THE RECHARGE AREA AND WATER QUALITY OF THE STEVENS POINT MUNICIPAL WELL FIELD

by

Richard K. Renaud

A Thesis

Submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

College of Natural Resources

UNIVERSITY OF WISCONSIN

Stevens Point, Wisconsin

May, 1987

APPROVED BY THE GRADUATE COMMITTEE OF:

Dr. Byron H. Shaw, Committee Chairman
Professor of Soil Science and of Water Science

Dr. N. Earl Spangenberg
Associate Professor of Forestry and of Water Science

Dr. Gerald E. Nienke
Associate Professor of Water Science

ABSTRACT

Determining the area from which the City of Stevens Point Municipal Supply Wells draws recharge waters is important first step in protecting the city's water supply. In determining the recharge area, land uses that may affect the water quality of the aquifer may be discouraged. To determine the groundwater flow characteristics of the recharge area 9 piezometers and 12 water table observation wells were used to estimate to groundwater flow approaching the well field. Nested well systems were installed both east and west of the Plover River to determine the extent of the cone of depression and whether the cone extended to or beyond the Plover River. Water table observations revealed that the cone of depression extends beyond the Plover River during most of the year, indicating that water from the river and east of the river is drawn into the aquifer near the well field. Piezometers placed in the bed of the river verified that the river was recharging the aquifer near the well field. Observations from the nested well systems demonstrated that the groundwater flow approaching the city supply wells is predominately horizontal, suggesting that the groundwater flow is dominated by the pumpage from the city supply wells. The horizontal gradients east of the Plover River indicated that pumpage from the city wells was affecting groundwater flow east of the river, creating the potential for groundwater flow beneath the river bed. The aquifer water quality was examined through sampling all piezometers, monitoring wells, city supply wells, regional private water supply wells, and regional surface water bodies. All samples were analyzed for inorganic constituents to examine the aquifer water

quality of the well field region and to use the specific constituents as natural traces of groundwater flow. The sampling revealed isolated high concentrations of many constituents. An area of impacted water was detected in the deeper aquifer adjacent to the well field east of the river. The elevated concentrations of nitrates, sulfates and chlorides suggested that the impacts were associated with agricultural fertilizers, animal wastes and septic systems. Impacted groundwater was also detected along Highway 66. Elevated concentrations of ammonia, sulfates, chloride, and to a lesser extent, nitrates are believed to be the result of roadsalt applications to the highway and septic system impacts. In each case however, the high values were significantly diluted as the city supply wells withdrew recharge water from the other regions with lower concentrations. The City is fortunate to have a relatively large undeveloped area near the well field to provide dilution of contaminates originating in the developed parts of the recharge area.

ACKNOWLEDGMENTS

I wish to thank Dr. Byron Shaw my major professor for his endless patients and continual support. Byron nearly always would listen to ideas related to this project and helped immensely in structuring the field work as well as the final written report. I also wish to thank Dick Stephens, Jeff Andrews and the staff of the Environmental Task Force for their companionship and technical assistance. For review of my graduate program and comment on this manuscript I thank Dr. Earl Spangenberg and Dr. Gerald Nienke. I must also thank Lloyd Murray and other members of the City of Stevens Point Board of Water and Sewage Commission for there assistance which provided access to existing data and financial assistance.

I also must extend a special expression of gratitude to my parents who provided me with support beyond description and instilled me with a sense of wonder and respect for the earth's resources. Lastly I need to express my love and gratitude to Peggy Dickinson who made many sacrifices and was very supportive during my graduate work.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. Introduction

Purpose of Investigation

The Central Sands Region of Wisconsin has been found to be vulnerable to groundwater quality problems. Pesticides used in agricultual practices, have been found to make their way to the groundwater because of the low attenuative capacity and the high permeabilities of the sandy soils and aquifer. Nitrate contamination is also widespread, resulting from fertilizers, animal waste and septic systems. The Village of Whiting which is located immediately to the south of Stevens Point has become dependent on the Stevens Point water supply since the Whiting supply was found to be contaminated with nitrates.

The land area where water originates to supply the Stevens Point wells is referred to as the recharge area. Contamination of the aquifer and potentially the Stevens Point water supply could occur by the introduction of contaminants from any location within the recharge area. The area surrounding the well field and therefore the immediate recharge area is becoming increasingly developed by urban sprawl and intensive agriculture. The increased human activity within the recharge area could impact the groundwater quality of the City of Stevens Point water supply. Also as the population and water demands of the city increase so does the required recharge area. Increased pumpage would extend the recharge area to include new areas. Land practices within the newly extended areas could potentially present new threats to the water quality.

The aquifer characteristics, amount of water removed from the aquifer, pumpage pattern, and the position of the city supply wells within the aquifer define the groundwater flow patterns near the well field and determine the required area of recharge. A specific concern with the City of Stevens Point Well Field is the possibility that pumpage from the city supply wells draws recharge water under the Plover River bed. This would extend the required recharge area to encompass land to the east of the Plover River and present the possibility that land use practices of this region may impact the aquifer water quality.

The purpose of this study was to determine the recharge area of the Stevens Point Well Field, and relate the recharge area to land use practices that may affect the city's water supply. A secondary goal of this study was to evaluate the over-all water quality to the Plover River Aquifer and the implications to the future water supply needs for the City of Stevens Point.

Scope of Work

This investigation concentrated on the recharge area of City Supply Wells #6-#9. The city's water supply relies almost exclusively on wells #6-#9, while using wells #4 and #5 for stand-by purposes only. To determine the flow characteristics near the well field four nested well systems were installed; two on each side of the Plover River. Five single depth piezometers were also installed north and east of the well field. Five observation wells, installed to monitor the potential impacts associated with fuel storage at the Stevens Point Municipal Airport were also monitored. Two piezometers were also placed within the Plover River to investigate the contribution of the river to the aquifer within the cone of depression. The water table was observed in all of the nested piezometers, single depth piezometer, airport observation wells, city supply wells and local surface water bodies. The aquifer inorganic water chemistry was examined through sampling all nested and monitoring wells, city supply wells, regional private water supply wells, airport observation wells, and local surface water bodies.

Location of the Stevens Point Municipal Well Field

The Stevens Point Well Field is located in the northeast corner of the city's limits in NW 1/4, Section 26 T.24N, R.8E. A plan view of the well field and surrounding area is given in Figure 1.

