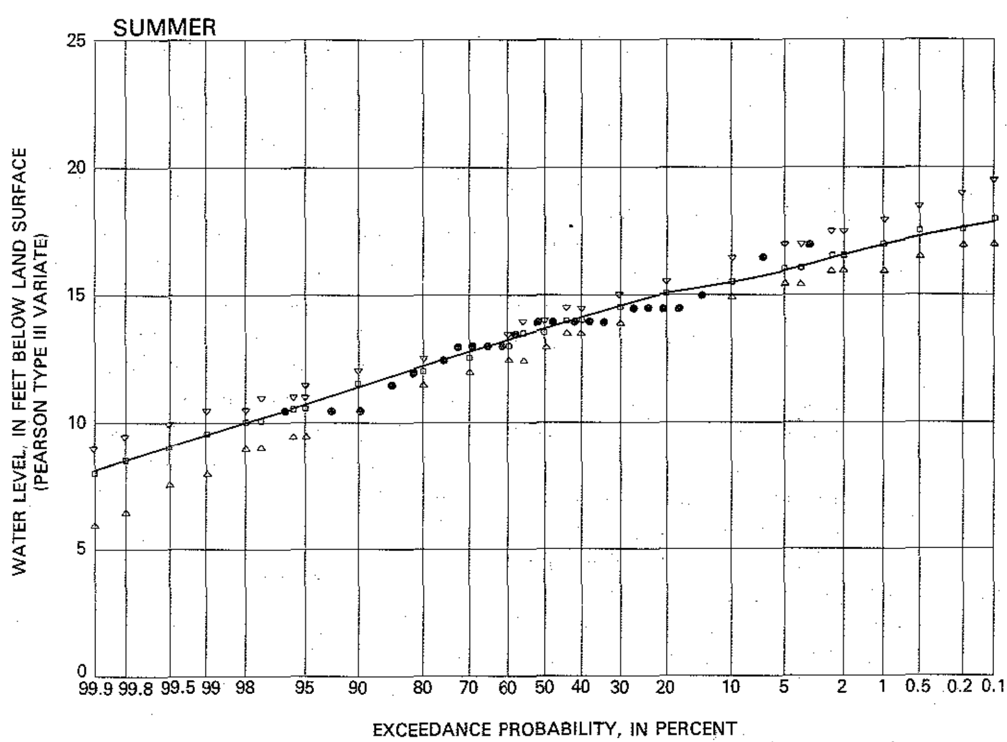


Figure 4. Pearson Type III analyses for well Wk-50 water levels—Continued.

nels. Water yields from Precambrian rocks depend on the degree and depth of weathering and the size and interconnection of fractures.

Table 8 summarizes the hydrologic information for the 11 wells in District 3. All 11 wells are in the sand-and-gravel aquifer. The mean water level ranges from 2.78 to 20.14 ft below land surface. The average annual amplitudes range from 1.36 to 5.57 ft and the fluctuability indices range from 1.43 to 7.37 ft. The very shallow depth to water in this district is a reflection of the less permeable bedrock near the surface. Seven of the 11 wells in this district have water levels within 10 ft of land surface.

Hydrogeologic District 4

This district trends north-south along Lake Michigan. It belongs to the the glaciated Paleozoic Province (Meinzer, 1923), with Districts 5, 6, and 7 (fig. 2). The primary source of water supplies is a thick, multilayered complex of water-bearing Paleozoic sandstone and dolomite interbedded with formations of low permeability. This complex is overlain by Pleistocene sediments of varying thickness and productivity. The sandstone aquifer is the most heavily pumped aquifer in the State. Heavy pumping from many municipal and industrial wells has caused a gradual decline of artesian pressure in the district.

Characteristic topographic features of the district are the clusters of drumlins in Dodge, Jefferson, and Dane Counties and two cuestas (ridges of more durable rock units) that have relatively steep, west-facing scarps and long, gentle backslopes that dip eastward.

Table 9 summarizes hydrologic characteristics of 38 wells in District 4. This district includes all the major aquifers recognized in Wisconsin. This district contains both water table and artesian wells; 17 of the 38 wells are affected by pumping.

The mean water levels of the 21 wells unaffected by pumping range from the artesian 9.40 ft above land surface to 194 ft below land surface. Twelve of these wells have mean water levels less than 50 ft but three have water levels greater than 100 ft below land surface. The average annual amplitudes and fluctuability indices range from 1.85 to 17.3 ft and 3.42 to 33.57 ft, respectively.

The mean water levels of the wells affected by pumping range from 2.68 to 358.49 ft below land surface. Six have means less than 50 ft below land surface but seven have means greater than 100 ft below land surface. The average annual amplitude ranges from 3.21 to 24.98 ft, which is similar to the range of the unaffected wells. The fluctuability indices, however, range from 4.86 to 160.93 ft. The effect of pumping is indicated in the fluctuability indices; 10 of 17 affected wells have indices over 25 ft, compared to only 2 of 21 unaffected wells.

Hydrogeologic District 5

This district is a narrow strip of south-central Wisconsin, 20 to 50 mi wide, underlain by Paleozoic rocks. Its northern part is covered by impermeable glacial-lake deposits. The rest of the district is covered by moderately thin, moderately permeable Pleistocene deposits.

Table 10 shows hydrologic data from 17 wells in District 5. Most wells in this district are in the sandstone aquifer, but 5 wells are in the sand-and-gravel aquifer. Two wells, Dn-5 and Je-9, are affected by municipal pumping. The mean water levels of all wells range from 4.23 to 92.41 ft below land surface; the average for the entire district is 33.95 ft below land surface. The average annual amplitudes are from 1.08 ft to 10.24 ft; the district average is 3.64 ft. The fluctuability indices range from 1.81 to 12.01 ft, with the exception of the two wells affected by pumping that have indices of 16.12 and 23.93 ft.

Hydrogeologic District 6

This district is the smallest hydrogeologic district of Wisconsin and it is formed by highly productive, water-bearing deposits of sand and sand and gravel overlying the sandstone aquifer. The topography of the district is flat or slightly rolling, with little relief.

Table 11 shows hydrologic data for six wells in District 6. All six are in the sand-and-gravel aquifer. The mean water levels range from 4.02 to 12.12 ft below land surface and the district average is 7 ft. The average annual amplitudes and fluctuability indices range from 2.29 to 3.91 ft and 1.89 to 6.87 ft, respectively.

Hydrogeologic District 7

This district is a crescent-shaped strip of west-central Wisconsin between the Drift-Crystalline Province (Meinzer, 1923) and the Driftless Area. The major source of water is the sandstone aquifer that underlies the entire district. In the north, however, most of the domestic and irrigation wells obtain water from the sand-and-gravel aquifer.

This district is a flat lowland in the east that becomes moderately hilly toward the north. The greater topographic relief is in the southwestern part of the district.

Table 12 shows hydrologic data from 11 wells in District 7. These wells are either in the sandstone aquifer or in sand and gravel. The mean depth to water ranges from 4.61 to 64.59 ft below land surface, and the district average is 31.59 ft. The average annual amplitudes and fluctuability indices range from 1.05 to 2.93 ft and 0.95 to 11.11 ft, respectively. The fluctuability indices for five of the wells are several times larger than the average annual amplitudes.

Hydrogeologic Districts 8 and 9

These districts are a part of the Unglaciated Paleozoic Province (Meinzer, 1923) and it is formed entirely by the Driftless Area. This area was apparently untouched by glaciers because it lacks evidence of glacial erosion and deposition. The sandstone aquifer is the principal source of water throughout the entire district. Adequate amounts of water can also be obtained from the Ordovician Galena

Dolomite, Decorah and Platteville Formations, Prairie du Chien Group, and the St. Peter Sandstone. Thick sand-and-gravel deposits beneath the alluvial valleys of perennial streams make up District 9.

The topographic relief is well defined. The area is characterized by deep valleys and flat-topped, often narrow ridges. The area is well drained and contains few natural lakes.

Table 13 shows hydrologic data for 24 wells in District 8. This district contains wells from several aquifers. Two wells are affected by pumping. The mean water levels range from 4.38 to 139.30 ft below land surface and the district average is 46.67 ft. The average annual amplitudes range from 1.07 to 11.08 ft; the district average is 4.24 ft. The fluctuability indices range from 1.26 to 16.89 ft except for the wells affected by pumping that have indices of 32.56 and 41.16 ft.

MULTIPLE-REGRESSION ANALYSIS BY HYDROGEOLOGIC DISTRICT

Multiple-regression analyses were run using the SAS Proc Stepwise procedure. The data were grouped by district and by aquifer. The results are discussed in terms of the coefficient of determination (r^2) of the model. The r^2 is the fraction of the variability in the dependent variable explained by the independent variables. Significance levels for the model and each variable within the model are also presented. The results of the analyses are summarized in table 14.

The model for the district analyses used average annual amplitude as a function of aquifer (represented by average transmissivity), mean water level (for the period of record), mean annual precipitation, and the standard deviation of the seasonal mean precipitation.

Hydrogeologic Districts 1 and 2

Data from 16 wells in Districts 1 and 2 were combined for analysis. In the first step, the variable aquifer was entered. This one-variable model had an r^2 of 0.77 and a significance level of 0.0001.

The second step entered a second variable, topographic setting. This two-variable model had an r^2 of 0.83 with a significance level of 0.0001. The significance levels were 0.02 for aquifer and 0.03 for topographic setting. Additional steps to improve the r^2 greatly reduced the significance levels.

Visual inspection of the data from District 1 (table 7) shows that the average annual amplitudes are fairly consistent and all are under 5 ft. These wells are also in the sand-and-gravel aquifer. The one-variable model would not be useful in this case because neither the amplitude nor the aquifer vary within the district. The two-variable model combining the aquifer and topographic setting would appear to be a better tool. This equation is:

$$\text{Average annual amplitude} = 0.023\ (\text{aquifer}) + 2.77\ (\text{topographic setting})$$

This equation does not work effectively for calculating amplitudes at a particular well but it does indicate that in this district average transmissivity and slope are important factors. Although recharge values were not available for this analysis, it seems likely that recharge, which is a function of topography and vertical conductivity through the unsaturated zone, would be an important variable in the regression equation.

Hydrogeologic District 3

Data for 12 wells in District 3 were analyzed. The variable, aquifer, was entered in the first step. This one-variable model had an r^2 of 0.80 and a significance level of 0.0001.

The second step entered the variable mean water level. The two variable model had an r^2 of 0.82 and a significance level of 0.0002. Individual significance levels of each variable were 0.01 for aquifer and 0.27 for mean water level. Additional steps to improve the r^2 greatly decreased significance levels for the variables used.

The one-variable model is not of much use for the same reasons as in the case of Districts 1 and 2. The two-variable model would be more useful but the significance level for the variable mean water level is poor. This equation is:

$$\text{Average annual amplitude} = 0.075\ (\text{mean water level}) + 0.045\ (\text{aquifer})$$

The regression analyses for this district would also be improved by the use of recharge data.

Hydrogeologic District 4

Data from 38 wells from District 4 were analyzed. The first step entered the standard deviation of the seasonal mean precipitation. The one-variable model had an r^2 of only 0.57 and a significance level of 0.0001.

The second step entered the variable mean water level. The two-variable model had an r^2 of 0.59 and a significance level of 0.0001. The standard deviation of the mean precipitation had a significance level of 0.03 and the mean water level of 0.19. Again, additional steps to improve the model failed.

One problem with analyzing the wells in this district is the wide variety of aquifer types present. This variety is evident in the poor regression results. The two-variable regression equation is:

$$\text{Average annual amplitude} = 0.065\ (\text{mean water level}) + 5.82\ (\text{standard deviation of seasonal mean precipitation})$$

There are no obvious variables that may be used to improve the analysis for this district.

Hydrogeologic District 5

Data for 17 wells in District 5 were analyzed. The first step entered the variable topographic setting. This model had an r^2 of 0.64 and a significance level of 0.0001.

Table 14. r^2, variables, and significance levels of regression equations

Hydrogeologic District	r^2	Variable	Significance level
1 & 2	0.83	Aquifer [1]	0.02
		Topographic setting [2]	.03
3	.82	Mean water level [3]	.27
		Aquifer	.01
4	.59	Mean water level	.19
		Standard deviation of seasonal mean precipitation	.03
5	.69	Standard deviation of seasonal mean precipitation	.14
		Topographic setting	.13
6	.96	Aquifer	.003
		Topographic setting	.32
7	.92	Standard deviation of seasonal mean precipitation	.009
		Topographic setting	.17
8	.83	Standard deviation of seasonal mean precipitation	.006
		Topographic setting	.005

Aquifer	r^2	Variable	Significance level
Sand and gravel	0.77	Standard deviation of seasonal mean precipitation	0.0001
		Mean water level	.18
Eastern dolomite	.98	Topographic setting	.02
Galena-Platteville	.98	Mean water level	.002
		Topographic setting	.09
Upper sandstone	.72	Mean water level	.02
		Standard deviation of seasonal mean precipitation	.05
		Topographic setting	.10
Sandstone (including upper and lower)	.59	Mean water level	.004
		Topographic setting	.31

[1] Average transmissivity.
[2] Slope.
[3] For the period of record.

The second step entered the standard deviation of the seasonal mean precipitation. The two-variable model had an r^2 of 0.69 and a significance level of 0.0001. Individual significance levels were 0.14 for the standard deviation of seasonal mean precipitation and 0.13 for topographic setting. Again, additional steps to improve the model failed.

The two-variable model equation is:

Average annual amplitude = 1.95 (standard deviation of seasonal mean precipitation) + 4.58 (topographic setting)

The analyses for this district may also be aided by including recharge or soil permeability data in the regression.

