HYDROGEOLOGY OF THE SAND AND GRAVEL AQUIFER IN THE VICINITY OF THE WILD ROSE STATE FISH HATCHERY, NORTH-CENTRAL WAUSHARA COUNTY, WISCONSIN

By T.D. Conlon

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To Obtain
inch per year (in/yr)	25.4	millimeter per year
mile (mi)	1.609	kilometer
foot (ft)	0.3048	meter
foot per second (ft/s)	0.3048	meter per second
foot per day (ft/d)	0.3048	meter per day
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
gallon per minute (gal/min)	0.06309	cubic meter per second
million gallons per day (Mgal/d)	0.04381	cubic meter per second
square mile (mi^2)	2.590	square kilometer

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Hydrogeology of the Sand and Gravel Aquifer in the Vicinity of the Wild Rose State Fish Hatchery, North-Central Waushara County, Wisconsin

By T.D. Conlon

Abstract

The sand and gravel aquifer in the vicinity of the Wild Rose State Fish Hatchery is approximately 200 feet thick.The aquifer consists mostly of sand that was deposited as glacial till and outwash approximately 15,000 years ago. Hydraulic conductivity of the aquifer at the hatchery, calculated from slug tests, is approximately 18 feet per day. Ground water recharges west of the hatchery, flows from northwest to southeast, and discharges to streams, lakes, springs, and flowing wells.

Springs and flowing wells are common at the hatchery because of upward hydraulic gradients in the sand and gravel aquifer. Total flow from springs and wells at the hatchery is approximately 3 million gallons per day. The recharge area for the ground water discharging at the hatchery extends at least 5 miles to the west. Ground water may flow from or under the Pine River to wells and springs at the hatchery.

INTRODUCTION

Ground water from a sand and gravel aquifer supplies most domestic, municipal, and agricultural water needs in Waushara County, Wis. In the central part of the county, springs flowing from the edge of an end moraine form the headwaters of many streams. The springs are present where the aquifer is not overlain by fine-grained material and where upward hydraulic gradients cause ground water to discharge at land surface. The U.S. Geological Survey, in cooperation with the Wisconsin Department of Natural Resources (WDNR), collected hydrologic data to determine the characteristics of the sand and gravel aquifer and springs at the headwaters of a tributary to the Pine River, where the WDNR operates the Wild Rose State Fish Hatchery.

The Wild Rose State Fish Hatchery began operations in 1908, using water from springs flowing from the base of a hillside 2 mi north of the village of Wild Rose. Over the years, driven wells with sand points were added to augment the flow from springs. In 1963, three wells were drilled. All wells flow naturally because of the upward hydraulic gradients in the underlying aquifer. Total flow from springs and wells at the hatchery on the west side of Highway 22 is approximately 3 Mgal/d (Holmstrom and others, 1995, p. 204).

Purpose and Scope

This report describes the hydrogeology of the sand and gravel aquifer in the vicinity of the Wild Rose State Fish Hatchery in Waushara County. This study builds on a previous study (Summers, 1965) by providing more detailed information, including lithologic-log data that were not available in 1965. The report includes information concerning the (1) thickness of the unconsolidated deposits, (2) altitude of the bedrock surface, and (3) hydraulic properties of the sand and gravel aquifer. The study is limited to describing the hydrogeology of the sand and gravel aquifer and springs. Evaluation of the hydraulic properties of the underlying bedrock was beyond the scope of the study described here.

Location and Physical Setting

The study area encompasses 5.6 mi^2 and includes the Wild Rose State Fish Hatchery, the village of Wild Rose, and the area immediately west of the hatchery (fig. 1) in north-central Waushara County, Wis. The study area lies in a hilly region east of a topographic