Previous Investigation of the Recharge Area

Investigation of a limited portion of the recharge area was performed to identify the potential impacts of the airport aviation fuel tanks on the city supply wells. This report examined the potential impact on the well field aquifer of a fuel spill or leak of the underground fuel storage facilities. (Hickok 1981)

As a result of this investigation, five observation wells were installed downflow from the fuel storage facilities between the fuel storage facility and the city supply wells. Four of these were installed along the southwest runway, while the fifth was installed 3,000 feet southeast of the fuel storage facilities near municipal supply well #9. Location of the observation wells are shown in Figure 2.

II. Water Demand and Service Area

The Stevens Point Municipal Supply Wells presently service the City of Stevens Point and the Village of Whiting. The Village of

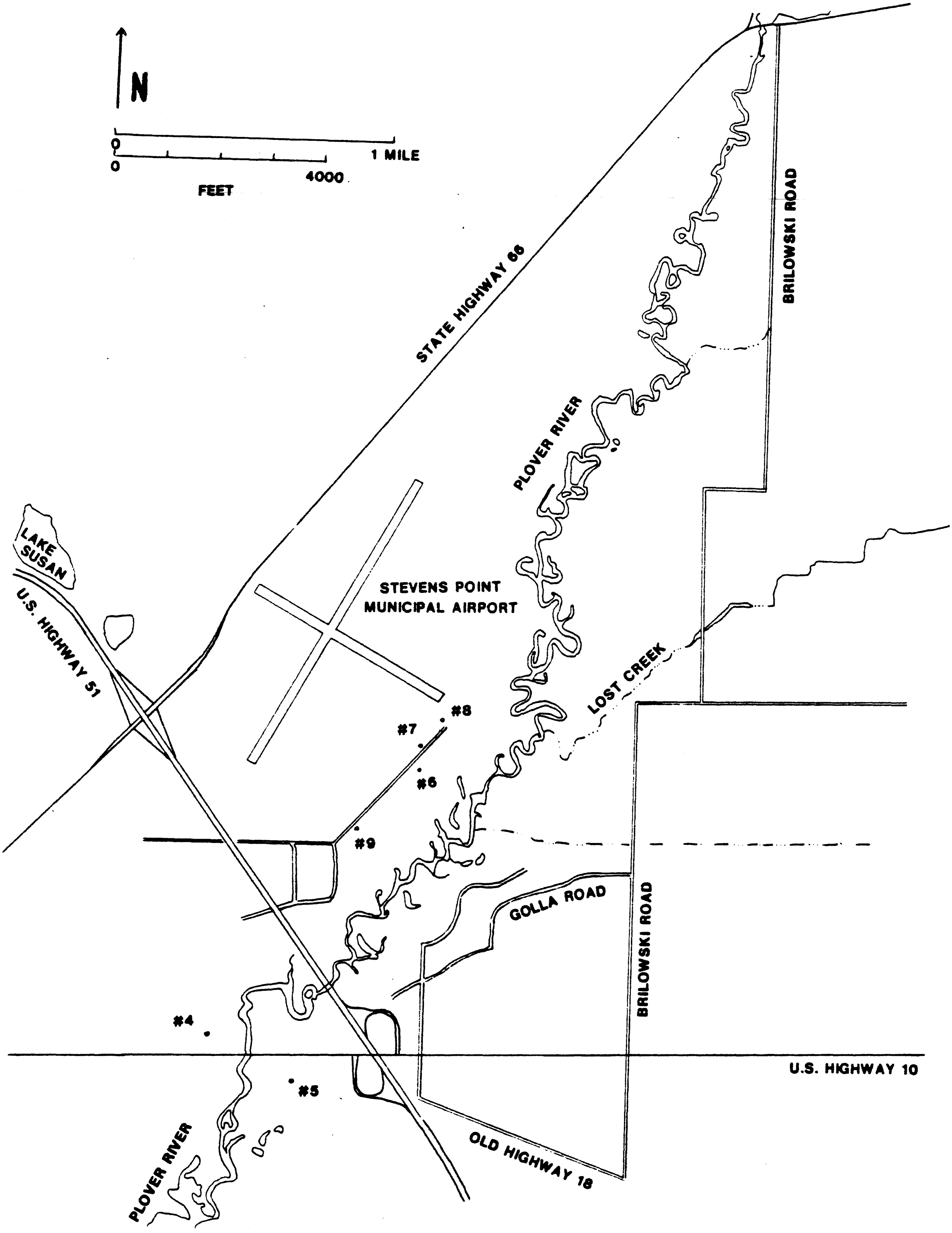


Figure 1. Stevens Point Water Supply Wells and Well Field Area

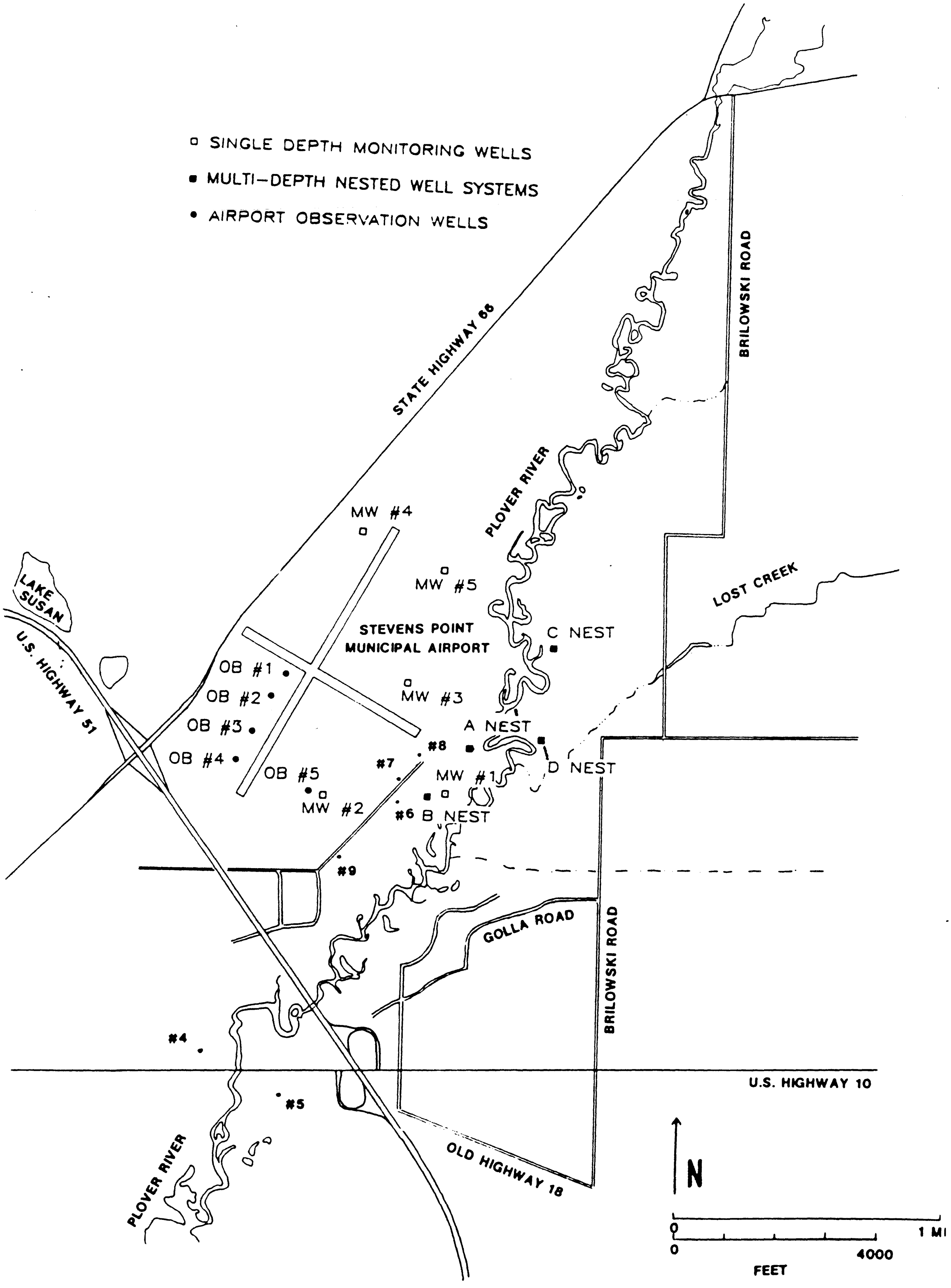


Figure 2. Location of Observation, Monitoring, Nested and Supply Wells.

Whiting was forced to rely on the Stevens Point water supply when their supply wells were found to contain high levels of nitrates. (Shaw 1984)

The Portage County Planning Commission estimates the 1984 population of Stevens Point and Whiting at 27,338. It is expected that the Portage County population will increase at an average annual rate of 2.76% (Portage County Planning Department). It is also estimated that the metropolitan area will grow at a greater rate than the county at large. The water demand will most likely increase at a greater rate than the population because of an expanding service area and an increase in per capita consumption.

The 1983 total annual water consumption was 1.6 billion gallons. The 1983 service population was estimated from the 1980 census data to be 26,410. The per capita use for 1983 was then estimated to be at 61,000 gallons/year/person.

The Town of Hull is presently exploring the feasibility of installing a high capacity well in the area of the Izaak Walton League land north of the Stevens Point Municipal Airport and the Municipal Well Field. This would be within the recharge area of the Stevens Point Municipal Well Field and most likely would change the shape of the recharge area and extend the recharge area outside its present boundaries.

III. Methods

In an effort to determine the regional groundwater flow characteristics, four nested well systems and several single depth monitoring wells were installed. Nested wells consists of three piezometers located a few feet apart. The piezometers were installed at depths of approximately 60, 40 and 20 feet below ground surface. Locations of the nested well systems were selected to examine the differences in piezometric potential and chemistry of the groundwater to the west of the Plover River, to that of the Plover River, and the groundwater east of the river.