Hydrogeologic District 6

Data from six wells from District 6 were analyzed. The first step entered the variable standard deviation of seasonal mean precipitation. This model had an r^2 of 0.95 and a significance level of 0.0002.

The second step entered the variable aquifer and replaced the standard deviation of seasonal mean precipitation with topographic setting. This model had an r^2 of 0.96 and a significance level of 0.0014. The individual significance levels were 0.003 for aquifer and 0.32 for topographic setting. Again, additional steps to improve the model failed.

The equation is:

Average annual amplitude = 0.06 (aquifer) − 2.08 (topographic setting)

The analyses of this district suffered from too few wells. The analyses would also benefit from the addition of recharge data.

Hydrogeologic District 7

Data from 11 wells from District 7 were analyzed. The first step entered the variable standard deviation of seasonal mean precipitation. This model had an r^2 of 0.90 and a significance level of 0.0001.

The second step entered the variable, topographic setting. This two-variable model had an r^2 of 0.92 and a significance level of 0.0097. The individual significance levels were 0.009 for standard deviation of seasonal mean precipitation and 0.17 for topographic setting. Again, additional steps to improve the model failed.

The equation is:

Average annual amplitude = 1.04 (standard deviation of seasonal mean precipitation) + 1.71 (topographic setting)

Hydrogeologic Districts 8 and 9

Data from 24 wells from District 8 were analyzed. The first step entered the variable mean water level. The one-variable model had an r^2 of 0.76 and a significance level of 0.0001.

The second step entered the variable standard deviation of seasonal mean precipitation. The two-variable model had an r^2 of 0.83 and a significance level of 0.0054. The individual significance levels were 0.005 for mean water level and 0.006 for standard deviation of seasonal mean precipitation. Additional steps to improve the model failed.

The equation is:

Average annual amplitude = 1.88 (standard deviation of seasonal mean precipitation) + 0.06 (mean water level)

MULTIPLE-REGRESSION ANALYSIS BY AQUIFER

The results of regression analyses on data subdivided by district were not particularly successful. The results indicated that another subdivision of the data might yield better results and another set of regression analyses were run on data subdivided by aquifer. The model used average annual amplitude as a function of the mean water level, topographic setting, and standard deviation of seasonal mean precipitation. Table 14 lists the variables from the most significant equations for each aquifer.

Sand-and-Gravel Aquifer

Data from 51 wells finished in the sand-and-gravel aquifer were analyzed. The best model for these data was a two-variable model:

Average annual amplitude = 2.29 (standard deviation of seasonal mean precipitation) − 0.02 (mean water level).

This model had an r^2 of 0.77 and significance levels of 0.0001 for deviation of seasonal mean precipitation and 0.18 for mean water level.

Silurian Dolomite Aquifer

Data from 10 wells finished in the Silurian dolomite aquifer were analyzed. The best model in this case was a one-variable model:

Average annual amplitude = 12.33 (topographic setting).

This model had an r^2 of 0.98 and a significance level of 0.02.

Galena-Platteville Aquifer

Six wells finished only in the Galena-Platteville aquifer were analyzed separately from the other wells in the upper sandstone aquifer. The best model was a two-variable model:

Average annual amplitude = 0.09 (mean water level) + 2.33 (topographic setting).

This model had an r^2 of 0.98 with significance levels of 0.002 for mean water level and 0.09 for topography setting.

Upper Sandstone Aquifer

Data from 21 wells finished in the upper sandstone aquifer were analyzed. Most of these wells were finished in the Prairie du Chien Group; others included a combination of the Galena-Platteville aquifer and St. Peter Sandstone or combination of the Galena-Platteville aquifer, St. Peter Sandstone, and Prairie du Chien Group.

The best model was the three-variable model:

Average annual amplitude = 0.17 (mean water level) + 8.34 (standard deviation of seasonal mean precipitation) − 12.48 (topographic setting).

This model had an r^2 of 0.72 and significance levels of 0.02 for mean water level, 0.05 for standard deviation of seasonal mean precipitation, and 0.10 for topographic setting.

Sandstone Aquifer (Includes Upper and Lower)

Wells penetrating both the lower and upper sandstone aquifer are included, with wells penetrating only the lower sandstone aquifer. Thirty-five wells from the aquifer were analyzed. The best model was a two-variable model:

Average annual amplitude = 0.08 (mean water level) + 2.89 (topographic setting).

This model had an r^2 of only 0.59 and significance levels of 0.004 for mean water level and only 0.31 for topographic setting.

The regression analyses on the wells grouped by aquifer failed to provide better results than the analyses grouped by hydrogeologic district. Several other attempts were made using different variables and different groupings, but all other combinations led to poorer results than the analyses presented.

CYCLIC FLUCTUATIONS AND LONG-TERM TRENDS

Background data, such as water-level measurements, are normally collected on a routine schedule for many years. An evaluation of the long-term data allows determination of trends that are established either locally or regionally for a particular ground-water system. The establishment of trends will allow prediction of the effects of natural factors and human-related stresses on the ground-water resource.

The determination of long-term trends and dominant patterns or frequencies of water-level fluctuations was not a primary objective of this study. However, selected hydrographs of average annual water level and frequency distribution analyses of annual maximum and minimum water levels were inspected for possible trends and to indicate the potential for future research.

Analysis of annual maximum and minimum water levels indicates several periods in the annual cyclic fluctuations, two periods of recession (winter and summer) and two periods of rising levels (spring and fall). Usually, the late winter minimum is the lowest level and the spring maximum is the highest level for every annual cycle. The summer-fall minimum and the fall maximum are less distinct and do not occur every year.

A composite frequency of extreme annual levels on 71 of the analyzed wells is presented in figure 5. The wells affected by pumping or by other human activities and closely grouped wells, which could distort the regional distribution of extremes, were eliminated. The lowest levels at the end of winter recession most frequently occur in December, February, or March. However, the record low usually occurs in August, September, or October during drought. Ground-water levels most often peak in May, April, or June. In the fall they may peak between September and December, depending upon complexities of meteorological, geomorphological, and geological factors.

There do not seem to be any distinct areal variations in annual extremes throughout the State. The diagram of monthly ranges of water levels for each hydrogeologic district (fig. 6) shows that the minimum water levels usually occur during the winter and summer recessions. The maximum levels usually occur in spring (May, April, or June).

Departure of a well hydrograph from the indicated distribution of highest and lowest monthly means is a good indication that the well is affected by other than normal conditions. For example, the combination of high levels occurring during December and January and low levels in July and August (such as on well Oc-1) indicate that a well is affected by pumping. Water levels are lowest during summer months when the demands for water are greatest; the water level then recovers during winter months when the water withdrawals are smaller.

High levels in January and low levels in December indicate generally declining water levels and the reverse (low in January and high in December) is characteristic for generally rising water levels. High frequency of both December and January as the highest and lowest is typical for wells with gradual long-term changes in water levels.

Several periods can be identified as having the highest or lowest recorded water levels throughout the State (table 15). The highest levels were recorded in 1946–47, 1952–53, 1960–61, 1973–76, and 1979–80. The record low levels occurred in 1948–49, 1958–59, 1964–65, and 1977. A low period that occurred in 1940 has been inferred from the 1939 drought year and cannot be documented for lack of wells with long-term observation records.

The long-term cyclicity of ground-water level fluctuations is documented on hydrographs of wells Sw-7, Ln-25a, Mt-7, Ju-8, and Ju-98 (fig. 7). Seasonal variations that tend to obscure the long-term trends are eliminated by plotting the average annual water levels. The hydrographs are very similar even though the wells are 80 to 100 mi apart and constructed in different geologic materials. The long-term trends and the duration of the cycles apparently depend little on the location and on the lithologic composition of the aquifers, but rather on precipitation (Zaporozec, 1984). The hydrographs show several periods of well-defined peaks and

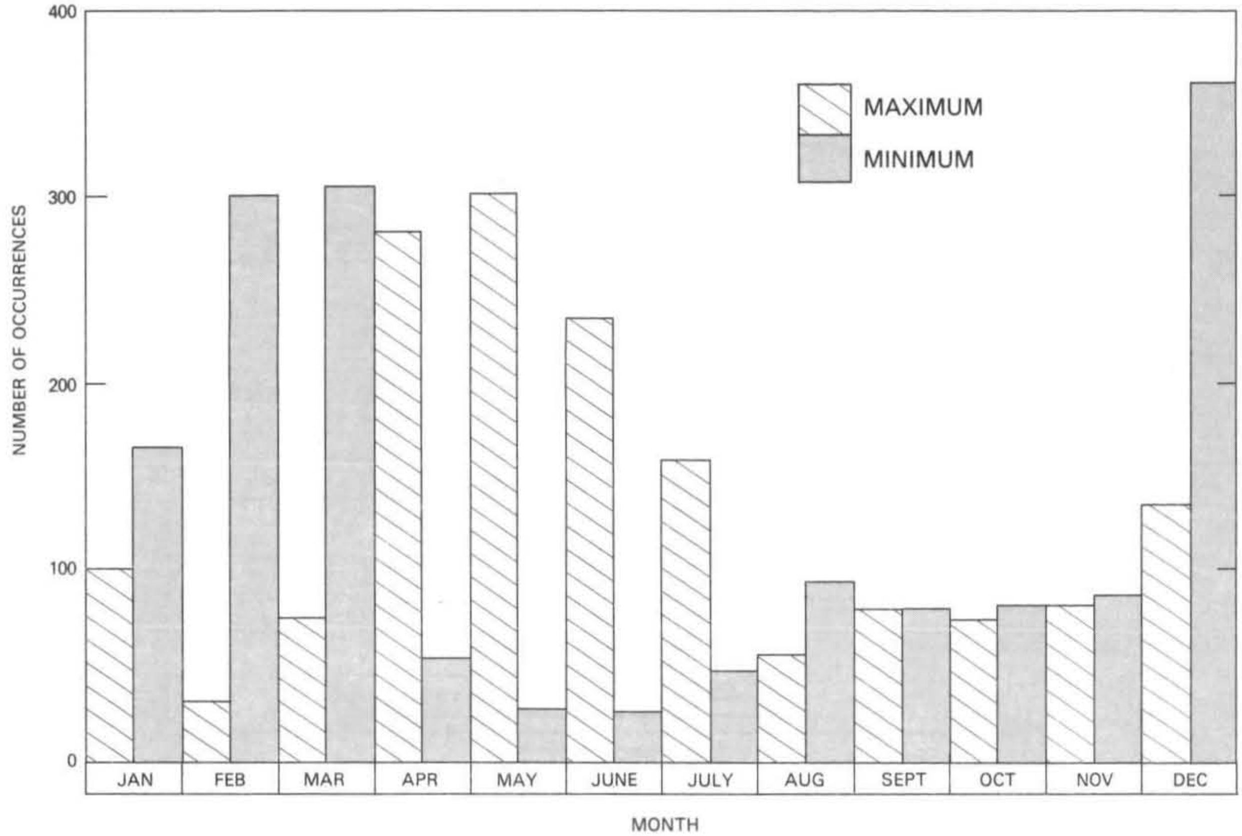


Figure 5. Frequency of occurrence of annual maximum and minimum water levels.

lows. The ground-water levels peaked in 1946, 1952, 1960, 1966, 1973, 1979. The average interval between these peaks is 6.6 years. The low levels occurred in 1949, 1958–59, 1964, 1970, and 1977. Their average interval is approximately 7.0 years, which is the same as that for high levels.

Long-term trends of water levels in these wells are difficult to establish by visual inspection. There is a slightly rising trend on well Mt-7, otherwise long-term trends seem to be nonexistent. The ground-water levels fluctuate only 1 or 2 ft from the mean level and are similar at the beginning and at the end of the record.

Long-term trends are very apparent on hydrographs of wells Br-46, Mr-28, Pt-276, Ro-3, and Ve-8 (fig. 8). The trend of average annual water levels has been generally increasing since the late 1950's and is in general agreement with the increasing trend of precipitation. Hydrographs of well Ve-8, which has the longest observation record in Wisconsin, indicate that the generally rising trend started even earlier at the end of an extensive drought period in the 1930's.

The generally increasing trend has been interrupted by the aforementioned cyclical fluctuations (table 14). The similarity of the hydrographs of wells in different geologic conditions (such as Pt-276, in sand and gravel, and Ro-3, in Cambrian sandstone) again shows that the long-term trends in water levels are also independent of the lithological composition.

Well Pr-6 is constructed in sand and gravel and has a water level near the land surface. The hydrograph of the well (fig. 9) shows that the well water level fluctuates with the amount of precipitation, and shows little or no long-term fluctuation.

Well Bt-2 is also constructed in sand and gravel, but its water level is about 30 ft deeper than the water level of well Pr-6. The hydrograph of well Bt-2 (fig. 10) is offset by one year from the graph of cumulative departure from normal precipitation to show that the thickness of the unsaturated zone regulates long-term water-level fluctuations.