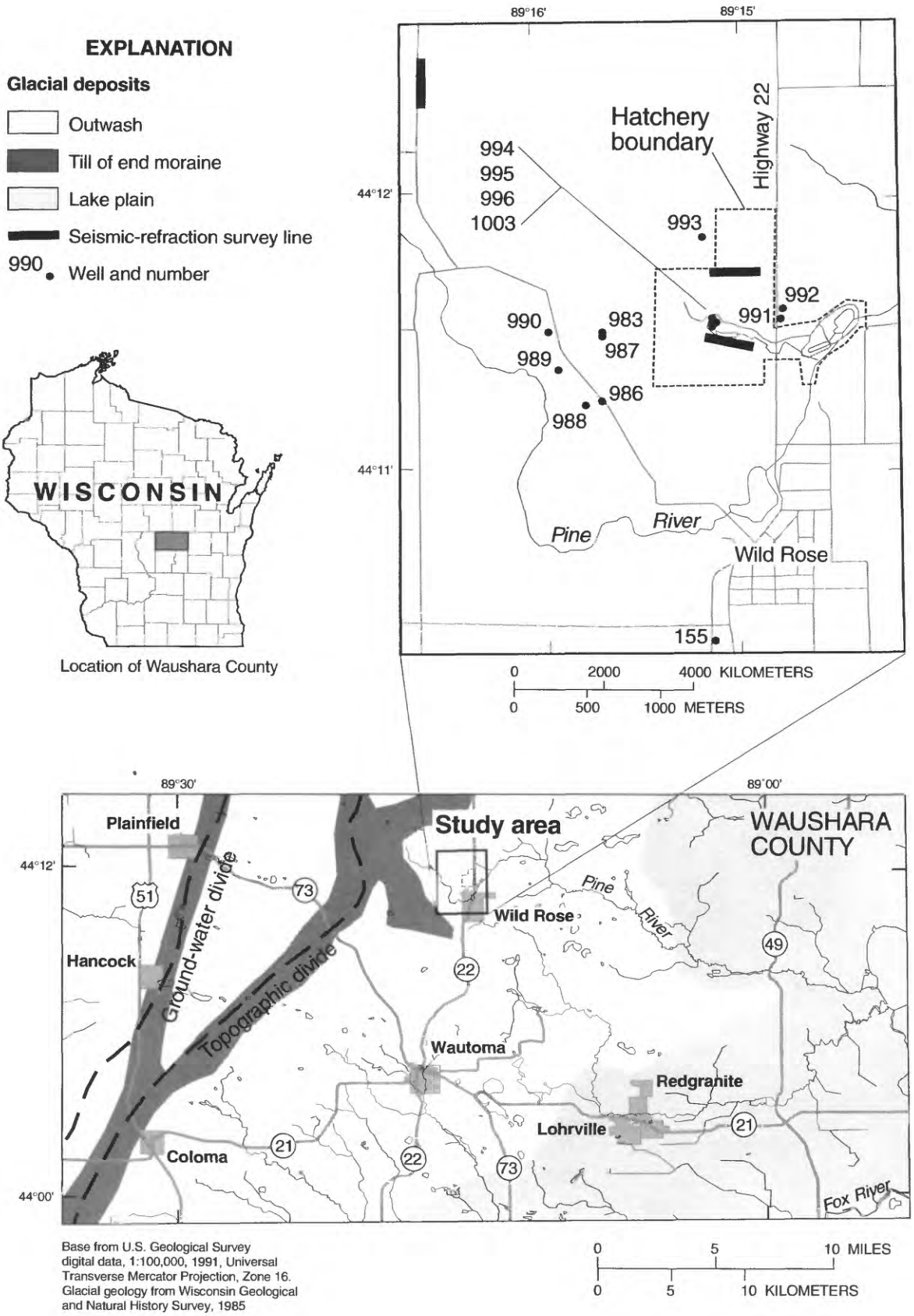

Figure 1. Glacial geology and location of study area in north-central Waushara County, Wis.

divide at an altitude of approximately 1,250 ft and to the west of a flatter region.

The topographic divide west of the study area (fig. 1) separates the Fox River drainage area, which flows to Lake Michigan, from the Wisconsin River drainage, which flows to the Mississippi River. The Pine River, a tributary to the Fox River, drains the study area. The springs and wells of the hatchery discharge to an unnamed tributary of the Pine River.

HYDROGEOLOGY

The extent, thickness, and type of glacial deposits determine the hydrogeology of the sand and gravel aquifer, which is the main aquifer in the study area. The underlying sandstone aquifer is thin or absent in places. The hydrogeology of the sandstone is not described in detail; however, the altitude of the top of the sandstone is described because it represents the bottom of the sand and gravel aquifer. East and south of the study area, the sandstone aquifer thickens and is important as a source of water supply.

Geologic Setting

The most important geologic event affecting the hydrogeology of the study area was the advance of the Green Bay Lobe of the Wisconsin Glaciation approximately 15,000 years ago. Glaciers deposited gravel, sand, silt, and clay over the area. The study area is near the location of the western terminus of the glaciers where moraines form the hills west of the hatchery. The glacial material was deposited on bedrock consisting of sandstone and granite. Summers (1965) provides a detailed discussion of the glacial and bedrock geology of Waushara County.

Bedrock Geology

Sandstone of Cambrian age overlies Precambrian granite in the county. The sandstone slopes southeastward at about 10–20 ft/mi (Summer, 1965, p. B10) and thickens south and east of the study area. The sandstone is absent in places.