Comparing the groundwater elevation within each piezometer of the nested well system and between the different nested well systems, information on the groundwater flow characteristics approaching the city supply wells was obtained.

In addition to the nested systems, five more single depth wells were installed at various points in the surrounding area. Figure 2 gives the location of the nested well systems, single depth monitoring wells and existing airport observation wells. Table 1 gives the reference elevation of the top of the wells and the elevation of the well intake screens.

Monitoring Well #1 was placed between the point of maximum drawdown induced by pumpage of the city supply wells and the Plover River (approximately 900 feet from city supply well #6, and 650 feet from the river) to investigate the river's contribution in recharging the well field. A water depth recorder was placed on the monitoring well which gave a continuous recording of the groundwater elevation within the monitoring well. A staff gauge was installed in the Plover River immediately adjacent to Monitoring Well #1 so that the river's stage could be measured. The river's stage was recorded on a weekly basis and values were interpolated from these data points.

Table 1.

Elevations of the Top of the Protective Casings, Well Screen in Mean Sea Level for Each Monitoring, and Observation Well.

Monitoring Well	Top	Screen
A - Nest		
A - 60	1080.6	1019.9
A - 40	1080.8	1039.7
A - 20	1080.5	1059.4
B - Nest		
B - 60	1082.3	1014.0
B - 40	1082.7	1041.7
B - 20	1082.5	1061.7
C - Nest		
C - 60	1081.8	1021.7
C - 40	1081.6	1041.1
C - 20	1082.2	1060.9
D - Nest		
D - 60	1082.1	1021.3
D - 40	1081.7	1041.0
D - 20	1081.5	1060.7
Monitoring Well #1	1075.9	1069.9
Monitoring Well #2	1105.3	1043.7
Monitoring Well #3	1105.2	1064.4
Monitoring Well #4	1110.7	1069.7
Monitoring Well #5	1101.5	1063.4
Observation Well #1	1104.4	1083.9
Observation Well #2	1101.4	1084.4
Observation Well #3	1101.1	1078.1
Observation Well #4	1100.3	1074.3
Observation Well #5	1104.2	1068.2

To investigate the river's contribution to the aquifer within the cone of depression, two shallow piezometers were installed within the river bed. A piezometer was placed on each side of the river as shown in Figure 3. The piezometric potential measurements were taken on several occasions and related to the river's water surface.

Well Construction

The majority of the wells were drilled using an auger type drilling rig, owned and operated by the Wisconsin Geologic and Natural History Survey. The wells consist of 1 1/4 in. Schedule 40 PVC pipe with 1 foot Timco well screens points, having slot openings of .008 of an inch. The wells used solvent welded slip joints. The PVC pipe that extended above the ground surface was covered with a 4" diameter protective steel housing. The augured hole was sealed with powdered bentonite around the outside of the well and the augured hole to prevent surface water seepage down the bore hole along the well piping.