Figure 10 (well Bt-2) shows broad, gradual changes in water levels over long periods of time. These changes result from the progressive cumulative effects of precipitation during alternating series of wet and dry years. Year-to-year fluctuations are very small. The long-term trends are very well defined by long intervals between successive years of high water levels and between successive years of low water levels. The record of well Bt-2 begins with the record low level that follows a period of prolonged drought in the 1930's. Other periods of drought caused similar declines in ground-water levels that culminated in 1951, 1965, and 1978 (each 13 years apart). These declines are offset by distinct rises

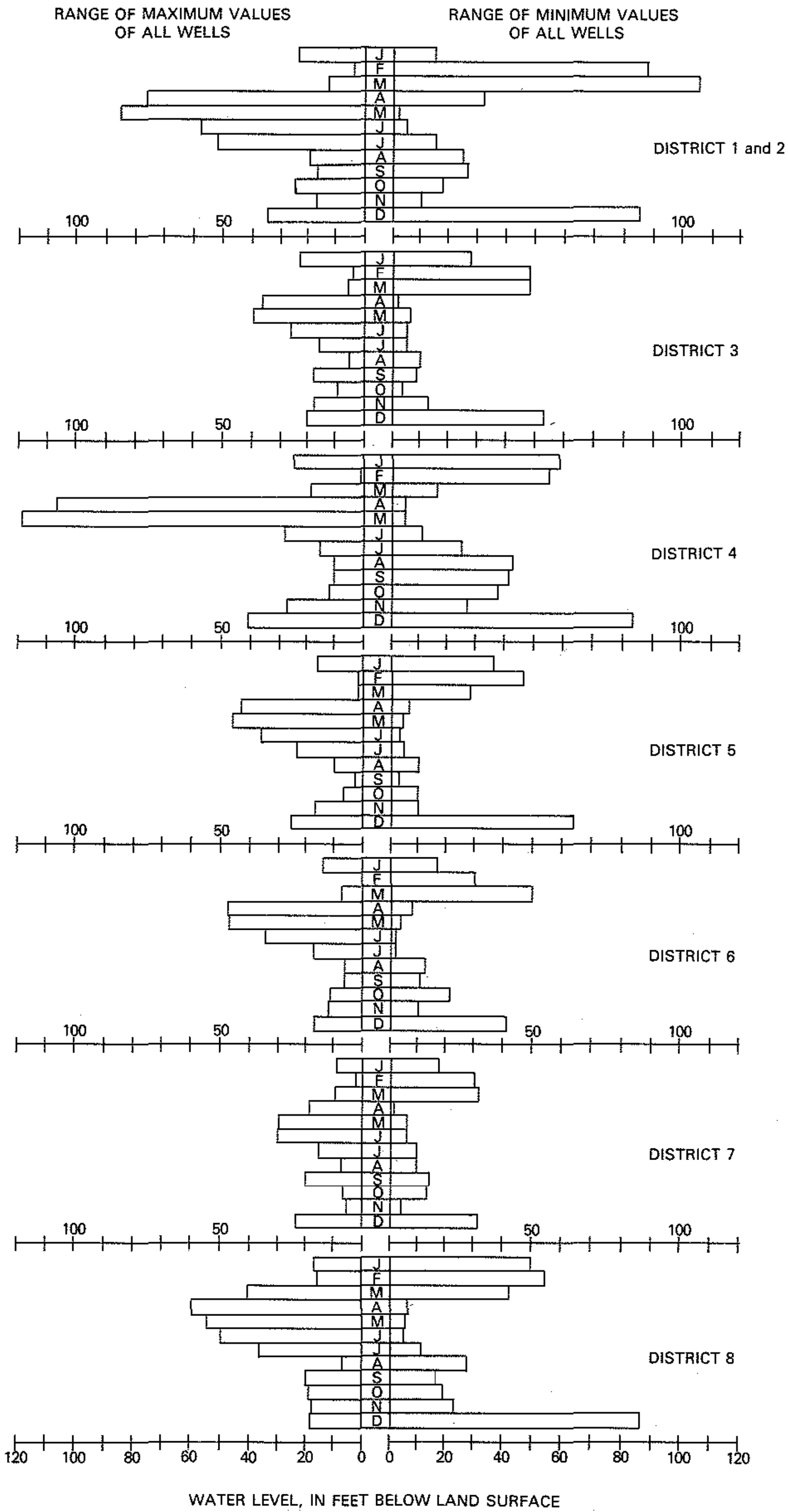


Figure 6. Range of monthly maximum and minimum water levels by hydrogeologic district.

Table 15. Tabulation of wettest and driest years

No.	Year	Interval between years	Corresponding statewide precipitation (in percent of normal)	No.	Year	Interval between years	Corresponding statewide precipitation (in percent of normal)
		Highest levels				Lowest levels	
1	1946-47	--	1945: 114 percent	1	(1940)[1]	--	1939: 80 percent
2	1952-53	6	1951: 124 percent	2	1948-49	9	1948: 80 percent 1949: 90 percent
3	1960-61	8	1959: 122 percent	3	1958-59	10	1958: 76 percent
4	1973-74	7	1972: 116 percent 1973: 116 percent	4	1964-65	6	1963: 77 percent
5	1979-80	6	1977: 115 percent 1978: 116 percent	5	1977-78	7	1976: 71 percent

[1] Not well documented.

in water levels that occurred in 1947, 1955, and 1974. It is apparent from this brief review that much remains to be learned about the long-term trends of ground-water level fluctuations. However, it is also apparent that the hydrographs of observation wells in Wisconsin exhibit such trends.

The foreign literature (Kovelevskiy, 1973; Zaltsberg, 1977) also shows that long-term cyclical fluctuations in water levels are common in other areas of the world in climatic zones similar to that of Wisconsin. Only further mathematical treatment of the available data will disclose whether such cycles really exist, and if so, their relation to cyclical precipitation. Verification of precipitation cycles and related ground-water levels could enhance the possibility of predicting water-level trends; prediction of trends could have a great practical value in ground water and lake management and agricultural production.

SUMMARY AND CONCLUSIONS

Stage-duration analyses and Pearson Type III analyses were run on data from 124 wells with at least 20 years of record. These methods analyze past water-level fluctuations but may be useful in estimating future fluctuations if the hydrologic system remains similar. The results of these analyses are available from the Wisconsin District office of the U.S. Geological Survey.

Data from these 124 wells were divided into groups representing 7 hydrogeologic districts. These data were analyzed using multiple-regression techniques. The regression model used average annual amplitude as the dependent variable and mean water level, mean annual precipitation, standard deviation of seasonal mean precipitation, aquifer type, and topographic setting as the independent variables. This procedure produced different regression equations for each hydrogeologic district.

Regression analyses also were run on data from groups of wells representing the different aquifers in Wisconsin. This regression model was the same as that for the hydrogeologic districts but aquifer was omitted as an independent variable.

Because of the many factors that influence ground-water-level fluctuations, it was impossible to obtain a regression model that accurately estimates average annual amplitude. The regression analyses are helpful, however, in identifying the primary factors controlling fluctuations in each district.

Analysis of annual maximum and minimum water levels indicates several periods in the annual cyclic fluctuations—two periods of recession (winter and summer) and two periods of rising levels (spring and fall). Usually, water levels are lowest in late winter and highest in spring for every annual cycle. The summer-fall minimum and the fall maximum are less distinct and do not occur every year.

A composite frequency analysis of extreme annual water levels on 71 of the wells shows that the lowest levels most frequently occur in December, February, or March. However, the record low usually occurs in August, September, or October during drought. Ground-water levels most often peak in May, April, or June. In the fall they may peak between September and December, depending upon complexities of meteorological, geomorphological, and geological factors.

The long-term cyclicity of ground-water level fluctuations is shown on several well hydrographs. Seasonal variations that tend to obscure the long-term trends are eliminated by plotting the average annual water levels. The hydrographs are very similar even though the wells are 80 to 100 mi apart

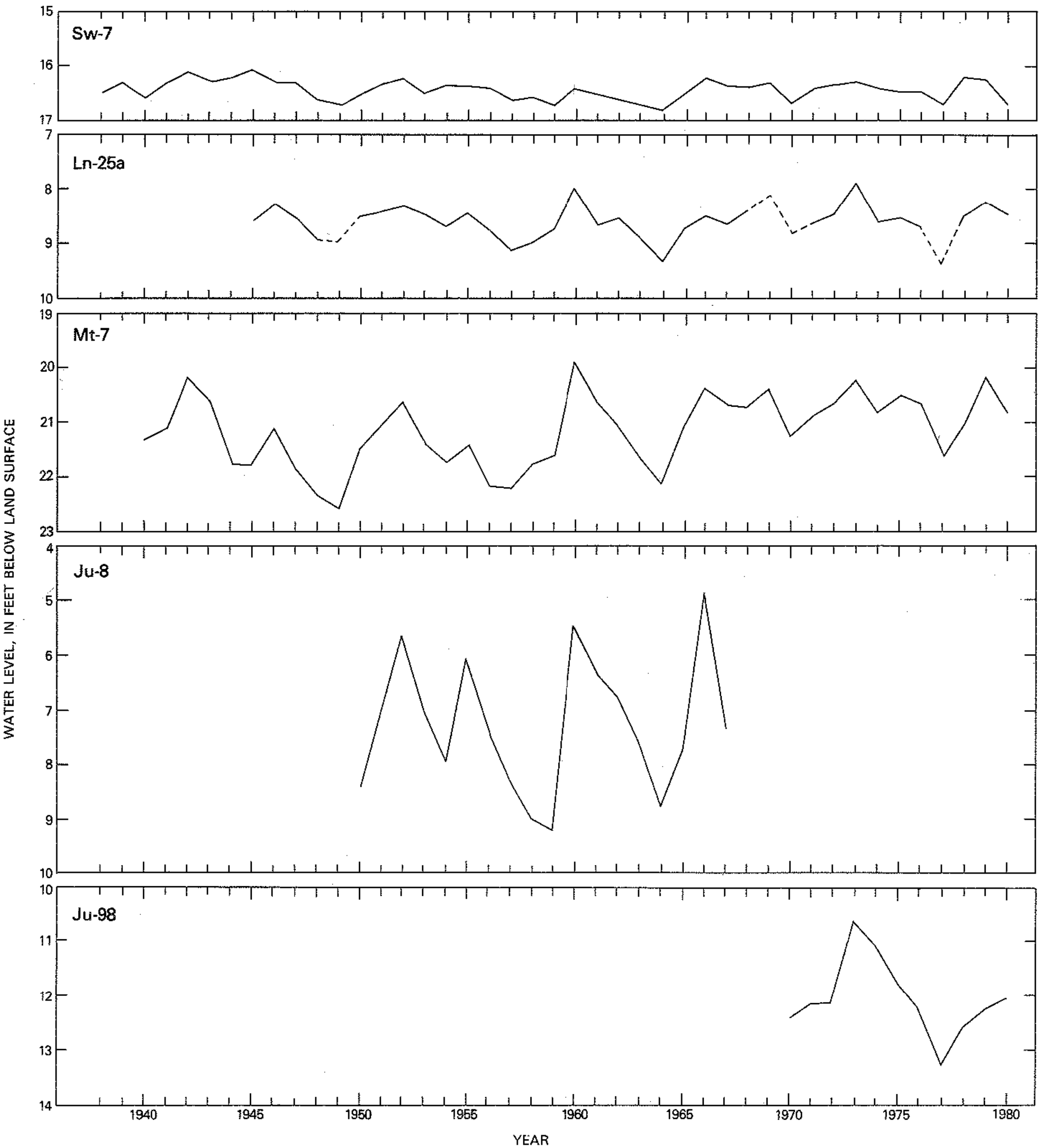


Figure 7. Average annual water levels of wells Sw-7, Ln-25a, Mt-7, Ju-8, and Ju-98.

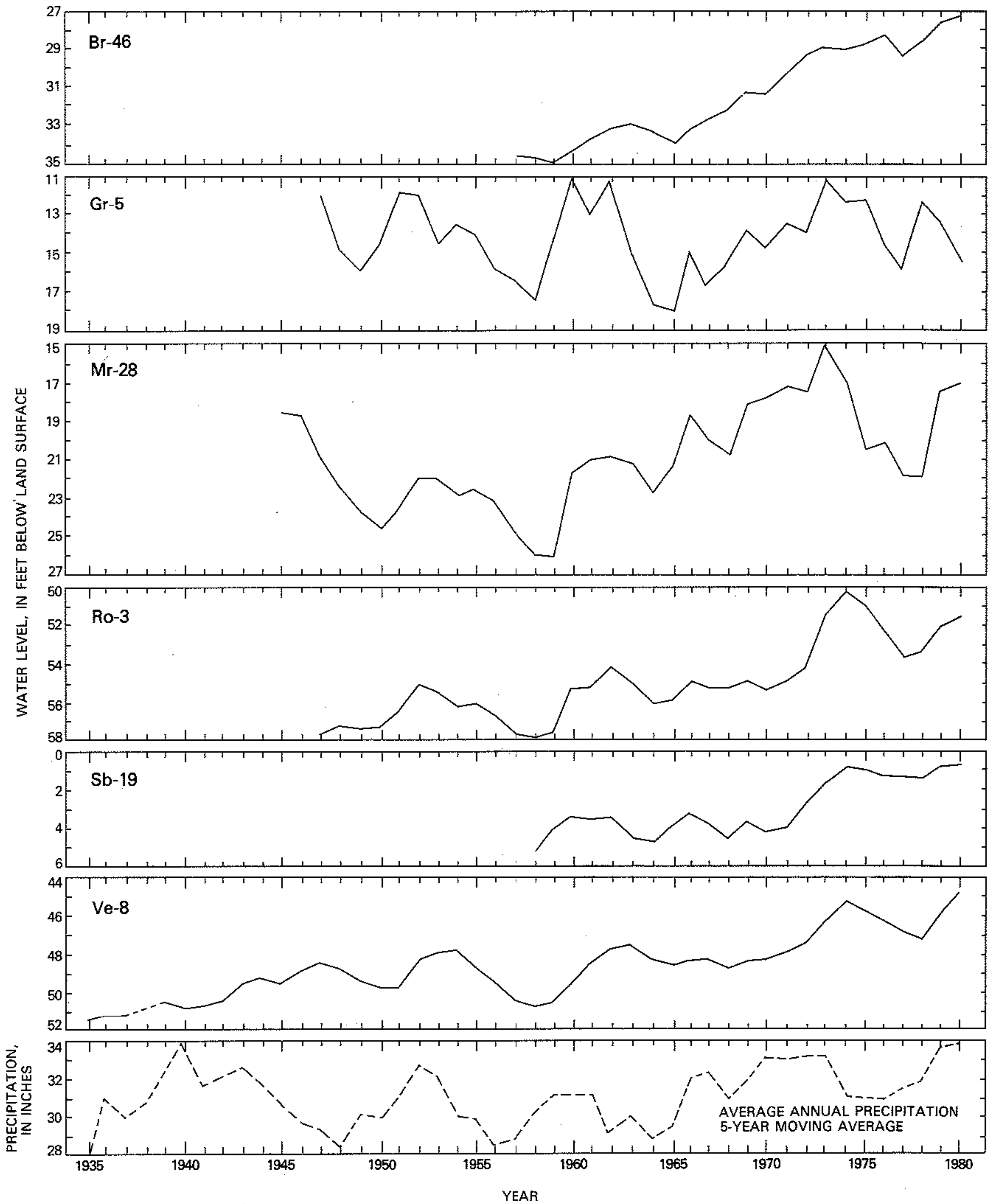


Figure 8. Average annual water levels for wells Br-46, Gr-5, Mr-28, Ro-3, Sb-19, and Ve-8.