Seismic refraction data were collected to provide additional information on the altitude of the bedrock surface and thickness of glacial material in the study area. Altitude of bedrock was interpreted from arrival times of refracted seismic waves along three survey lines (fig. 2) with a time-delay and iterative ray-tracing program (Scott and others, 1972).

Information from the seismic refraction survey indicates the seismic velocity in the bedrock is approximately 18,000 ft/s. Woollard and Hansen (1954) reported that the seismic velocities of nearby sandstones and Precambrian rocks are approximately 9,000 ft/s and approximately 18,000 ft/s, respectively. The seismic data collected as part of this study indicate that beneath the three seismic lines the sandstone is absent or too thin to be resolved by the seismic refraction method.

Assuming that the sandstone is absent, the altitude of the bedrock surface (fig. 2) beneath the seismic lines ranges from 700 to 800 ft. In the southern part of the study area, a thin layer of sandstone was noted at well 155 at an altitude of 661 ft (Appendix A, fig. 2). The altitude of the bedrock is greatest in the northern part of the study area. Other wells in the area are completed in the sand and gravel deposits overlying the bedrock. The altitude of bedrock is less than the altitude of the bottom of these wells and is shown as a filled circle in figure 2.

Glacial Geology

The occurrence and thickness of the unconsolidated deposits are a result of glacial processes that were at work approximately 15,000 years ago. The Green Bay Lobe of the Wisconsin Glaciation extended across the study area westward to the edge of the area now known as the Central Wisconsin Sand Plains. Unconsolidated sediments were deposited beneath and in front of the glacier. The two predominant types of deposits in the north-central part of the county are outwash consisting of sand and gravel deposited by glacial meltwater, and till consisting of a mixture of gravel, sand, silt, and clay deposited by the ice as end moraines (fig. 1).

The glacial deposits beneath the study area are outwash and consist of mostly sand and gravel according to available lithologic logs (Appendix A). Analyses of soil samples collected by the hatchery staff indicate that the upper 20 ft of the unconsolidated deposits beneath the hatchery consists of fine to medium sand. Data from the three seismic refraction lines and from well 155 (fig. 3 and Appendix A) indicate that the thickness of the glacial deposits ranges from 180 to 300 ft. Glacial deposits are thickest in the southern part of