Water table observations were made with the use of a popping device which would signal when the end of a tape measure would contact the water table. The water table at the city supply wells was measured by sliding a tape measure along the well casing and recording the wetted portion of the tape measure. This method provided consistent results when repeated.

Chemistry Analysis

All of the city water supply wells, nested wells, monitoring wells, airport observation wells and the Plover River were sampled

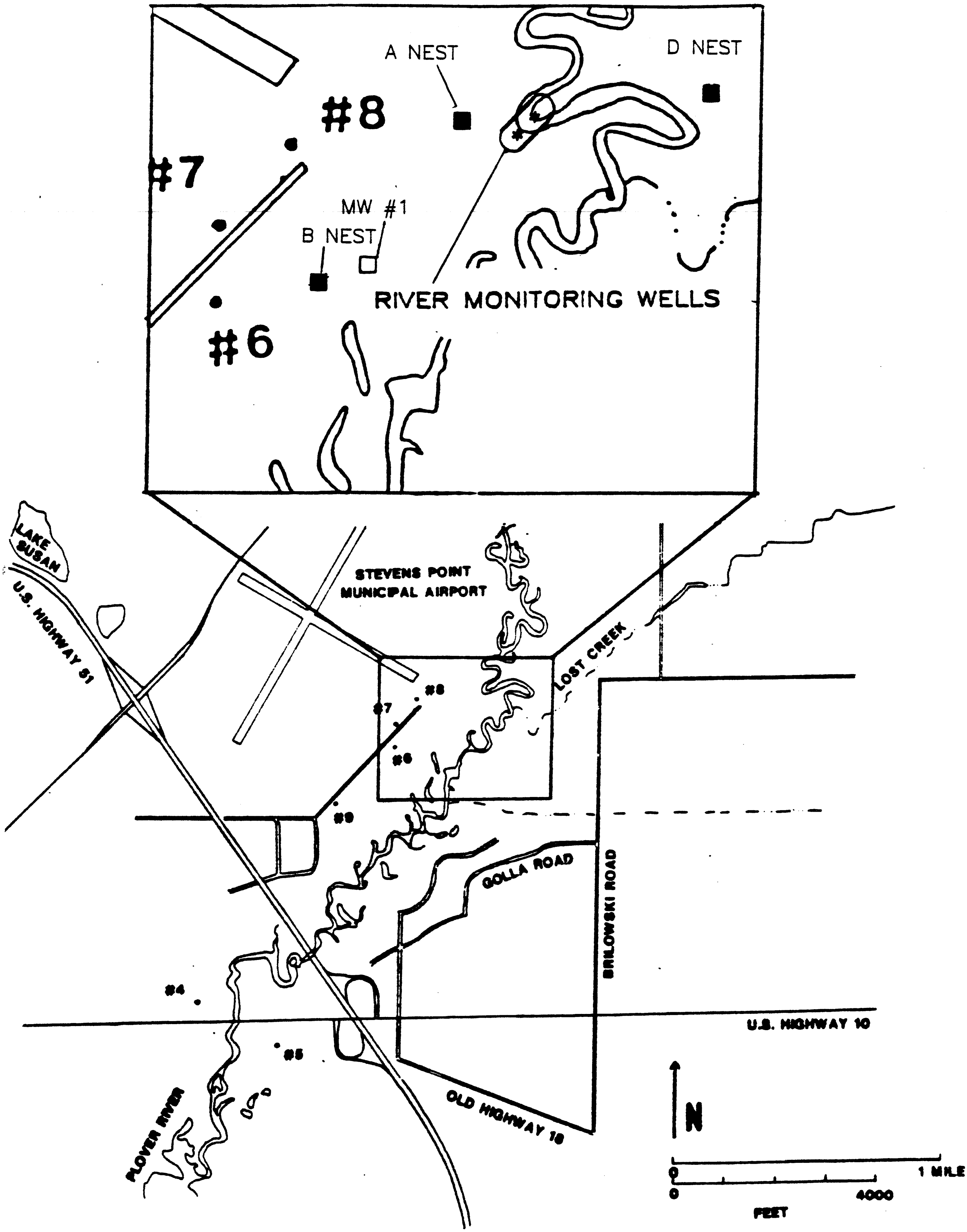


Figure 3 . Location of River Monitoring Wells.

several times and analyzed for the following constituents: K^+, Mg^{++}, Mn^{++}, Fe^{++}, Ca^{++}, total hardness, alkalinity, conductivity, pH, Total Kjeldahl Nitrogen, COD, Reactive P, Total P, Tritium, NH_4^+, NO_2^- & NO_3^-, Cl^- and $SO_4^=$. The chemical analysis was an attempt to evaluate the overall water quality of the Plover River Aquifer in the well field region and to use specific chemical constituents as natural tracers of groundwater flow.

All lab analyses of the water chemistry were performed by the Environmental Task Force of the College of Natural Resources, University of Wisconsin - Stevens Point. Analytical methods were based on "Standard Methods for the Examination of Water and Wastewater 15Ed".

Methodology for Tritium analysis was developed through communications with Dr. Ed Gasque, Biology Department, and Dr. Donald Showalter of the Chemistry Department, both at the University of Wisconsin - Stevens Point.

The radio-active tritium was measured by the use of liquid scintillation counting. The following outlines the procedure used:

1. Water samples would be mixed with a scintillation solution at a ratio of one ml of sample to 19 ml scintillation solution. This ratio was found to produce the most efficient counts.
2. Samples were thoroughly mixed.
3. The sample vials were placed into the Packard Model 3330 scintillation machine. The window was set at 50 - 1000 and the gain was at 50%.
4. Total counts were recorded over 100 minutes.
5. The actual radio-activity was determined by dividing the

recorded counts by the counting efficiency. The counting efficiency was determined with the use of a quenching (efficiency) curve developed from standards with a known radioactivity.

Sampling

Monitoring wells with the water surface depth at less than 18 feet were sampled with a gasoline powered pump. The sample was taken immediately following the removal of a volume of water equal to three well volumes. Those wells with the water level at a depth of 18 feet or greater were sampled with a 1" PVC bailer. Again a minimum of three well volumes were removed prior to sampling and the bailer was thoroughly rinsed between wells.