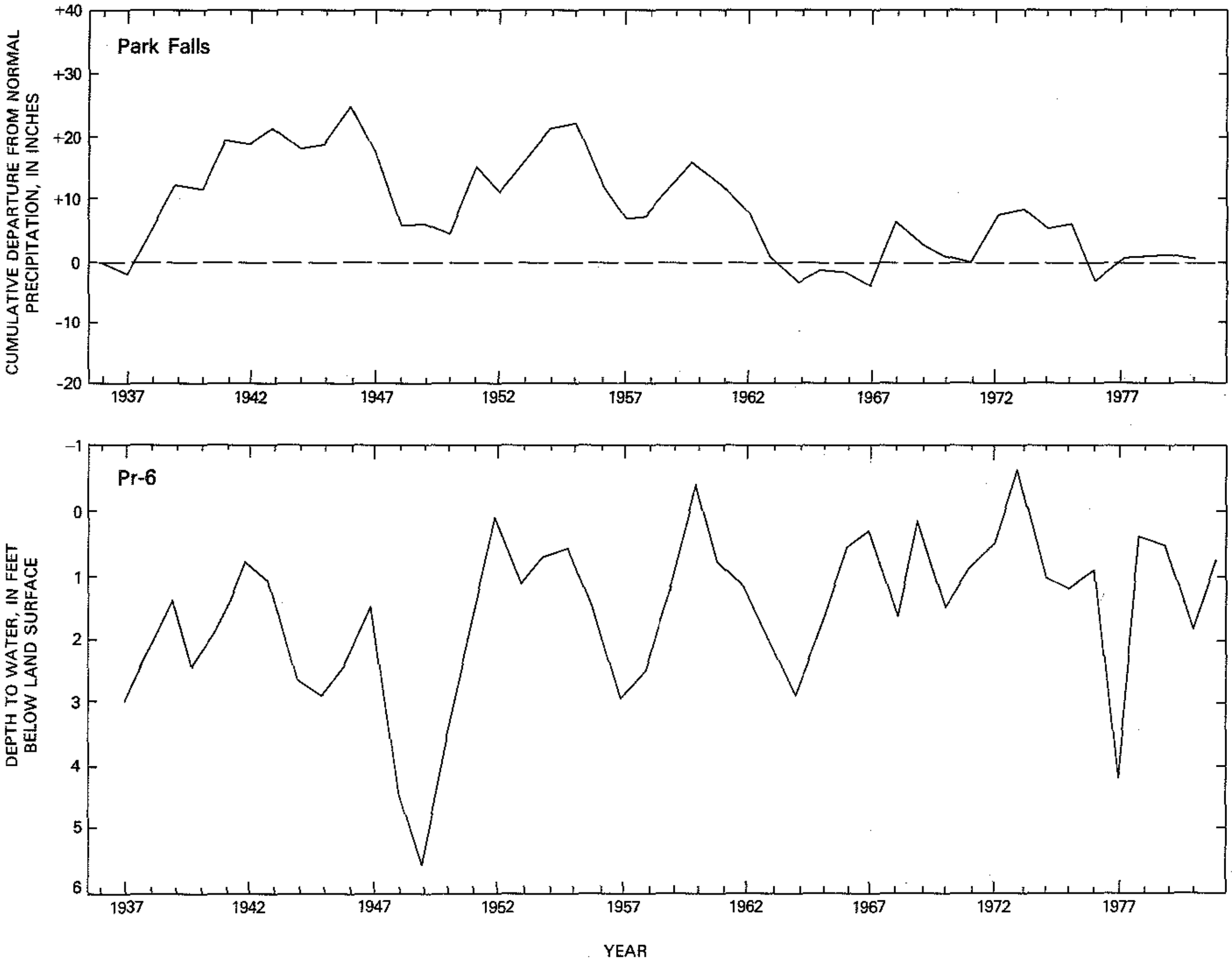


Figure 9. Comparison of average annual water level for well Pr-6 and cumulative departure from normal precipitation.

and constructed in different geologic materials. The long-term trends and the duration of the cycles apparently depend little on the location and on the lithologic composition of the aquifers, but rather on precipitation. The hydrographs show several periods of well-defined peaks and lows. The ground-water levels reached peaks in 1946, 1952, 1960, 1966, 1973, 1979. The average interval between these peaks is 6.6 years. The low levels occurred in 1949, 1958–59, 1964, 1970, and 1977; average interval between the low levels is approximately 7.0 years, which is similar to that for high levels.

Long-term trends are also documented on well hydrographs. The trend of average annual water levels has been generally increasing since the late 1950's and is in general agreement with the increasing trend of precipitation. Hydrographs of well Ve-8, which has the longest period of record in Wisconsin, indicate that the generally rising trend started even earlier, at the end of an extensive drought period in the 1930's.

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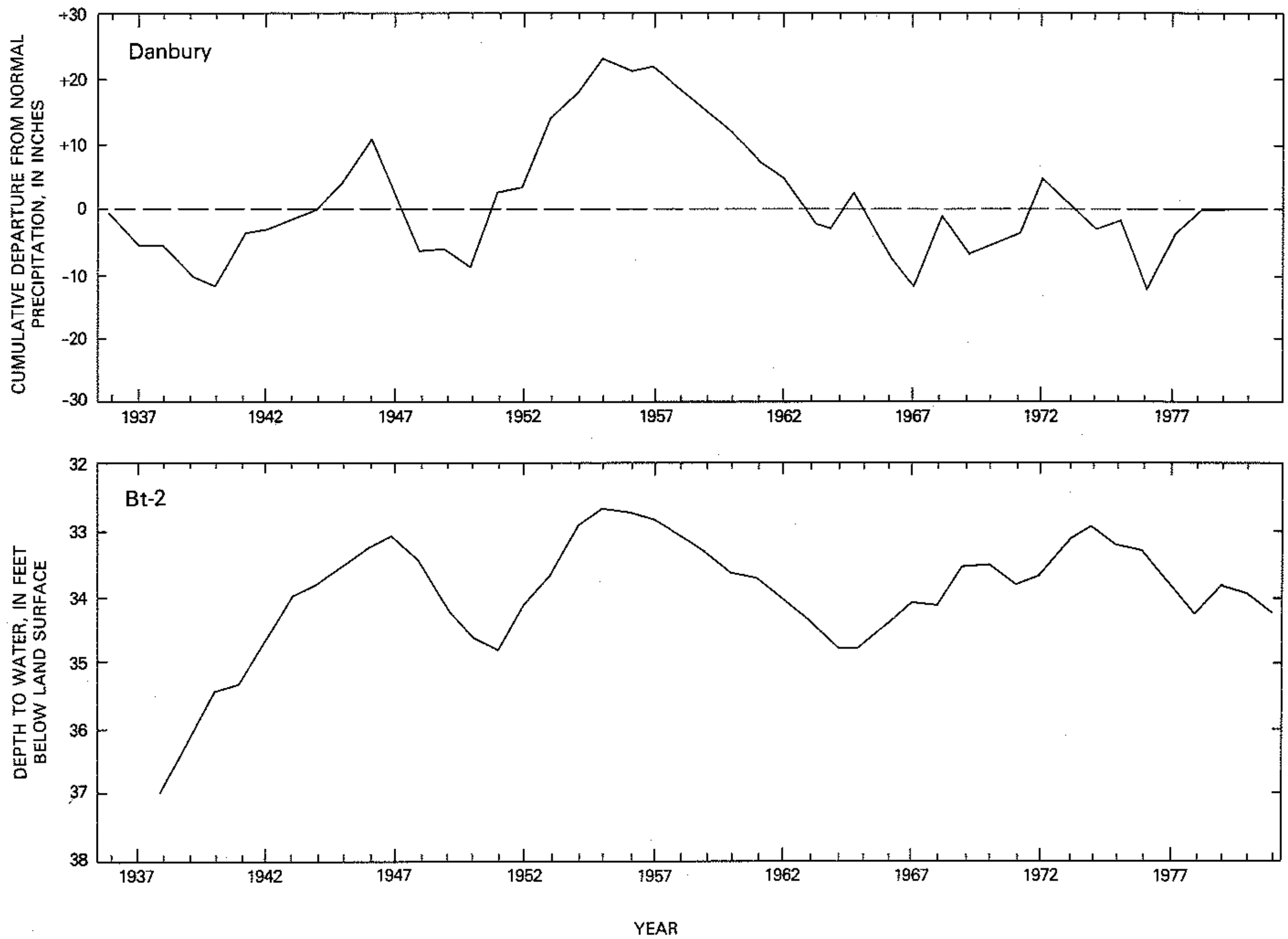

Figure 10. Comparison of average annual water level for well Bt-2 and cumulative departure from normal precipitation.

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Table 3. Summary of observation wells selected for analysis

Local number	Period of record	Altitude	Depth	Aquifer	Hydrogeologic district	District table number	Nearest precipitation station
As-43/04W/32-0006	1959-80	1,470	89	Sand and gravel	2	6	Winter 6 NNW
Br-33/13W/21-0046	1960-80	1,155	81	Sandstone -- lower	7	11	Amery
Bn-24/20E/18-0013	1959-80	690	250	Sandstone -- upper	4	8	Green Bay WSO AP
Bn-24/20E/29-0051	1949-70	698	800	Sandstone -- upper	4	8	Green Bay WSO AP
Bn-24/20E/24-0076	1951-80	590	500	Sandstone -- undifferentiated	4	8	Green Bay WSO AP
Bn-25/21E/07-0078	1951-76	587	198	Sandstone undifferentiated	4	8	Green Bay WSO AP
Bn-25/22E/14-0080	1950-80	690	1,043	Sandstone --lower	4	8	Green Bay WSO AP
Bf-24/11W/14-0022	1959-80	810	384	Sandstone --lower	8	12	Mondovi
Bt-39/16W/17-0002	1938-80	981	46	Sand and gravel	1	6	Danbury
Ca-20/19E/02-0006	1953-80	820	1,050	Sandstone -- lower	4	8	Brillion
Ck-26/03W/04-0001	1954-80	1,210	150	Sandstone -- lower	7	11	Willard 2 NNE
Co-11/09E/36-0022	1949-71	940	75	Sandstone -- upper	5	9	Arlington Univ Farm
Dn-09/11E/34-0004	1947-80	965	70	Sandstone -- undifferentiated	5	9	Madison WSO AP
Dn-07/09E/23-0005	1947-80	930	1,015	Sandstone -- lower	5	9	Arboretum-Univ of Wis
Dn-08/06E/26-0011	1957-78	818	59	Sand and gravel	8	12	Blue Mounds 6 SSE
Dn-09/06E/29/0083	1962-80	740	146	Sand and gravel	8	12	Prairie du Sac 2 N
Dn-09/10E/33-0441	1960-80	965	105	Sandstone -- lower	5	9	Madison WSO AP
Dg-11/16E/05-0004	1946-73	980	475	Sandstone -- undifferentiated	4	8	Horicon
Dg-09/13E/01-0011	1946-78	905	60	Sand and gravel	4	8	Watertown
Dr-29/27E/30-0007	1947-80	725	111	Silurian dolomite	4	8	Sturgeon Bay Exp Farm
Dr-26/23E/22-0011	1950-72	630	816	Sandstone -- undifferentiated	4	8	Sturgeon Bay Exp Farm
Ds-47/10W/23-0001	1945-80	1,019	40	Sand and gravel	1	--	Brule Ranger Station
Du-26/13W/31-0053	1958-80	780	75	Sandstone -- lower	7	11	Mondovi
EC-26/06W/32-0013	1952-74	955	26	Sand and gravel	7	11	Fairchild Ranger Station
FL-15/17E/11-0012	1954-80	753	817	Sandstone -- upper	4	8	Fond du Lac
FL-15/18E/11-0300	1958-79	995	210	Silurian dolomite	4	8	Fond du Lac
Fr-41/14E/18-0002	1949-80	1,152	18	Sand and gravel	2	6	Newald 4 N
Gr-05/02W/06-0005	1947-80	980		Sandstone -- upper	8	12	Lancaster 4 WSW
Gn-02/07E/21-0001	1947-80	995	75	Galena-Platteville	8	12	Monroe 1 W
Gn-03/06E/18-0002	1948-80	1,020	150	Galena-Platteville	8	12	Monroe 1 W
Iw-06/03E/32-0032	1959-80	1,200	92	Galena-Platteville	8	12	Dodgeville 1 NE
Ja-20/03W/30-0005	1954-80	845	190	Sandstone -- lower	8	12	Black River Falls
Je-07/14E/25-0009	1947-80	813	716	Sandstone -- lower	5	9	Lake Mills
Ke-02/22E/27-0004	1948-80	730	190	Silurian dolomite	4	8	Kenosha
Ke-02/22E/20-0005	1948-79	702	28	Sand and gravel	4	8	Kenosha
Lf-03/05E/25-0001	1946-74	820	55	Sandstone -- upper	8	12	Blanchardville 2
Lf-02-01E/04-0011	1948-80	1,010	64	Galena-Platteville	8	12	Cuba City
Lf-02/04E/33-0012	1957-80	835	46	Sandstone -- upper	8	12	Darlington
Lf-01/02E/33-0057	1947-72	1,000	265	Galena-Platteville	8	12	Cuba City
Lf-04/04E/35-0078	1954-80	855	29	Sandstone -- upper	8	12	Blanchardville 2
Lf-01/02E/35-0121	1954-80	1,030	300	Galena-Platteville	8	12	Cuba City
La-31/10E/35-0009	1949-80	1,469	19	Sand and gravel	3	7	Antigo 1 SSW
La-31/11E/07-0026	1944-75	1,521	23	Sand and gravel	3	7	Antigo 1 SSW
La-31/12E/08-0027	1952-80	1,594	93	Sand and gravel	2	6	Antigo 1 SSW
La-31/11E/20-0064	1949-80	1,508	20	Sand and gravel	3	7	Antigo 1 SSW
La-31/11E/20-0118	1943-80	1,510	18	Sand and gravel	3	7	Antigo 1 SSW
La-31/11E/29-0200	1949-80	1,491	15	Sand and gravel	3	7	Antigo 1 SSW
Mr-26/03E/33-0007	1951-80	1,190	49	Sand and gravel	3	--	Marshfield Exp Farm
Mr-28/02E/18-0008	1953-76	1,345	48	Sand and gravel	3	7	Curtiss
Mr-29/03E/24-0027	1945-80	1,445	42	Sand and gravel	3	7	Rib Falls
Mr-27/09E/31-0028	1945-80	1,229	27	Sand and gravel	3	7	Eau Pleine Reservoir
Mt-30/23E/19-0005	1947-73	610	703	Sandstone -- undifferentiated	4	8	Peshtigo
Mt-37/20E/34-0007	1940-80	980	33	Sand and gravel	2	6	Breakwater
Mq-16/08E/12-0009	1950-80	880	274	Sandstone -- lower	5	9	Montello
Ml-07/21E/34-0022	1950-80	728	1,690	Sandstone -- undifferentiated	4	8	West Allis
Ml-07/22E/29-0045	1947-80	591	1,544	Sandstone -- undifferentiated	4	8	West Allis
Ml-06/21E/32-0094	1948-80	770	1,845	Sandstone -- undifferentiated	4	8	Milwaukee WSO AP
Ml-08/21E/35-0118	1947-80	679	135	Silurian dolomite	4	8	Milwaukee Mt. Mary College
Ml-07/22E/17-0120	1947-80	685	400	Silurian dolomite	4	8	West Allis
Ml-06/21E/06-0130	1947-80	788	500	Silurian dolomite	4	8	West Allis
Ml-06/21E/32-0148	1947-80	774	180	Silurian dolomite	4	8	Milwaukee WSO AP