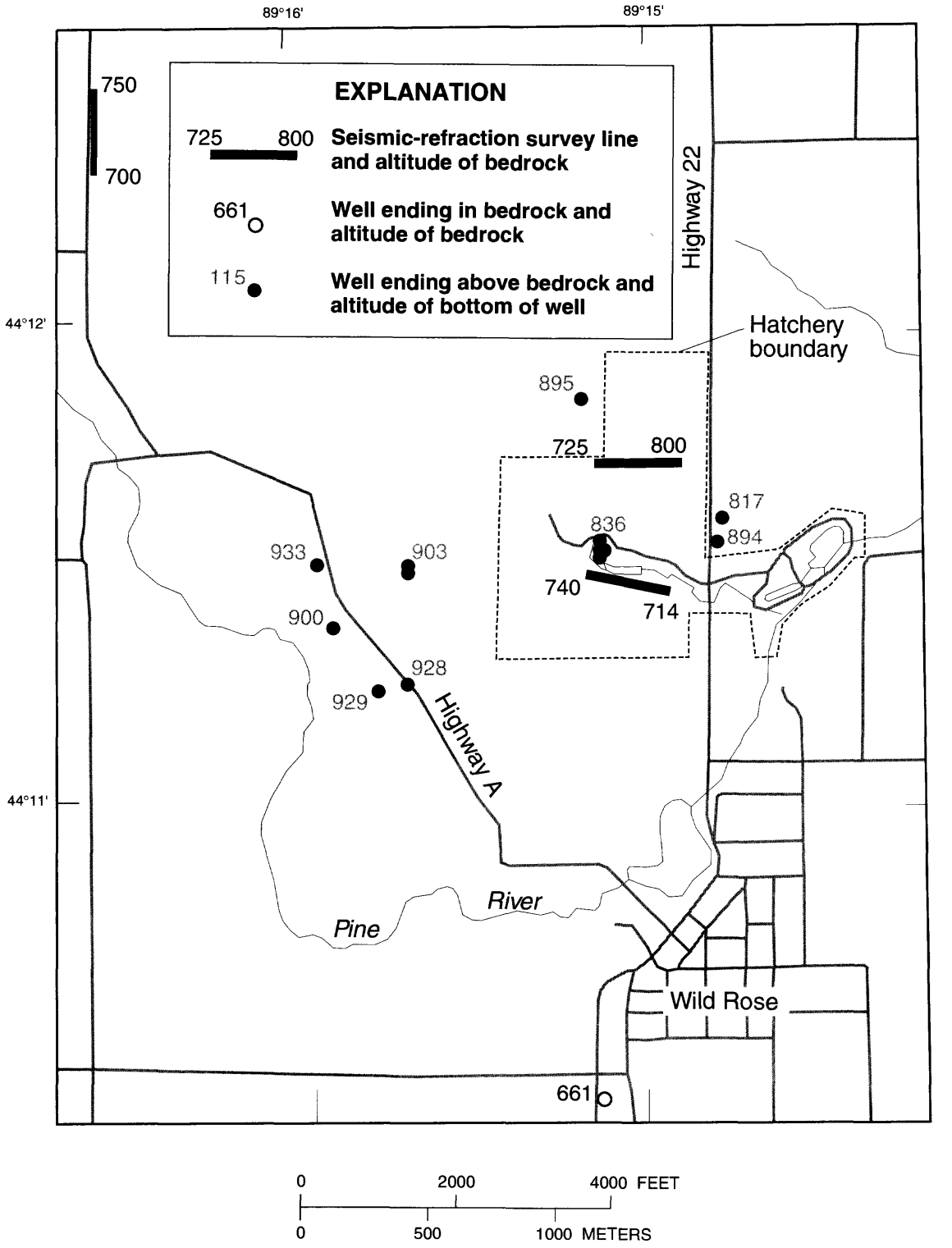

Figure 2. Altitude of bedrock surface, in feet above sea level, north-central Waushara County, Wis.