Conductivity and pH were measured in the field immediately after the samples were taken. Conductivity was adjusted to 25^{o}C. A separate sample was taken for the analysis of dissolved metals in a container acidified with HNO_3^- to keep the dissolved metals in solution.

IV. Aquifer Evaluation

Geology

The Stevens Point municipal wells are located in outwash sand and gravel deposits. The sands and gravels of this deposit are very well sorted and contain only small amounts of silt and clay. (Hickock, 1981) The well logs from the Wisconsin Geological and Natural History Survey indicate that the aquifer is composed of a homogeneous layer of sand overlying mixed sand and gravels. Figure 4 gives the boring log for the City Supply Well #7.

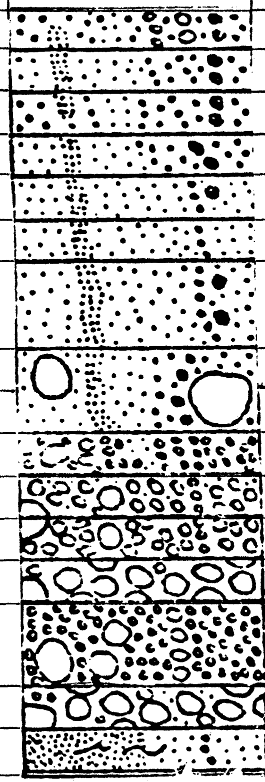
Depths	Graphic Section	Rock Type	Color	Mode	Range
0-5		Sand	Or brown	C	fn/VC
5-10		"	Gry	M/C	"
10-15		"	"	C	"
15-20		"	"	M/C	"
20-25		"	"	M	"
25-30		"	"	"	fn/C
30-35		"	"	"	fn/VC
35-40		"	"	"	"
40-45		"	Mixed	M/C	"
45-50		"	"	"	"
50-55		Gravel	"	Gran	Gran/M
55-60		"	"	S pab	Gran/L peb
60-65		"	"	"	"
65-70		"	"	"	"
70-75		"	"	M peb	Gran/L peb
75-80		"	"	"	"
80-85		"	"	M peb	"
85-90		Sand	Gry or Pnk	Fn/M	Vfn/C

Figure 4. Boring Log for City Supply Well #7.

Borings to the west of the Plover River encountered uniform sand to a depth of 55 to 60 feet. Gravel was then encountered at a depth of 60 feet. Boring associated with the deep piezometers to the east of the river showed no evidence of the deeper layer of gravel to a depth of 60 feet. The city supply wells are screened within these mixed sand and gravel deposits. City Supply Wells #6 - #8 are cased to a depth of 54 feet with the screen extending to depths of 90 feet for well #6, 85 feet for well #8 and 80 feet for well #7. City Supply Well #9 is cased to a depth of 50 feet and screened to a depth of 80 feet.

The bedrock consists of Precambrian Igneous and Metamorphic rock. In 1980 E.A. Hickok and Associates used seismic soundings to determine the bedrock topography of the well field area. The results of that investigation indicated that the depth to bedrock west of the city wells (approximately 1,300 feet) is shallow (20 to 30 feet below land surface), and drops off to the east, under the city supply wells and the Plover River with a depth of about 100 feet at well #6. Figure 5 is based on the results of the seismic survey and illustrates a cross-section through the well field showing the bedrock topography and the groundwater table under normal conditions.

The solid bedrock is capped by a weathered layer ranging in thickness from one to seven feet, typically consisting of clay and friable rock. (Hickok 1981) Borings also indicate that the aquifer becomes shallower in the areas upstream within the Plover River Valley. The boring of MW #5 which is located about 5,000 feet upstream of the well field intersected the weathered bedrock layer

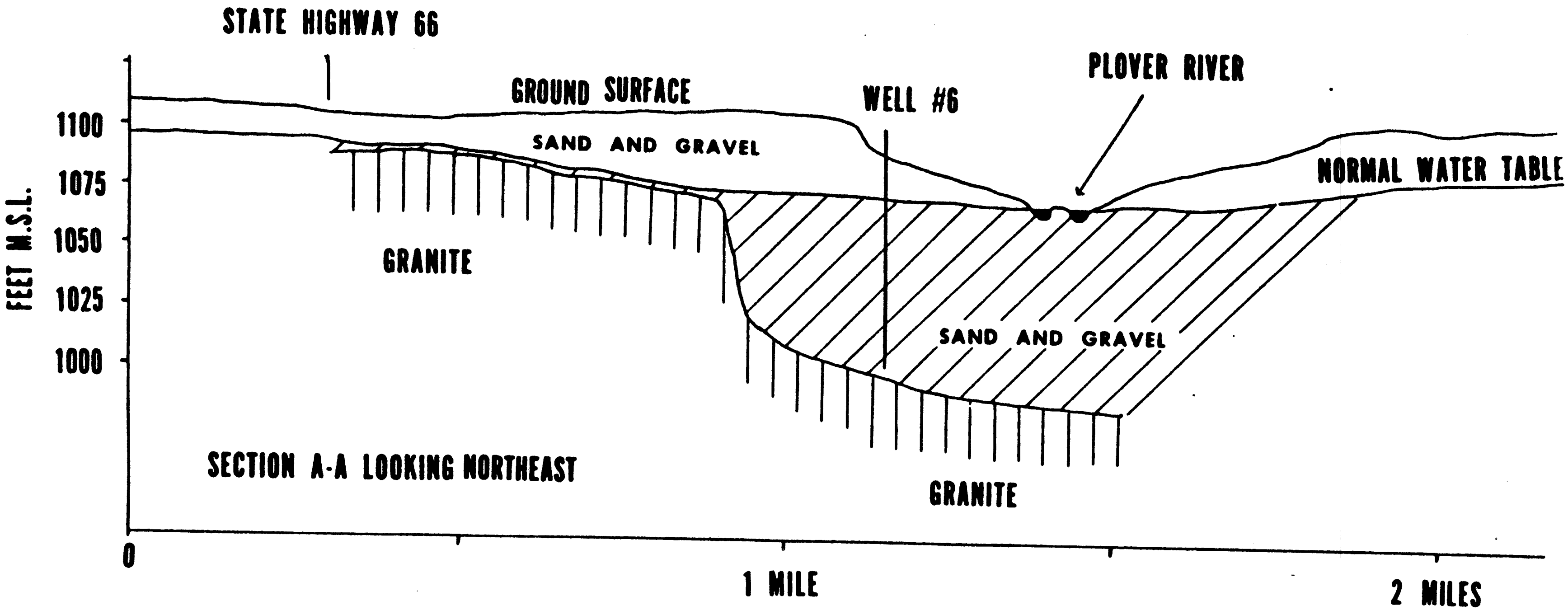


Figure 5. Cross Section of Well Field Illustrating Bedrock Surface.

at an elevation of 1063 (MSL) or 38 feet below the land's surface. Bedrock outcroppings are observed near the outfall of Jordan Pond.