Table 3. Summary of observation wells selected for analysis—Continued

Local number	Period of record	Altitude	Depth	Aquifer	Hydrogeologic district	District table number	Nearest precipitation station
Mo-15/04W/34-0002	1936-80	1,100	44	Sandstone -- upper	8	12	Cashton
Mo-15/05W/35-0010	1935-80	880	17	Sand and gravel	8	12	Cashton
Mo-16/03W/27-0011	1936-75	925	110	Sand and gravel	8	12	Cashton
Mo-18/02W/29-0017	1951-80	909	192	Sandstone -- lower	8	12	Sparta
Oc-28/22E/19-0001	1948-78	591	?	Sandstone -- upper	4	8	Oconto 4 W
On-39/08E/18-0022	1945-80	1,607	27	Sand and gravel	2	6	Rainbow Reservoir
On 37/06E/27 0023	1045-80	1,529	37	Sand and gravel	2	6	Rhinelander
On-36/09E/09-0024	1945-80	1,650	33	Sand and gravel	2	6	Rhinelander
Ou-23/18E/02-0003	1960-80	785	110	Sandstone -- upper	4	8	Green Bay WSO AP
Ou-21/19E/04-0005	1953-80	660	408	Sandstone -- undifferentiated	4	8	Green Bay WSO AP
Ou-21/17E/15-0029	1952-80	839	300	Sandstone -- upper	4	8	Appleton
Ou-24/17E/08-0170	1953-78	798	131	Sandstone -- upper	5	9	Clintonville
Pi-26/17W/07-0051	1960-80	1,240	110	Sandstone -- lower	7	11	Ellsworth 1 E
Pk-35/17W/08-0040	1959-80	1,250	52	Sand and gravel	7	11	Amery
Pk-32/17W/07-0075	1960-80	1,040	96	Sandstone -- lower	7	11	Amery
Pt-24/10E/28-0015	1951-80	1,133	52	Sand and gravel	5	9	Waupaca
Pt-22/07E/35-0035	1951-80	1,054	11	Sand and gravel	6	10	Coddington 1 E
Pt-21/08E/10-0036	1951-80	1,074	12	Sand and gravel	6	10	Coddington 1 E
Pt-21/07E/35-0041	1951-80	1,594	11	Sand and gravel	6	10	Coddlington 1 E
Pt-24/06E/02-0082	1952-80	1,142	40	Sand and gravel	3	7	Stevens Point
Pt-23/10E/18-0276	1959-80	1,120	17	Sand and gravel	6	10	Waupaca
Pt-23/08E/25-0376	1960-80	1,099	36	Sand and gravel	6	10	Coddington 1 E
Pr-40/01W/24-0006	1938-80	1,510	13	Sand and gravel	2	6	Park Falls
Ra-03/22E/21-0005	1948-80	730	1,810	Sandstone -- undifferentiated	4	8	Racine
Ro-02/12E/02-0003	1948-80	833	470	Sandstone -- upper	5	9	Janesville
Ro-04/13E/27-0008	1961-80	877	722	Sandstone -- lower	5	9	Whitewater
Ru-33/08W/11-0037	1958-80	1,085	77	Sand and gravel	2	6	Weyerhauser 2 SSE
Ru-35/03W/14-0089	1959-80	1,380	25	Sand and gravel	2	6	Jump River 3 E
SC-29/20W/24-0021	1960-80	681	393	Sandstone -- lower	7	11	New Richmond
SC-31/16W/29-0094	1960-80	1,059	73	Sandstone -- upper	8	12	New Richmond
SC-31/16W/08-0095	1961-80	1,060	120	Sand and gravel	7	11	New Richmond
Sk-10/06E/03-0001	1947-80	865	435	Sandstone -- lower	8	12	Prairie du Sac 2 N
Sw-41/09W/28-0007	1938-80	1,190	25	Sand and gravel	7	11	Hayward Ranger Station
Sh-26/18E/30-0001	1948-80	917	132	Sandstone -- upper	4	8	Shawano 2 SSW
Sh-26/16E/02-0003	1947-73	957	30	Sandstone -- upper	5	9	Shawano 2 SSW
Sh-25/17E/28-0004	1948-80	812	50	Sandstone -- upper	5	9	Shawano 2 SSW
Sb-15/21E/28-0019	1960-80	820	450	Silurian dolomite	4	8	Plymouth
Ta-31/04W/13-0001	1958-80	1,200	29	Sand and gravel	2	6	Holcombe
Ta-31/01E/28-0006	1958-80	1,460	35	Sand and gravel	2	6	Medford
Tr-19/08W/35-0001	1949-80	1,020	195	Sandstone -- lower	8	12	Galesville
Tr-19/09W/33-0009	1954-80	740	71	Sand and gravel	8	12	Trempealeau Dam 6
Ve-14/07W/26-0008	1946-80	710	53	Sand and gravel	8	12	Genoa Dam 8
Ve-13/04W/31-0041	1958-80	1,260	507	Sandstone -- lower	8	12	Viroqua 2 NW
Vi-41/10E/09-0003	1949-80	1,658	22	Sand and gravel	2	6	Buckatabon
Vi-40/10E/10-0021	1945-80	1,640	28	Sand and gravel	2	6	Eagle River
Ww-03/15E/33-0009	1948-80	965	287	Silurian dolomite	4	8	Whitewater
Ww-02/17E/04-0024	1952-73	1,038	1,702	Sandstone -- lower	4	8	Lake Geneva
Wb-39/12W/31-0001	1948-71	1,064	18	Sand and gravel	7	11	Spooner Exp Farm
Wk-06/19E/02-0014	1947-80	875	1,300	Sandstone -- lower	4	8	Waukesha
Wk-07/17E/05-0020	1947-80	880	773	Sandstone -- lower	4	8	Oconomowoc
Wk-05/19E/02-0031	1948-80	962	508	Silurian dolomite	4	8	Waukesha
Wk-08/20E/19-0050	1953-80	878	86	Silurian dolomite	4	8	Germantown
Wp-21/13E/25-0002	1954-80	764	205	Sandstone -- lower	5	9	Pine River 3 NE
Wp-22/14E/12-0013	1959-80	754	203	Sand and gravel	5	9	New London
Wp-21/11E/09-0063	1958-79	904	94	Sand and gravel	5	9	Waupaca
Ws-19/08E/15-0008	1952-80	1,080	18	Sand and gravel	6	10	Hancock Exp Farm
Ws-20/11E/02-0053	1958-80	923	177	Sand and gravel	5	9	Pine River 3 NE
Ws-18/10E/01-0105	1957-80	873	14	Sand and gravel	5	9	Hancock Exp Farm
Wi-20/17E/20-0001	1947-80	771	340	Sandstone -- upper	4	8	Appleton
Wi 18/16E/23-0006	1951-80	765	200	Sandstone -- upper	4	8	Oshkosh
Wi-20/17E/22-0020	1956-78	746	900	Sandstone -- upper	4	8	Appleton
Wd-22/06E/16-0001	1959-80	1,030	25	Sand and gravel	3	7	Wisconsin Rapids
Wd-23/04E/02-0029	1944-64	1,135	18	Sand and gravel	3	7	Pittsville

Table 6. Selected seasonal probabilities of exceedance for wells analyzed in the report

Well number	Probability of exceedance (feet below land surface) 2 percent	10 percent	20 percent	80 percent	90 percent	98 percent
			District 2 -- Spring			
As-6	31.7	30.7	30.3	28.2	27.9	27.0
Bt-2	36.2	35.0	34.4	33.2	33.0	32.8
Fr-2	11.3	11.0	10.8	9.9	9.6	9.2
La-27	83.6	82.3	81.7	78.6	77.5	76.2
Mt-7	22.5	21.9	21.6	20.4	20.1	19.6
On-22	18.9	18.3	17.8	15.9	15.1	14.2
On-23	33.3	32.2	31.6	29.7	29.0	28.2
On-24	22.1	21.6	21.4	20.5	20.2	19.7
Pr-6	3.4	2.7	2.3	1.2	1.0	.7
Ru-37	13.9	13.5	13.3	12.2	11.8	11.2
Ru-89	21.6	19.7	18.1	14.5	13.6	12.5
Ta-1	11.0	10.0	9.6	8.2	8.0	7.7
Vi-3	11.9	11.5	11.3	10.4	10.2	9.8
Vi-21	16.8	16.0	15.4	13.8	13.4	12.6
			District 2 -- Summer			
As-6	31.1	30.3	29.9	28.0	27.6	26.4
Bt-2	36.2	35.0	34.4	33.2	33.0	32.8
Fr-2	11.6	11.4	11.3	10.8	10.5	10.3
La-27	83.8	82.1	81.6	78.2	77.6	75.6
Mt-7	22.7	22.0	21.6	20.2	19.8	19.2
On-22	18.4	17.2	16.7	14.4	14.0	13.0
On-23	33.0	31.9	31.2	28.8	28.0	27.0
On-24	21.8	21.3	21.0	19.8	19.5	18.9
Pr-6	3.6	2.9	2.5	1.3	1.1	.8
Ru-37	13.9	13.6	13.4	12.4	12.1	11.5
Ru-89	20.0	18.1	17.2	14.6	14.1	13.0
Ta-1	10.8	10.4	10.2	9.0	8.6	7.9
Vi-3	12.4	12.0	11.7	10.7	10.4	9.9
Vi-21	16.9	15.7	15.0	13.2	12.8	12.2
			District 2 -- Fall			
As-6	31.0	30.3	29.8	27.8	27.3	26.0
Bt-2	36.0	35.0	34.4	33.2	33.0	32.7
Fr-2	11.6	11.5	11.5	10.8	10.6	10.0
La-27	83.0	82.2	81.6	78.1	77.2	74.6
Mt-7	22.9	22.3	21.9	20.6	20.3	19.9
On-22	18.4	17.5	16.8	15.1	14.7	13.9
On-23	33.3	31.8	31.3	28.8	28.2	27.0
On-24	22.0	21.4	21.2	20.0	19.6	19.1
Pr-6	4.6	3.4	3.0	1.4	1.2	.9
Ru-37	14.6	14.0	13.6	12.4	12.0	11.6
Ru-89	19.5	18.7	17.6	15.0	14.3	12.8
Ta-1	11.8	10.6	10.2	8.8	8.4	8.2
Vi-3	12.2	11.8	11.5	10.7	10.5	10.2
Vi-21	16.6	15.8	15.2	13.6	13.2	12.6
			District 2 -- Winter			
As-6	31.2	30.4	30.0	28.0	27.6	26.6
Bt-2	36.0	35.1	34.4	33.3	32.8	32.6
Fr-2	11.1	10.9	10.8	10.6	10.5	10.3
La-27	83.1	82.0	81.7	78.1	77.1	75.0
Mt-7	23.0	22.4	22.1	20.9	20.6	20.1
On-22	18.5	17.6	17.3	15.5	15.0	14.0
On-23	33.6	32.2	31.5	29.3	28.6	27.8
On-24	22.2	21.7	21.4	20.4	20.2	19.6
Pr-6	5.0	4.2	3.9	2.4	2.2	1.8
Ru-37	14.3	13.7	13.4	12.3	12.0	11.6
Ru-89	21.1	19.2	18.1	15.0	14.7	13.6
Ta-1	11.1	10.4	10.1	9.0	8.8	8.4
Vi-3	11.6	11.3	11.1	10.3	10.1	9.7
Vi-21	17.0	16.0	15.6	14.0	13.6	13.0