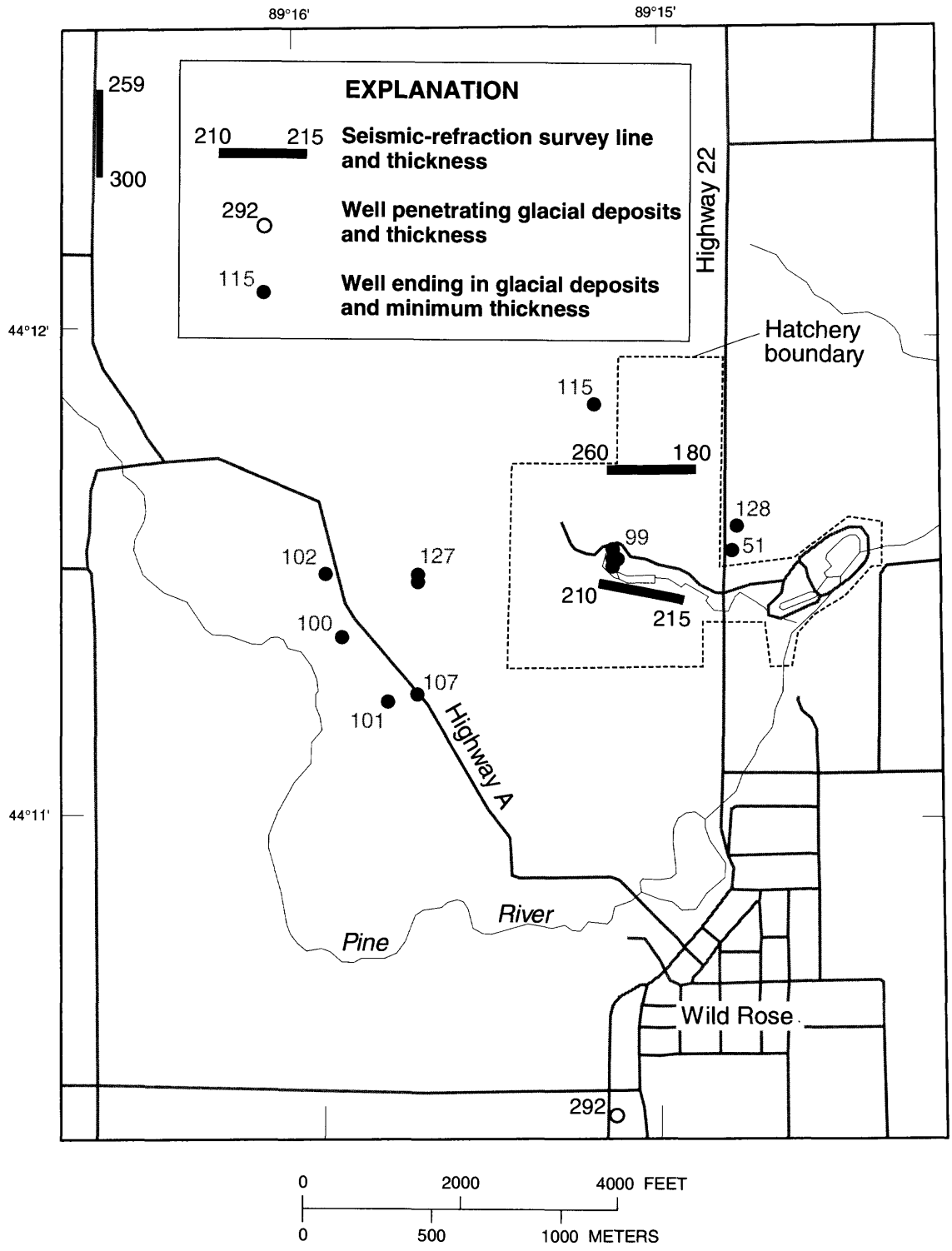

Figure 3. Thickness of glacial deposits, in feet, north-central Waushara County, Wis.

the study area and beneath the hills in the western part of the study area.

Sand and Gravel Aquifer

The sand and gravel aquifer, which consists of permeable glacial deposits, underlies most of the area of Waushara County, including the study area. The glacial deposits are considered a single unconfined aquifer (Summers, 1965, p. B14). The bottom of the aquifer is considered to be the top of the bedrock (fig. 2). Most wells in the study area are completed in the sand and gravel aquifer because it provides a sufficient water supply.

Ground water flows from topographically high recharge areas to topographically low discharge areas and wells. Regionally, ground water flows southeasterly from a ground-water divide that coincides with the westernmost end moraine in Waushara (fig. 1) and Portage Counties (Summers, 1965; Holt, 1965). The ground-water flow direction within the study area is from west and northwest to east on the basis of water levels reported on drillers' construction reports of domestic wells and the altitude of the Pine River (fig. 4). Water discharging from the hatchery wells and springs originates west of the hatchery. Because the water-level altitude in the Pine River 1 mi west of the hatchery is greater than water levels in nearby wells and hatchery springs (fig. 4), water discharging at the hatchery may originate at the river.

The hatchery area is a ground-water discharge area because the hydraulic gradient is upward; that is, ground-water levels measured in wells are greater than the altitude of the land surface. Ground water discharges naturally from springs and seeps at the land surface because no confining unit is present to limit flow from the aquifer to the land surface.

Water levels measured in well 1003 screened from 7 to 9 ft below land surface are shown with daily precipitation measured in Hancock, Wis., in figure 5. Trends in water levels are due to changes in recharge to the sand and gravel aquifer. The water level is lower in the well during periods of low recharge, such as during the winter months when the ground is frozen. The water level rises in the spring when snow melts and rain can infiltrate into the aquifer. During the summer months, water levels in the aquifer decline because precipitation is transpired or evaporated, except during heavy rainfall periods, such as in August and September 1995. In the fall, before the ground freezes and after vegetation dies or is dormant, water levels rise again because the effects of evapotranspiration are diminished. Overall, the water level in the well fluctuated less than 0.5 ft. This small fluctuation is common in discharge areas.

Aquifers transmit water from recharge areas to discharge areas. Hydraulic conductivity is a measure of the ability of an aquifer to transmit water. Displacement-recovery tests, or "slug" tests (Bouwer and Rice, 1976), were used in this study to calculate the horizontal hydraulic conductivity of the sand and gravel aquifer in the immediate vicinity of wells 994 and 996 at the Wild Rose State Fish Hatchery. The hydraulic conductivity at the two wells completed in sand is approximately 18 ft/d, which is within the range for a clean sand (Freeze and Cherry, 1979, p. 29).

Springs and Flowing Wells

Many springs flow from the eastern and southeastern side of the end moraine in central and western Waushara County (Summers, 1965, pls. 1 and 3). Within the study area, springs are a major source of water to the Wild Rose State Fish Hatchery. The springs of the hatchery are widespread and occur where ground water flows to the land surface as seeps or sand boils in and near hatchery raceways.

Flow from springs and wells at the hatchery west of Highway 22 is approximately 3 Mgal/d (Holmstrom and others, 1995). A water-table map (Summers, 1965, pl. 1) indicates that ground water that flows to springs and wells at the hatchery originates west of the springs. Recharge to the aquifer is from precipitation (Summers, 1965, p. B14). The area over which precipitation must fall to maintain a flow of 3 Mgal/d can be estimated by dividing the measured flow by the rate of water recharging the sand and gravel aquifer. A recharge rate of approximately 7 in/yr was estimated and is within the range of recharge reported by Summers (1965, p. B15). Given this recharge rate, the area necessary to maintain a spring flow of 3 Mgal/d is approximately 10 mi^2. An area of 10 mi^2 would capture water as far away as the topographic divide located approximately 5 mi west of the springs.