Although groundwater accumulates in the fractures within the bedrock and in the shallow weathered zones, it is considered to be part of the the same water body as the overlying drift. The bedrock could then contribute to the recharge of the city supply wells but the yield from the bedrock is generally minimal. (Holt 1965)

<u>Groundwater Table</u>

Observations of the groundwater elevations, and the pumpage relative to the average daily pumpage are given in Table 2. Observation at the nested well systems generally illustrated horizontal gradients (to a depth of 60 feet) with only mild and sporadic observations of vertical flow. The pumpage rate (expressed as relative pumpage to the annual average daily pumpage) demonstrated no direct association with the occasional observation of vertical gradients. Downward gradients were consistently observed between the intermediate and deep piezometers (40 - 60 feet deep) at Nest C, with an average downward component of -.03 ft/ft. Figures 6 and 7 present the well field in cross-section and illustrate the flow components as determined by averaging observed vertical gradients from the nested well systems. The mild upward flow component near a discharge source (Nest D is within 30 feet while Nest A and C are within 600 feet of the Plover River Channel) is a strong indication that the pumpage of the city supply wells is controlling the groundwater flow and is acting as the predominate discharge source within the area monitored with the nested well systems.

Table 2.

Observations of Groundwater Elevations in Feet (MSL).

DATE	A-60	A-40	A-20	B-60	B-40	B-20	C-60	C-40	C-20	D-60	D-40	D-20	DAILY PUMPAGE/ AVE. DAILY PUMPAGE
07/09/84													
08/07/84	1072.0	1072.0	1072.0	1069.7	1069.7	1069.7							1.1
08/09/84	1072.1	1072.1	1072.0	1069.8	1069.7	1069.7							1.1
08/22/84	1071.9	1071.9	1071.9	1069.6	1069.5	1069.6	1075.6	1076.2	1076.2	1073.7	1073.7	1073.7	1.0
08/28/84	1072.2	1072.3	1072.2	1069.6	1069.5	1069.5	1075.6	1076.1	1076.1	1073.7	1073.6	1073.6	1.3
09/11/84	1072.1	1072.2	1072.1	1069.2	1069.2	1069.2							1.2
09/17/84	1072.7	1072.8	1072.8	1070.0	1069.9	1069.9							1.0
09/24/84	1072.3	1072.3	1072.3	1069.7	1069.6	1069.5							1.2
10/04/84	1072.5	1072.5	1072.5	1070.0	1069.8	1069.9							1.3
10/10/84				1070.8	1070.7	1070.6							1.0
10/17/84	1073.3	1073.3	1073.3	1070.9	1070.8	1070.8							1.0
10/30/84	1073.5	1073.5	1073.4	1071.4	1071.4	1071.4							1.0
11/07/84	1073.9	1073.9	1074.0	1072.1	1071.9	1072.1							0.9
11/14/84	1073.6	1073.6	1073.5	1071.6	1071.5	1071.6	1076.8	1077.5	1077.3	1075.1	1075.0	1074.9	0.9
11/29/84													1.1
02/28/85	1073.6	1073.7	1073.6							1075.5	1075.6	1075.6	
03/14/85	1073.0	1072.7	1073.0	1070.8	1070.7	1070.7							
AVERAGE	1072.8	1072.8	1072.8	1070.4	1070.3	1070.3	1076.0	1076.6	1076.5	1074.5	1074.5	1074.5	1.1
MINIMUM	1071.9	1071.9	1071.9	1069.2	1069.2	1069.2	1075.6	1076.1	1076.1	1073.7	1073.6	1073.6	0.9
MAXIMUM	1073.9	1073.9	1074.0	1072.1	1071.9	1072.1	1076.8	1077.5	1077.3	1075.5	1075.6	1075.6	1.3
STAN DEV	0.676	0.670	0.680	0.856	0.840	0.873	0.566	0.638	0.544	0.812	0.853	0.838	0.129

Table 2 (cont.)

Observations of Groundwater Elevations in Feet (MSL).

DATE	MW #2	MW #3	MW #4	MW #5	OB #1	OB #2	OB #3	OB #4	OB #5	CSW #6	CSW #7	CSW #8	DAILY PUMPAGE/ AVE. DAILY PUMPAGE
07/09/84					1092.2	1092.2	1086.0	1082.2	1070.4	1062.5	1058.8	1060.7	
08/07/84	1070.5												1.1
08/09/84	1070.7												1.1
08/22/84	1070.5												1.0
08/28/84	1070.5									1058.1	1058.8	1060.7	1.3
09/11/84													1.2
09/17/84													1.0
09/24/84	1070.6												1.2
10/04/84													1.3
10/10/84													1.0
10/17/84	1070.8												1.0
10/30/84	1071.4												1.0
11/07/84	1071.8												0.9
11/14/84	1072.6	1077.1	1090.9	1083.5	1088.4	1088.9	1085.6	1082.3	1072.9				0.9
11/29/84		1077.0	1091.7	1084.0									1.1
02/28/85													
03/14/85													
AVERAGE	1071.0	1077.1	1091.3	1083.8	1090.3	1090.6	1085.8	1082.3	1071.7	1060.3	1058.8	1060.7	1.1
MINIMUM	1070.5	1077.0	1090.9	1083.5	1088.4	1088.9	1085.6	1082.2	1070.4	1058.1	1058.8	1060.7	0.9
MAXIMUM	1072.6	1077.1	1091.7	1084.0	1092.2	1092.2	1086.0	1082.3	1072.9	1062.5	1058.8	1060.7	1.3
STAN DEV	0.698	0.050	0.400	0.250	1.900	1.650	0.200	0.050	1.250	2.200	0.000	0.000	0.129