Table 6. Selected seasonal probabilities of exceedance for wells analyzed in the report—Continued

Well number	Probability of exceedance (feet below land surface) 2 percent	10 percent	20 percent	80 percent	90 percent	98 percent
			District 3-- Spring			
La-9	15.0	14.2	13.6	10.7	10.0	13.5
La-26	9.2	8.4	8.0	5.5	4.6	3.0
La-64	16.0	15.4	15.3	13.6	13.0	11.8
La-118	13.0	12.5	12.0	9.8	9.2	7.6
La-200	7.8	6.9	6.4	5.0	4.6	4.3
Mr-8	4.5	3.6	3.2	1.8	1.4	.8
Mr-27	10.0	9.1	8.7	5.6	4.8	2.6
Mr-28	25.8	23.6	22.6	18.1	17.2	14.5
Pt-82	6.6	4.9	4.0	2.8	1.6	1.2
Wd-1	7.2	6.7	6.4	5.5	5.3	5.0
Wd-29	12.3	9.6	8.6	5.7	5.0	4.5
			District 3 -- Summer			
La-9	14.7	13.7	13.0	10.6	9.7	8.1
La-26	9.2	8.2	7.4	5.4	5.0	4.2
La-64	15.6	15.0	14.6	13.2	12.8	12.0
La-118	12.5	11.8	11.4	9.2	8.6	7.4
La-200	7.4	6.8	6.4	5.3	5.0	4.5
Mr-8	5.6	4.4	3.8	2.0	1.6	1.2
Mr-27	9.6	8.1	7.6	4.7	3.6	2.1
Mr-28	25.7	23.6	22.7	17.6	16.1	13.6
Pt-82	6.6	4.8	4.0	2.2	2.0	2.6
Wd-1	7.0	6.7	6.5	5.8	5.6	5.4
Wd-29	8.4	7.6	7.2	6.0	5.8	5.5
			District 3 -- Fall			
La-9	15.0	14.1	13.1	10.6	10.0	8.7
La-26	9.8	8.8	8.2	5.6	5.0	3.6
La-64	15.8	15.5	15.0	13.8	13.4	12.6
La-118	13.2	12.4	12.0	10.0	9.6	8.6
La-200	7.3	7.8	6.5	5.2	4.8	4.2
Mr-8	6.0	4.4	3.6	1.6	1.2	.8
Mr-27	10.7	9.6	8.6	4.6	3.6	1.7
Mr-28	25.8	23.6	22.6	17.6	16.7	14.0
Pt-82	7.0	5.4	4.8	2.5	1.8	1.0
Wd-1	7.1	6.9	6.7	6.1	5.9	5.6
Wd-29	13.0	11.1	10.0	6.6	5.7	4.2
			District 3 -- Winter			
La-9	14.8	13.8	13.4	11.0	10.5	9.5
La-26	11.1	10.0	9.2	6.6	5.7	4.7
La-64	16.6	16.0	15.6	14.2	13.8	13.0
La-118	14.0	13.2	12.8	10.6	10.0	8.8
La-200	7.9	7.3	7.0	5.7	5.4	4.9
Mr-8	6.4	4.8	4.0	1.8	1.4	.8
Mr-27	11.1	10.0	9.2	6.2	5.0	3.1
Mr-28	25.6	24.1	22.7	18.0	17.1	15.0
Pt-82	7.7	6.2	5.4	3.0	2.4	1.4
Wd-1	7.2	7.0	6.8	6.1	5.9	5.5
Wd-29	15.0	12.5	11.1	7.0	5.5	4.1

Table 6. Selected seasonal probabilities of exceedance for wells analyzed in the report—Continued

Well number	Probability of exceedance (feet below land surface)					
	2 percent	10 percent	20 percent	80 percent	90 percent	98 percent
			District 4 -- Spring			
Bn-13	21.1	17.6	16.2	11.1	10.0	9.1
Bn-78	20.0	12.2	8.1	-3.5	-7.9	-11.8
Ca-6	218.5	208.2	203.1	182.9	178.1	170.0
Dg-4	119.2	118.0	117.4	115.2	114.5	113.6
Dg-11	53.9	46.1	40.0	26.1	22.0	18.0
Dr-11	63.2	56.3	52.2	42.2	40.0	36.9
FL-300	7.9	6.4	5.5	3.2	2.8	2.0
Ke-4	91.9	89.1	86.9	79.0	77.1	73.1
Ke-5	5.8	4.6	4.0	2.4	2.4	2.2
Ml-118	50.1	43.0	38.9	27.3	24.1	19.1
Ml-148	39.1	35.0	33.0	29.1	32.1	28.1
Oc-1	8.7	5.6	4.2	-.4	-1.5	-2.9
Ou-3	46.1	42.1	40.0	34.0	33.1	32.0
Ou-29	63.1	61.6	60.6	58.1	57.0	56.0
Sh-1	64.6	62.1	60.7	55.6	54.6	52.5
Ww-9	79.6	79.1	78.0	74.6	73.1	70.5
Ww-24	296.0	284.1	276.2	258.0	254.1	250.1
Wk-20	37.1	35.0	33.9	30.0	29.1	27.4
Wk-31	136.5	135.5	134.5	131.2	129.6	128.0
Wk-50	16.4	15.0	14.0	11.1	10.6	9.5
Wl-1	67.1	63.2	60.0	51.1	48.0	44.2
			District 4 -- Summer			
Bn-13	23.2	19.5	17.6	12.1	11.6	10.0
Bn-78	22.1	16.0	12.2	-3.9	-8.0	-15.9
Ca-6	222.8	210.3	204.4	184.2	180.0	172.0
Dg-4	120.4	119.7	119.0	117.0	116.4	115.2
Dg-11	49.0	41.1	38.0	26.9	25.0	21.9
Dr-11	63.1	56.2	52.2	42.3	40.0	37.0
FL-300	8.9	7.4	7.0	3.9	3.5	2.0
Ke-4	94.9	92.1	90.0	81.0	78.1	73.1
Ke-5	5.8	5.1	4.7	3.4	3.1	2.6
Ml-118	50.0	44.1	40.0	29.1	26.1	21.2
Ml-148	37.4	35.0	33.5	30.0	29.1	28.5
Oc-1	13.6	9.7	7.6	1.7	.6	-.9
Ou-3	47.1	43.0	41.1	34.1	33.0	31.1
Ou-29	62.6	61.7	60.6	57.5	57.0	55.5
Sh-1	64.3	62.2	60.6	56.7	56.1	54.5
Ww-9	79.4	78.9	77.9	74.1	72.5	69.5
Ww-24	298.1	286.0	278.0	258.1	254.1	248.1
Wk-20	37.4	35.5	34.5	31.6	30.5	29.6
Wk-31	137.2	135.5	134.6	130.5	129.5	127.6
Wk-50	16.5	15.7	15.0	12.1	11.1	10.0
Wl-1	69.3	65.2	63.0	54.1	51.1	47.0

Table 6. Selected seasonal probabilities of exceedance for wells analyzed in the report—Continued

Well number	Probability of exceedance (feet below land surface) 2 percent	10 percent	20 percent	80 percent	90 percent	98 percent
			District 4 -- Fall			
Bn-13	23.6	20.0	18.0	12.5	11.5	10.7
Bn-78	20.0	14.1	12.0	-1.9	-5.8	-15.9
Ca-6	224.3	214.2	208.5	186.3	180.0	172.1
Dg-4	121.7	120.6	119.5	117.1	116.6	115.0
Dg-11	47.9	43.0	41.1	30.0	28.1	23.2
Dr-11	63.1	56.4	52.1	42.1	40.0	37.1
FL-300	10.6	9.0	7.9	4.6	3.5	2.0
Ke-4	95.0	91.1	90.0	81.1	79.1	74.1
Ke-5	13.0	8.0	6.5	3.0	3.0	3.0
Ml-118	51.1	43.9	40.0	28.9	25.1	22.0
Ml-148	37.1	35.0	33.9	31.2	30.6	29.5
Oc-1	13.2	7.3	5.3	.0	-.8	-.8
Ou-3	47.1	44.0	42.1	36.1	34.1	31.0
Ou-29	63.6	62.1	61.1	58.2	57.1	55.6
Sh-1	64.6	62.6	61.7	57.7	56.7	55.0
Ww-9	80.6	79.1	78.5	74.5	73.0	70.5
Ww-24	297.9	285.9	280.0	258.0	254.1	248.1
Wk-20	37.4	35.7	34.4	30.0	29.2	27.5
Wk-31	137.5	135.6	135.0	131.5	130.5	129.1
Wk-50	18.7	17.0	16.1	13.0	12.0	10.6
Wi-1	70.0	66.3	63.4	54.1	52.4	48.1
			District 4 -- Winter			
Bn-13	22.5	19.1	17.0	12.0	11.6	10.0
Bn-78	17.2	7.1	3.2	-8.0	-8.9	-9.9
Ca-6	222.1	210.2	204.1	184.2	180.0	172.0
Dg-4	120.3	119.5	118.4	116.2	115.5	114.0
Dg-11	52.9	47.1	43.0	31.2	28.0	21.9
Dr-11	63.2	56.2	53.2	42.1	40.0	37.0
FL-300	10.0	7.9	7.5	4.5	4.0	3.5
Ke-4	92.1	89.0	87.0	80.0	78.1	74.0
Ke-5	12.6	7.1	5.0	3.0	3.0	3.0
Ml-118	51.0	44.1	40.0	28.1	25.1	22.0
Ml-148	38.0	36.0	35.0	31.6	30.5	29.0
Oc-1	6.3	4.2	3.1	-.5	-.9	-1.8
Ou-3	47.0	43.1	41.0	35.2	33.9	31.0
Ou-29	64.1	62.1	61.2	57.5	57.1	56.0
Sh-1	65.0	63.3	62.0	57.6	56.7	54.0
Ww-9	80.0	79.1	78.5	74.6	73.0	69.5
Ww-24	298.0	284.1	276.1	258.0	254.1	250.0
Wk-20	37.4	35.5	33.9	30.0	29.0	27.5
Wk-31	137.5	136.1	135.0	131.5	130.6	129.1
Wk-50	19.5	17.1	15.6	12.5	11.5	10.7
Wl-1	69.3	64.2	62.1	52.1	49.2	45.1

Table 6. Selected seasonal probabilities of exceedance for wells analyzed in the report—Continued