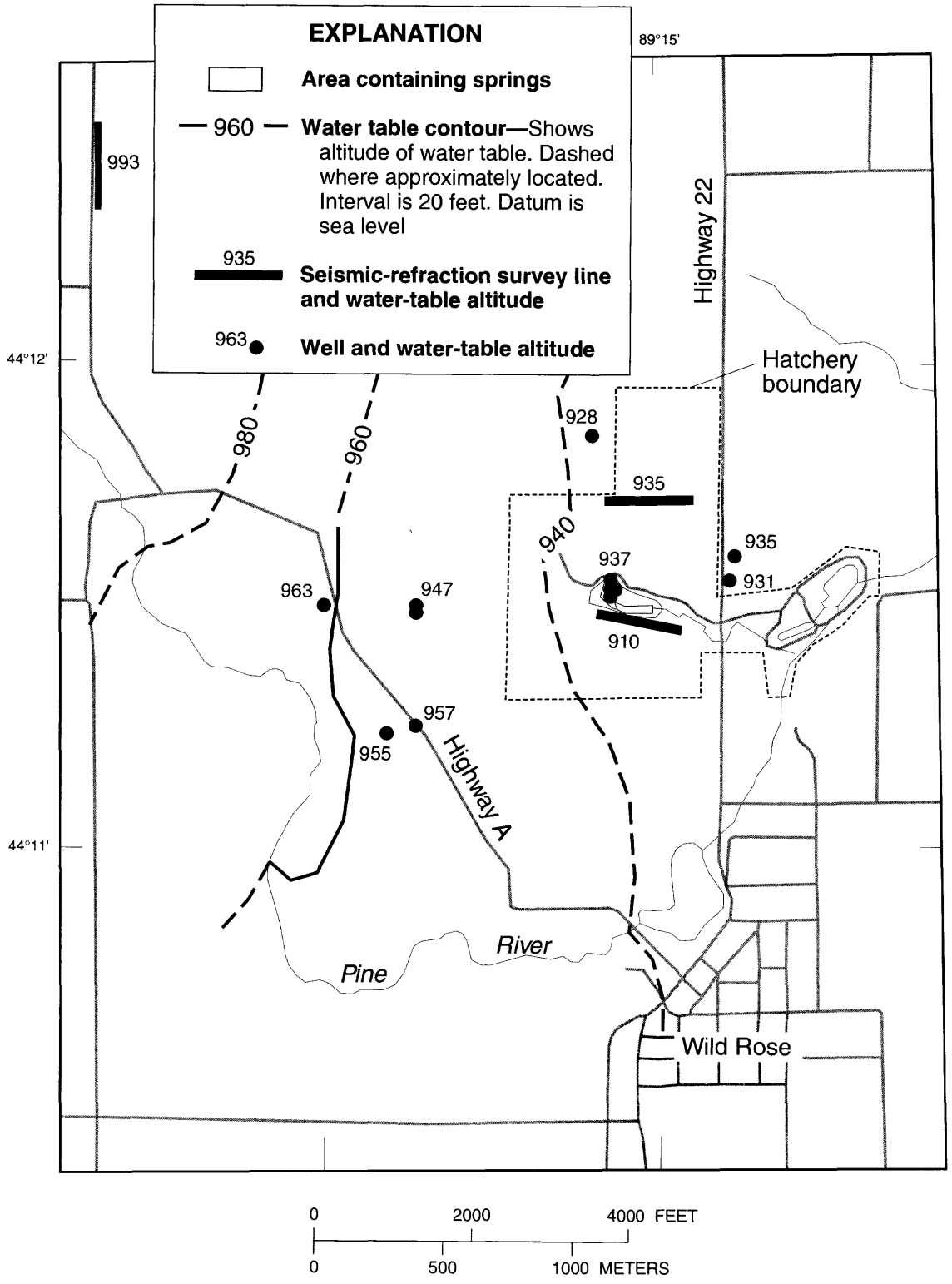

Figure 4. Altitude of water table, north-central Waushara County, Wisconsin.