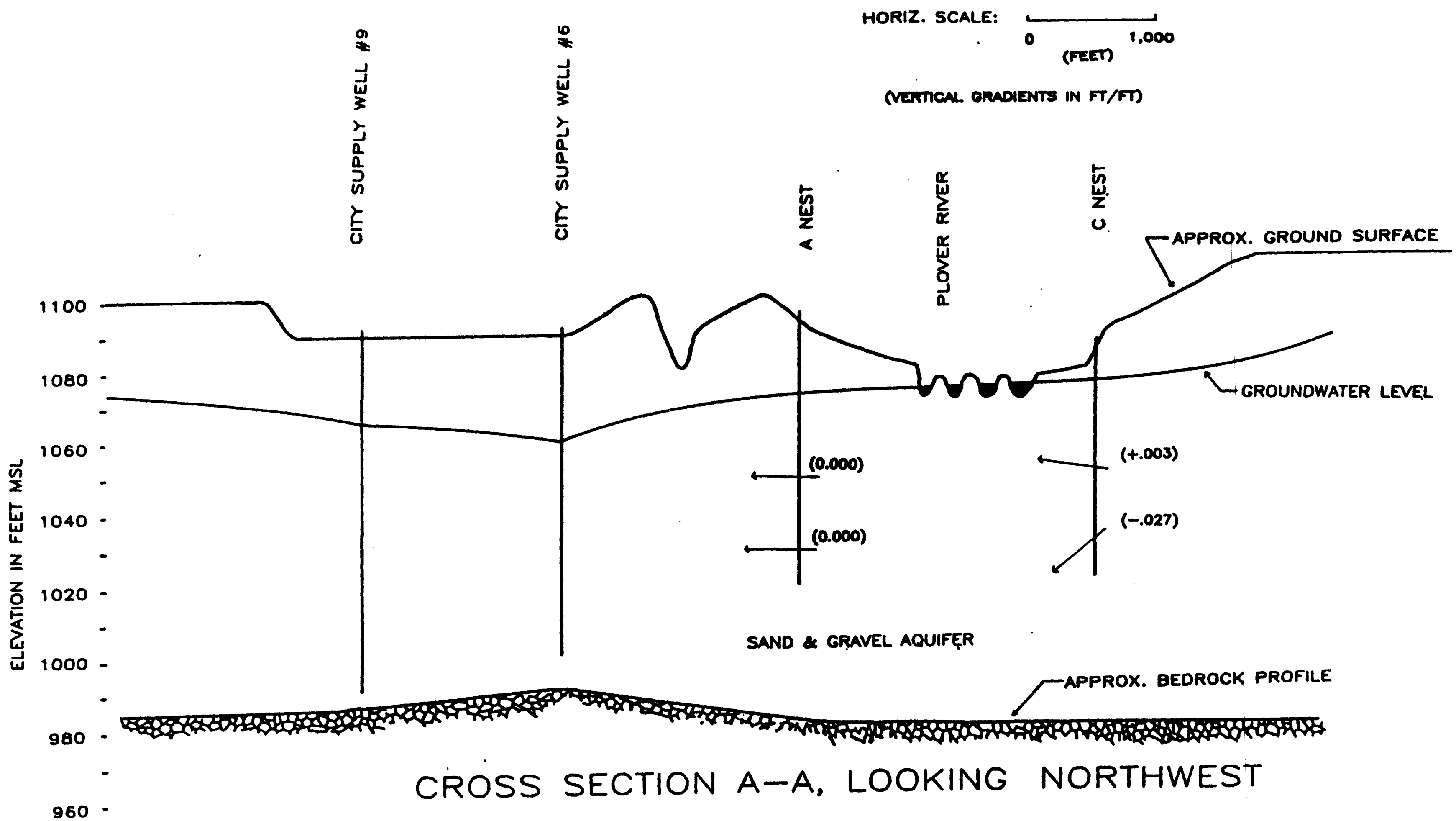


Figure 6. Cross-Section A-A of the Well Field Illustrating Vertical Gradients.