Well number	Probability of exceedance (feet below land surface) 2 percent	10 percent	20 percent	80 percent	90 percent	98 percent
			District 5 -- Spring			
Co-22	59.0	57.6	56.5	58.4	52.6	51.2
Dn-4	52.2	49.1	48.3	40.0	38.2	33.3
Dn-441	79.2	77.6	76.6	72.1	70.7	67.6
Mq-9	18.0	17.4	17.0	15.8	15.4	14.6
Ou-170	10.0	8.7	8.1	5.0	4.4	3.6
Pt-15	38.1	37.2	36.1	32.7	32.0	30.0
Ro-3	58.0	57.1	56.6	53.6	52.0	50.0
Ro-8	73.1	70.0	79.0	61.9	60.0	57.1
Sh-3	15.7	13.2	11.6	7.1	6.2	4.6
Sh-4	8.6	7.4	6.8	4.7	4.0	3.2
Wp-2	14.9	14.4	14.2	12.6	12.0	11.0
Wp-13	16.1	13.2	11.6	8.1	7.6	7.0
Wp-63	21.8	21.4	21.1	20.0	19.7	19.0
Ws-53	40.0	39.1	38.0	35.5	35.0	33.5
Ws-105	6.6	5.6	5.0	2.4	1.8	.8
			District 5 -- Summer			
Co-22	59.2	57.7	56.6	53.1	52.7	51.1
Dn-4	52.1	49.3	47.2	39.3	37.1	33.2
Dn-441	78.4	77.0	75.9	71.6	70.0	66.6
Mq-9	17.9	17.2	17.0	15.6	15.3	14.4
Ou-170	10.6	9.0	7.9	5.7	5.0	4.1
Pt-15	38.3	36.7	36.1	32.6	31.6	29.6
Ro-3	57.9	57.5	57.0	53.5	52.6	50.0
Ro-8	74.1	70.9	69.2	62.2	60.0	56.1
Sh-3	15.0	13.1	12.2	8.0	7.1	5.6
Sh-4	8.5	7.6	7.2	5.7	5.2	4.4
Wp-2	14.8	14.3	14.0	13.0	12.7	12.4
Wp-13	19.6	16.3	14.1	10.0	9.1	8.5
Wp-63	21.4	21.2	21.0	19.6	19.2	18.0
Ws-53	39.5	38.5	38.0	35.0	34.6	32.9
Ws-105	6.4	5.6	5.0	3.2	2.6	1.8
			District 5 -- Fall			
Co-22	58.6	57.0	56.7	53.1	52.1	50.8
Dn-4	52.4	49.0	47.4	41.1	39.6	36.0
Dn-441	78.1	77.2	76.1	72.1	70.5	67.6
Mq-9	17.8	17.4	17.1	15.6	15.2	14.6
Ou-170	11.7	9.7	9.1	6.6	6.1	5.0
Pt-15	38.3	36.6	36.1	32.7	31.6	29.6
Ro-3	58.5	57.6	57.0	53.5	52.6	50.0
Ro-8	72.9	71.3	79.1	62.2	59.1	66.0
Sh-3	17.3	15.0	14.2	10.6	10.0	8.6
Sh-4	9.5	8.6	8.3	6.0	5.6	4.6
Wp-2	14.7	14.4	14.2	13.4	13.2	12.7
Wp-13	17.3	14.6	13.0	9.5	9.0	7.9
Wp-63	21.6	21.2	21.0	20.0	19.7	19.1
Ws-53	39.8	38.8	38.2	35.8	35.0	33.8
Ws-105	7.0	6.0	5.4	3.4	3.0	2.2
			District 5 -- Winter			
Co-22	59.2	57.7	56.4	52.9	52.2	50.7
Dn-4	52.6	49.5	47.9	43.1	41.6	39.1
Dn-441	78.6	77.5	76.7	72.6	71.1	68.0
Mq-9	18.2	17.5	17.2	15.8	15.6	15.0
Ou-170	11.6	9.7	9.1	6.2	5.5	4.6
Pt-15	38.3	37.2	36.1	32.6	31.5	30.0
Ro-3	58.5	57.5	57.0	53.5	52.5	50.6
Ro-8	73.9	71.0	69.2	62.4	60.0	56.3
Sh-3	17.7	15.6	14.6	11.7	10.6	9.1
Sh-4	9.9	8.8	8.2	5.8	5.2	4.2
Wp-2	14.7	14.5	14.4	13.7	13.4	12.9
Wp-13	15.6	13.6	12.0	8.1	7.6	6.5
Wp-63	21.7	21.3	21.1	20.3	20.1	19.8
Ws-53	40.0	39.0	38.4	36.2	35.9	34.8
Ws-105	7.6	6.4	5.8	3.7	3.0	2.2

Table 6. Selected seasonal probabilities of exceedance for wells analyzed in the report—Continued

Well number	Probability of exceedance (feet below land surface) 2 percent	10 percent	20 percent	80 percent	90 percent	98 percent
			District 6 -- Spring			
Pt-36	5.6	5.2	4.9	3.7	3.4	2.8
Pt-41	6.0	5.1	4.5	2.4	2.0	1.0
Pt-276	10.0	8.6	7.6	3.7	2.1	-.4
Pt-376	14.2	14.2	13.7	11.1	10.0	8.0
Ws-8	15.0	13.5	12.4	9.5	8.5	7.0
			District 6 -- Summer			
Pt-36	6.1	5.6	5.4	4.3	4.0	3.5
Pt-41	5.4	4.8	4.4	3.0	2.6	2.0
Pt-276	9.6	8.2	7.3	3.1	1.6	-1.0
Pt-376	13.6	13.0	13.0	10.5	9.5	7.0
Ws-8	14.5	13.0	12.0	9.1	8.0	6.6
			District 6 -- Fall			
Pt-36	6.6	6.2	5.8	4.6	4.2	3.4
Pt-41	6.7	5.8	5.4	3.4	2.6	1.4
Pt-276	10.0	9.3	8.1	3.6	2.6	-.4
Pt-376	14.2	13.6	13.2	11.2	10.5	9.0
Ws-8	14.5	13.1	12.6	9.0	8.7	7.0
			District 6 -- Winter			
Pt-36	6.6	6.2	5.9	4.9	4.6	4.0
Pt-41	7.2	6.3	5.8	3.6	2.8	1.6
Pt-276	10.5	9.6	8.6	4.5	3.1	.0
Pt-376	14.6	14.0	13.8	11.8	11.0	9.6
Ws-8	14.5	13.5	12.4	10.0	9.0	8.0

Table 6. Selected seasonal probabilities of exceedance for wells analyzed in the report—Continued

Well number	Probability of exceedance (feet below land surface) 2 percent	10 percent	20 percent	80 percent	90 percent	98 percent
			District 7-- Spring			
Br-46	36.1	34.1	33.0	28.9	28.0	26.6
Ck-1	71.1	70.0	68.2	62.3	60.0	56.1
Du-53	34.9	34.4	34.2	32.9	32.2	31.2
EC-13	14.1	14.1	14.1	11.6	10.7	7.7
Pl-51	47.1	46.0	45.0	42.5	41.6	40.0
Pk-40	39.6	37.5	36.6	33.6	32.5	31.1
Pk-75	61.0	60.0	59.4	58.0	57.8	57.4
SC-21	8.9	8.2	7.8	6.2	5.8	5.0
SC-95	47.0	44.7	43.0	38.0	37.1	35.0
Sw-7	16.9	16.7	16.5	16.1	16.0	15.8
Wb-1	5.3	5.1	4.9	4.5	4.4	4.3
			District 7 -- Summer			
Br-46	35.6	34.5	32.5	28.6	27.5	25.6
Ck-1	72.2	70.0	68.4	61.1	59.1	54.0
Du-53	35.5	34.6	34.2	32.2	31.6	30.5
EC-13	14.2	13.8	13.4	11.5	10.6	9.1
Pl-51	46.2	45.0	44.5	42.0	41.4	40.2
Pk-40	40.7	38.0	36.5	32.5	32.0	31.1
Pk-75	60.8	59.6	59.0	57.6	57.4	57.0
SC-21	10.6	9.6	9.0	7.2	6.8	6.4
SC-95	46.6	44.1	42.6	38.2	37.0	35.0
Sw-7	16.9	16.7	16.6	16.1	15.9	15.7
Wb-1	5.2	4.8	4.5	3.8	3.6	3.3
			District 7 -- Fall			
Br-46	35.6	33.6	32.5	28.5	27.5	26.0
Ck-1	72.1	70.0	68.1	61.2	58.1	54.0
Du-53	35.3	34.6	34.2	32.2	31.6	30.4
EC-13	14.2	13.9	13.8	12.6	12.2	11.2
Pl-51	46.8	45.6	44.9	42.2	41.6	40.7
Pk-40	40.5	37.4	36.7	32.5	31.6	30.5
Pk-75	62.0	59.7	59.2	57.4	57.2	56.6
SC-21	9.6	8.8	8.4	7.0	6.8	6.3
SC-95	46.6	44.1	42.5	38.0	37.0	35.7
Sw-7	17.0	16.9	16.8	16.2	16.0	15.6
Wb-1	5.3	5.0	4.9	4.2	4.0	3.7
			District 7 -- Winter			
Br-46	35.5	34.0	33.1	29.0	27.9	26.5
Ck-1	72.2	70.0	67.9	62.1	60.0	56.1
Du-53	35.4	34.9	34.5	32.8	32.2	31.2
EC-13	14.5	14.2	14.2	13.0	12.4	11.2
Pl-51	48.0	46.5	45.6	42.5	42.0	41.1
Pk-40	39.7	37.7	36.1	33.0	32.1	31.1
Pk-75	61.0	59.9	59.2	57.8	57.6	57.4
SC-21	9.0	8.2	7.6	6.4	6.0	5.6
SC-95	47.0	44.6	43.1	38.0	37.0	35.0
Sw-7	17.1	17.0	16.9	16.6	16.4	16.3
Wb-1	5.8	5.5	5.3	4.8	4.7	4.6

Table 6. Selected seasonal probabilities of exceedance for wells analyzed in the report—Continued

Well number	Probability of exceedance (feet below land surface) 2 percent	10 percent	20 percent	80 percent	90 percent	98 percent
			District 8-- Spring			
Bf-22	13.1	10.6	9.1	4.6	3.6	1.5
Dn-11	13.3	13.1	12.9	12.2	11.9	11.5
Dn-83	10.8	10.0	9.4	8.0	7.8	7.2
Gr-5	18.0	16.5	16.1	12.5	11.5	9.6
Gn-1	66.1	63.9	62.1	56.1	54.0	50.0
Gn-2	140.5	138.0	136.5	131.1	129.6	127.0
Iw-32	66.0	64.2	62.1	54.1	57.0	45.0
Ja-5	21.4	20.8	20.6	18.9	18.2	17.0
Lf-1	23.8	23.2	22.8	21.0	20.4	19.2
Lf-11	39.0	36.1	35.0	28.2	26.0	22.1
Lf-12	40.0	37.1	35.1	28.2	26.1	22.0
Lf-78	20.0	17.6	16.1	10.7	9.1	6.6
Lf-121	80.0	76.2	74.1	65.1	62.0	58.1
Mo-2	15.6	13.1	11.7	7.6	6.7	5.0
Mo-10	12.1	10.0	9.2	4.7	3.0	1.1
Mo-11	8.0	7.5	7.1	5.6	5.3	4.4
Mo-17	6.5	5.8	5.2	3.4	3.1	2.0
SC-94	34.8	34.2	33.8	31.8	31.2	30.3
Sk-1	83.0	76.0	73.1	63.2	61.1	58.0
Tr-1	143.6	142.1	141.2	137.1	136.1	133.5
Tr-9	58.2	56.1	54.8	49.8	48.1	45.6
Ve-41	154.2	144.1	138.2	114.3	106.1	92.1
			District 8 --Summer			
Bf-22	13.0	11.1	9.6	5.5	4.6	3.1
Dn-11	13.6	13.4	13.3	12.6	12.4	11.9
Dn-83	11.0	10.6	10.2	9.0	8.6	7.8
Gr-5	18.5	17.0	15.5	11.6	10.5	8.5
Gn-1	65.5	63.6	62.5	56.6	55.0	52.1
Gn-2	139.6	138.0	136.5	131.6	130.0	126.6
Iw-32	68.1	64.0	63.1	55.0	53.1	50.0
Ja-5	21.2	20.2	19.6	17.8	17.6	17.0
Lf-1	24.0	23.4	23.2	21.2	20.4	19.2
Lf-11	39.0	36.0	34.1	217.1	24.1	20.0
Lf-12	39.2	37.2	35.5	30.0	28.6	25.6
Lf-78	17.5	16.6	15.6	12.5	11.6	8.6
Lf-121	79.1	75.0	72.2	63.1	60.0	56.0
Mo-2	15.6	13.1	12.1	7.7	6.6	4.6
Mo-10	12.8	10.7	9.7	5.0	3.6	1.6
Mo-11	8.5	7.8	7.7	6.2	5.9	5.2
Mo-17	5.8	5.2	4.9	3.4	3.1	2.2
SC-94	35.0	34.0	33.6	31.4	30.8	29.8
Sk-1	93.0	77.1	74.0	63.1	61.0	57.1
Tr-1	143.6	142.1	141.2	137.0	136.2	133.6
Tr-9	58.3	56.2	54.7	49.8	47.7	44.6
Ve-41	156.0	146.0	141.0	112.0	106.0	91.0

Table 6. Selected seasonal probabilities of exceedance for wells analyzed in the report—Continued

Well number	Probability of exceedance (feet below land surface) 2 percent	10 percent	20 percent	80 percent	90 percent	98 percent
			District 8 -- Fall			
Bf-22	10.6	9.1	8.7	5.0	4.1	2.1
Dn-11	13.7	13.4	13.2	12.6	12.4	12.1
Dn-83	11.8	11.4	11.0	9.2	8.6	7.2
Gr-5	18.5	17.0	16.1	12.5	12.0	10.7
Gn-1	68.0	65.1	64.0	58.2	56.0	54.0
Gn-2	140.0	137.9	136.5	130.7	129.1	125.6
Iw-32	66.5	64.6	63.0	57.0	55.0	51.1
Ja-5	22.2	21.2	20.8	18.6	18.2	17.2
Lf-1	23.8	23.4	23.2	22.0	21.6	20.6
Lf-11	39.2	36.0	35.1	28.1	27.0	23.1
Lf-12	40.5	39.6	39.1	30.0	29.1	20.7
Lf-78	19.6	18.6	17.6	14.1	13.0	11.0
Lf-121	79.1	76.2	73.1	65.2	63.1	58.0
Mo-2	18.2	15.7	14.1	8.6	7.1	4.6
Mo-10	12.1	11.1	10.0	6.7	5.6	3.0
Mo-11	8.5	7.9	7.6	6.3	6.0	5.5
Mo-17	7.0	6.2	5.9	4.0	3.4	2.4
SC-94	35.0	34.2	33.8	31.9	31.4	30.4
Sk-1	81.1	76.0	72.0	63.1	61.1	58.0
Tr-1	143.7	142.6	141.6	137.7	136.2	133.5
Tr-9	58.3	55.6	54.7	49.7	48.1	46.6
Ve-41	154.3	144.1	138.1	112.1	104.1	90.0
			District 8 -- Winter			
Bf-22	10.5	9.6	8.6	4.6	4.2	1.0
Dn-11	13.4	13.3	13.2	12.8	12.7	12.4
Dn-83	11.6	10.8	10.4	9.2	8.8	8.2
Gr-5	18.0	17.0	16.5	13.6	12.5	10.5
Gn-1	69.0	66.1	65.1	58.1	56.0	52.1
Gn-2	142.1	139.0	137.1	130.0	128.1	124.0
Iw-32	66.5	64.6	63.0	57.0	55.0	51.1
Ja-5	22.2	21.2	20.8	18.6	18.2	17.2
Lf-1	23.8	23.4	23.2	22.0	21.6	20.6
Lf-11	39.2	36.0	35.1	28.1	27.0	23.1
Lf-12	40.5	39.6	39.1	30.0	29.1	20.7
Lf-78	19.6	18.6	17.6	14.1	13.0	11.0
Lf-121	79.1	76.2	73.1	65.2	63.1	58.0
Mo-2	18.2	15.7	14.1	8.6	7.1	4.6
Mo-10	12.1	11.1	10.0	6.7	5.6	3.0
Mo-11	8.5	7.9	7.6	6.3	6.0	5.5
Mo-17	7.0	6.2	5.9	4.0	3.4	2.4
SC-94	35.0	34.2	33.8	31.9	31.4	30.4
Sk-1	81.1	76.0	72.0	63.1	61.1	58.0
Tr-1	143.7	142.6	141.6	137.7	136.2	133.5
Tr-9	58.3	55.6	54.7	49.7	48.1	46.6
Ve-41	154.3	144.1	138.1	112.1	104.1	90.0