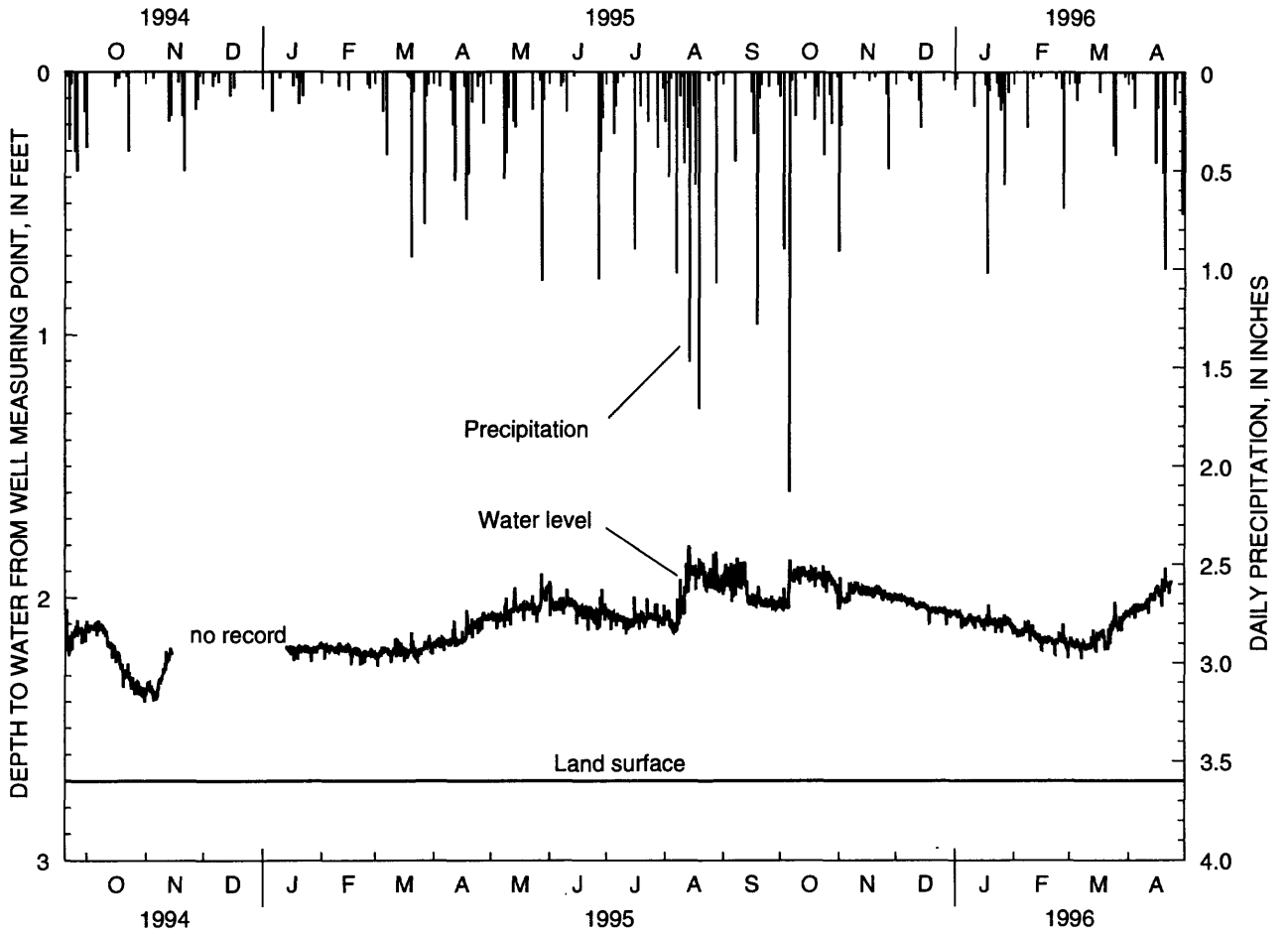

Figure 5. Water levels in well 1003 at Wild Rose State Fish Hatchery, Waushara County, and precipitation at Hancock, Wis., September 20, 1994 through April 23, 1996.

SUMMARY

A surficial sand and gravel aquifer is the main source of water supply for north-central Waushara County and the Wild Rose State Fish Hatchery. The aquifer extends throughout the area, is about 200 feet thick, and is underlain either by granite or a thin layer of sandstone. Analysis of slug tests indicate that the hydraulic conductivity of the aquifer is approximately 18 feet per day.

The source of water for springs and wells at the hatchery is precipitation that infiltrates into the aquifer west of the hatchery. The direction of ground-water flow is from west and northwest to east, where it discharges to streams and lakes, and where upward gradients exist, to springs and flowing wells. The recharge area for ground water discharging from the springs and wells at the hatchery extends at least 5 miles to the west and includes part of the Pine River and areas west of the river.

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APPENDIX A

Appendix A. Lithologic logs for selected wells in north-central Waushara County, Wis.
[Location of wells shown in figure 1; USGS Name is a three-part system where "WS" indicates that the well is in Waushara County, the next 7 digits provides location by township, range (east or west), and section, and the third part is the well number]

Well 155: USGS Name WS-20/10E/25-0155
Altitude of land surface, 953 ft above sea level. Date drilled 1902.
Depth to static water level (negative values are height above land surface), not available.
Specific capacity, not available.