Table 7. General statistical data for wells in Hydrogeologic Districts 1 and 2

Well number	Mean water level (feet below land surface)	Median water level (feet below land surface)	Highest monthly water level (feet below land surface)	Lowest monthly water level (feet below land surface)	Average annual amplitude (ft)	Fluctuability index (ft)	Average annual precipitation (in.)
As-6	32.35	29.03	25.50	32.35	2.12	3.22	31.32
Bt-2	33.86	33.74	32.51	37.13	.56	1.99	30.12
Fr-2	10.79	10.86	7.96	12.09	1.77	1.34	32.16
La-27	79.80	80.07	73.43	84.11	1.80	.73	31.2
Mt-7	21.16	21.14	18.43	23.19	1.43	2.18	29.52
Dn-22	16.14	16.14	12.51	19.14	2.19	3.38	31.32
On-23	30.21	30.11	26.37	33.57	1.60	3.58	30.60
On-24	20.69	20.7	18.72	22.21	1.22	1.87	30.96
Pr-6	2.27	2.22	.29	5.55	2.52	2.55	32.64
Ru-37	12.86	12.85	10.36	14.8	1.79	1.88	31.32
Ru-89	16.24	16.04	11.1	23.01	4.15	4.82	31.32
Ta-1	9.39	9.42	6.75	13.11	2.20	2.07	32.16
Ta-6	22.13	22.03	15.91	27.10	3.49	6.51	32.28
Vi-3	10.97	10.97	9.23	12.35	1.56	1.66	32.16
Vi-21	14.48	14.4	11.52	16.84	1.46	3.09	32.16

Table 8. General statistical data for wells in Hydrogeologic District 3

Well number	Mean water level (feet below land surface)	Median water level (feet below land surface)	Highest monthly water level (feet below land surface)	Lowest monthly water level (feet below land surface)	Average annual amplitude (ft)	Fluctuability index (ft)	Average annual precipitation (in.)
La-9	11.91	12.02	7.3	15.22	1.69	3.92	31.2
La-26	6.96	6.93	1.74	10.4	3.23	4.39	31.2
La-64	14.37	14.38	10.61	16.39	2.15	2.76	31.2
La-118	10.95	11.01	5.09	13.8	2.78	3.68	31.2
La-200	5.96	5.93	3.39	8.76	2.04	2.34	31.2
Mr-8	2.78	2.56	.65	6.65	2.88	3.31	31.92
Mr-27	6.60	7.02	.78	11.58	5.02	5.78	31.80
Mr-28	20.14	20.32	12.77	26.05	1.91	7.37	31.56
Pt-82	3.48	3.10	.77	9.18	3.14	3.99	31.44
Wd-1	6.25	6.29	4.71	7.6	1.36	1.43	31.44
Wd-29	7.70	6.72	3.88	14.18	5.57	6.24	31.56

Table 9. General statistical data for wells in Hydrogeologic District 4

Well number	Mean water level (feet below land surface)	Median water level (feet below land surface)	Highest monthly water level (feet below land surface)	Lowest monthly water level (feet below land surface)	Average annual amplitude (ft)	Fluctuability index (ft)	Average annual precipitation (in.)
Bn-13	14.8	14.2	9.38	22.66	3.85	9.0	27.84
Bn-51	105.81	101.51	86.25	131.29	6.63	34.8	27.84
Bn-76	103.28	76.23	41.24	248.97	24.98	160.93	27.84
Bn-78	-9.40	-9.5	-18.0	-2.5	17.30	9.84	27.84
Bn-80	131.31	127.6	119.83	158.45	3.75	28.60	27.84
Ca-6	194.73	191.23	172.73	219.83	5.83	33.57	27.84
Dg-4	117.47	117.42	113.42	122.3	3.68	4.52	30.36
Dg-11	34.73	34.63	16.24	55.57	14.35	21.26	31.56
Dr-7	39.37	42.07	8.00	56.12	24.20	19.66	28.80
Dr-11	47.16	43.71	40.21	60.63	2.71	16.15	28.80
FL-12	64.75	65.04	52.59	71.65	5.11	11.28	28.92
FL-300	5.56	5.50	-.56	11.25	4.25	5.03	28.92
Ke-4	84.28	84.58	73.70	97.35	5.49	12.92	31.44
Ke-5	4.21	3.75	.41	20.14	3.91	3.42	31.44
Mt-5	20.84	20.78	12.63	27.54	5.51	9.89	30.36
Ml-22	280.45	286	160.0	333.0	23.25	85.60	30.60
Ml-45	38.70	42.37	16.88	57.75	8.96	32.14	30.60
Ml-94	270.94	263.64	201.55	344.82	8.49	96.36	30.60
Ml-118	34.11	31.47	22.18	48.99	5.06	19.41	30.60
Ml-120	71.66	96.43	60.94	107.95	3.21	32.97	30.60
Ml-130	63.98	63.35	55.52	76.23	3.34	8.89	30.60
Ml-148	32.41	32.42	26.20	40.03	3.98	6.01	28.92
Oc-1	2.58	1.74	-4.00	17.18	8.86	9.12	28.68
Ou-3	38.11	37.48	30.24	47.61	3.78	10.31	27.84
Ou-5	37.25	36.95	18.42	54.65	5.33	24.41	27.84
Ou-29	59.23	59.01	54.84	64.48	3.01	5.05	29.52
Ra-5	174.13	167.99	112.24	254.2	6.98	110.14	29.88
Sb-19	2.68	2.68	-1.0	7.03	2.91	4.06	31.08
Sh-1	59.01	58.72	52.22	64.6	4.70	7.38	30.96
Ww-9	76.19	76.52	67.99	80.98	1.85	5.29	32.28
Ww-24	68.00	63.5	51.16	95.20	7.46	31.67	35.28
Wk-14	358.49	344.24	254.45	467.06	14.9	137.0	30.72
Wk-20	32.34	32.40	25.84	40.1	5.33	6.63	29.88
Wk-31	132.86	132.97	126.57	137.99	2.22	5.45	30.72
Wk-50	13.61	13.44	9.23	19.66	4.59	5.77	28.56
Wi-1	57.22	57.40	38.05	72.76	9.81	15.74	29.52
Wi-6	27.96	28.80	17.2	45.13	5.86	15.13	29.16
Wi-20	79.83	81.50	53.94	109.20	22.89	27.87	29.52

Table 10. General statistical data for wells in Hydrogeologic District 5

Well number	Mean water level (feet below land surface)	Median water level (feet below land surface)	Highest monthly water level (feet below land surface)	Lowest monthly water level (feet below land surface)	Average annual amplitude (ft)	Fluctuability index (ft)	Average annual precipitation (in.)
Co-22	54.82	55.17	50.92	59.82	2.20	5.47	30.84
Dn-4	44.08	44.59	29.24	53.14	6.34	10.65	31.68
Dn-5	92.41	90.84	83.60	120.27	6.68	16.12	30.84
Dn-441	74.06	74.33	66.53	80.48	3.00	7.52	31.68
Je-9	29.74	27.17	15.16	50.65	10.24	23.93	31.68
Mq-9	16.38	16.46	13.87	18.21	1.08	2.13	29.64
Ou-170	7.13	7.27	2.89	12.86	2.87	3.91	30.24
Pt-15	34.16	34.19	28.50	38.8	1.10	4.83	30.72
Ro-3	55.05	55.38	49.88	59.43	1.63	5.96	32.28
Ro-8	65.33	65.4	55.87	73.7	4.03	12.01	32.28
Sk-3	11.22	11.53	1.38	16.76	7.21	8.3	30.96
Sh-4	6.53	6.52	2.67	10.16	3.16	3.76	30.96
Wp-2	13.67	13.76	9.67	15.91	1.92	1.81	29.88
Wp-13	10.9	10.46	5.03	21.3	5.3	6.57	30.72
Wp-63	20.5	20.53	17.45	22.0	1.21	1.75	30.72
Ws-53	36.92	37.07	32.97	40.41	1.66	3.91	29.88
Ws-105	4.23	4.3	1.01	7.75	2.25	3.34	29.64

Table 11. General statistical data for wells in Hydrogeologic District 6

Well number	Mean water level (feet below land surface)	Median water level (feet below land surface)	Highest monthly water level (feet below land surface)	Lowest monthly water level (feet below land surface)	Average annual amplitude (ft)	Fluctuability index (ft)	Average annual precipitation (in.)
Pt-35	4.40	4.55	1.49	6.43	2.29	1.89	30.12
Pt-36	4.95	5.12	.88	6.47	2.65	2.51	30.12
Pt-41	4.02	4.12	.60	7.21	3.91	4.05	30.12
Pt-276	5.64	5.75	-.89	11.09	3.05	6.87	30.72
Pt-376	12.12	12.25	4.77	14.69	2.71	3.35	30.12
Ws-8	10.88	10.82	6.06	14.83	1.90	4.98	29.64

Table 12. General statistical data for wells in Hydrogeologic District 7

Well number	Mean water level (feet below land surface)	Median water level (feet below land surface)	Highest monthly water level (feet below land surface)	Lowest monthly water level (feet below land surface)	Average annual amplitude (ft)	Fluctuability index (ft)	Average annual precipitation (in.)
Br-46	30.87	30.79	26.44	34.89	1.33	5.89	29.16
Ck-1	64.59	65.63	55.45	70.64	2.33	11.11	31.68
Du-53	33.34	33.53	29.06	37.33	2.28	2.78	30.0
EC-13	12.9	13.22	4.78	14.85	2.44	2.74	30.96
Pi-51	43.63	43.52	40.13	48.65	2.64	4.22	30.84
Pk-40	34.75	34.28	31.04	41.38	2.15	6.00	30.84
Pk-75	58.54	58.4	55.95	61.02	1.18	2.57	29.16
SC-21	7.46	7.36	4.93	12.02	2.93	2.87	30.0
SC-95	40.41	40.29	30.93	47.75	2.26	7.70	29.16
Sw-7	16.46	16.52	14.21	17.29	1.05	.95	31.32
Wb-1	4.61	4.64	2.9	5.79	1.43	1.46	28.08

Table 13. General statistical data for wells in Hydrogeologic Districts 8 and 9

Well number	Mean water level (feet below land surface)	Median water level (feet below land surface)	Highest monthly water level (feet below land surface)	Lowest monthly water level (feet below land surface)	Average annual amplitude (ft)	Fluctuability index (ft)	Average annual precipitation (in.)
Bf-22	6.96	7.20	1.10	14.36	3.97	6.96	30.00
Dn-11	12.84	12.91	11.16	13.64	1.13	1.26	29.4
Dn-83	9.55	9.67	7.05	12.08	2.72	2.88	29.4
Gr-5	14.20	14.54	8.60	19.03	3.30	5.97	33.24
Gn-1	60.14	60.69	47.96	69.72	7.93	11.20	34.80
Gn-2	133.79	134.32	123.28	143.94	4.71	9.31	34.80
Iw-32	59.09	59.57	39.4	68.81	7.57	9.96	33.12
Ja-5	19.32	19.38	15.53	22.6	2.55	3.26	32.4
Lf-1	22.6	22.6	16.00	24.17	2.50	2.57	33.84
Lf-11	30.97	31.24	18.94	38.81	4.04	10.85	34.44
Lf-12	33.28	34.25	18.16	40.22	11.08	11.83	33.84
Lf-57	105.18	107.19	75.76	130.81	5.14	32.56	33.84
Lf-78	14.72	15.15	3.89	19.81	6.72	7.09	33.84
Lf-121	68.43	68.50	56.77	78.37	5.59	14.12	33.84
Mo-2	10.26	10.02	4.70	18.61	4.35	7.93	41.76
Mo-10	7.45	8.10	.60	12.01	4.06	7.27	41.76
Mo-11	6.74	6.68	3.2	9.00	2.02	2.28	41.76
Mo-17	4.38	4.38	.91	7.61	2.44	2.97	29.76
SC-94	32.68	32.83	28.29	36.04	1.58	3.30	29.16
Sk-1	58.21	67.2	58.87	83.49	5.91	16.89	29.4
Tr-1	139.30	139.71	133.18	146.56	3.28	6.75	30.12
Tr-9	51.88	52.05	44.51	57.11	2.10	8.37	30.72
Ve-8	48.59	48.45	44.19	51.64	1.07	5.01	41.76
Ve-41	124.78	127.86	98.18	149.60	6.08	41.16	41.76

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