Lithology	Depth interval (feet)
Sand and clay	0–150
Sand and gravel	151–250
Sand	251–291
Sandstone	292–295
Granite	296–297

Well 983: USGS Name WS-20/10E/24-0983
Altitude of land surface, 1,030 ft above sea level. Date drilled 07/12/77.
Depth to static water level (negative values are height above land surface), 83 ft.
Specific capacity, 1.3 gal/min/ft drawdown.

Lithology	Depth interval (feet)
Sand	0–35
Sand and clay	36–59
Sand	60–127

Well 986: USGS Name WS-20/10E/24-0986
Altitude of land surface, 1,035 ft above sea level. Date drilled 08/27/61.
Depth to static water level (negative values are height above land surface), 78 ft.
Specific capacity, 5.0 gal/min/ft drawdown.

Lithology	Depth interval (feet)
Sand and gravel	0–65
Clay	66–72
Sand	73–84
Clay	85–97
Sand	98–107

Well 987: USGS Name WS-20/10E/24-0987
Altitude of land surface, 1,035 ft above sea level. Date drilled 06/04/66.
Depth to static water level (negative values are height above land surface),74 ft.
Specific capacity, 10.0 gal/min/ft drawdown.

Lithology	Depth interval (feet)
Sand	0–72
Clay	73–96
Sand	97–112

Well 988: USGS Name WS-20/10E/24-0988
Altitude of land surface, 1,030 ft above sea level. Date drilled 06/25/81.
Depth to static water level (negative values are height above land surface), 75 ft.
Specific capacity, 1.8 gal/min/ft drawdown.

Lithology	Depth interval (feet)
Sand and gravel	0–101

Well 989: USGS Name WS-20/10E/24-0989
Altitude of land surface, 1,000 ft above sea level. Date drilled 06/10/83.
Depth to static water level (negative values are height above land surface), 68 ft.
Specific capacity, 2.9 gal/min/ft drawdown.

Lithology	Depth interval (feet)
Sand and gravel	0–56
Sand and clay	57–80
Sand	81–100

Well 990: USGS Name WS-20/10E/24-0990
Altitude of land surface, 1,035 ft above sea level. Date drilled 10/19/84.
Depth to static water level (negative values are height above land surface), 72 ft.
Specific capacity, 3.3 gal/min/ft drawdown.

Lithology	Depth interval (feet)
Sand and gravel	0–102

Well 991: USGS Name WS-20/11E/19-0991
Altitude of land surface, 945 feet above sea level. Date drilled 12/15/69.
Depth to static water level (negative values are height above land surface), 14 feet.
Specific capacity, 5.0 gal/min/ft drawdown.

Lithology	Depth interval (feet)
Sand and gravel	0–31
Clay	32–34
Sand	35–51

Well 992: USGS Name WS-20/11E/19-0992
Altitude of land surface, 945 ft above sea level. Date drilled 06/20/73.
Depth to static water level (negative values are height above land surface), 10 ft.
Specific capacity, 3.6 gal/min/ft drawdown.

Lithology	Depth interval (feet)
Sand	0–21
Sand and clay	22–118
Sand	119–128

Well 993: USGS Name WS-20/10E/24-0993
Altitude of land surface, 1,010 ft above sea level. Date drilled 09/28/76.
Depth to static water level (negative values are height above land surface), 82 ft.
Specific capacity, 2.2 gal/min/ft drawdown.

Lithology	Depth interval (feet)
Sand	0–115

Well 994: USGS Name WS-20/10E/24-0994
Altitude of land surface, 935 ft above sea level. Date drilled 03/08/63.
Depth to static water level (negative values are height above land surface), -2 ft.
Specific capacity, 6.0 gal/min/ft drawdown.

Lithology	Depth interval (feet)
Sand	0–62

Well 995: USGS Name WS-20/10E/24-0995
Altitude of land surface, 935 ft above sea level. Date drilled 03/27/63.
Depth to static water level (negative values are height above land surface), -1 ft.
Specific capacity, 8.0 gal/min/ft drawdown.

Lithology	Depth interval (feet)
Sand and gravel	0–44

Well 996: USGS Name WS-20/10E/24-0996
Altitude of land surface, 935 ft above sea level. Date drilled 04/03/63.
Depth to static water level (negative values are height above land surface), -1 ft.
Specific capacity, 8.2 gal/min/ft drawdown.

Lithology	Depth interval (feet)
Sand	0–99

Well 1003: USGS Name WS-20/10E/24-1003
Altitude of land surface, 935 ft above sea level. Date drilled 06/23/94.
Depth to static water level (negative values are height above land surface), -1 ft.
Specific capacity, not available.

Lithology	Depth interval (feet)
Sand	0–9

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