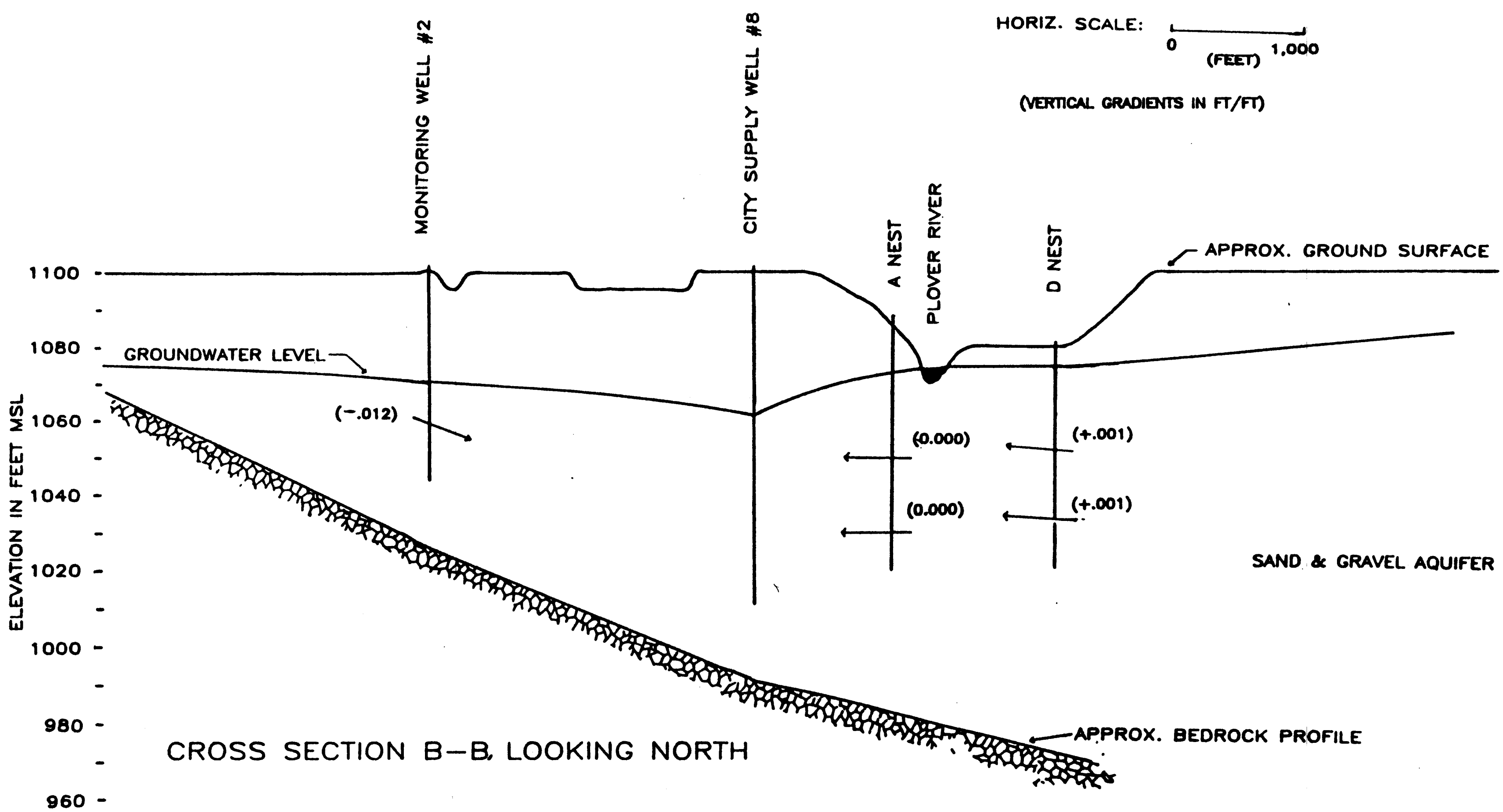
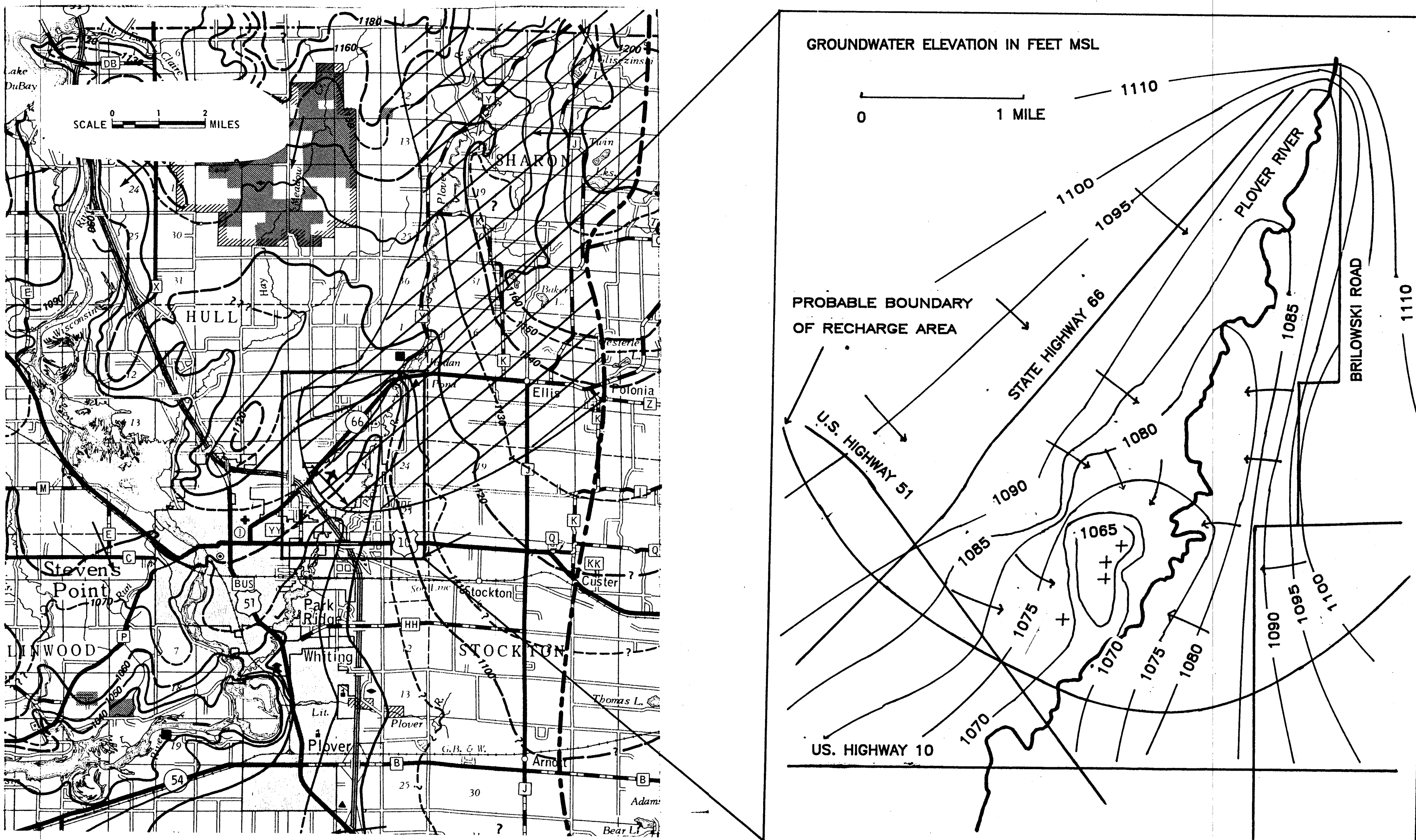


Figure 7. Cross-Section B-B of the Well Field Illustrating Vertical Gradients

Figure 8 gives a groundwater table map of the well field area while under the influence of pumpage from the Stevens Point Supply Wells. This map is shown with a map developed from regional groundwater elevation by the Wisconsin Geologic and Natural History Survey (8a). The well field isolation (Figure 8b) was developed by the use of a computer interpolation from the average groundwater elevation observations from the city supply wells, airport observation wells, the nested wells and the monitoring wells. The groundwater elevations outside of the area in which direct observations of the groundwater table were hand-drawn by interpolations from water table observation of monitoring wells and from the regional groundwater table map given in Figure 8a. The recharge area boundry and flow lines presented in Figure 8b are drawn in to illustrate the major flow pattern and approximate southern extent of the recharge area. The shaded area of Figure 8a shows the extent of the total area in Portage County which potential recharges the well field and Plover River. The recharge area for the Plover River extends further into Marathon County.

The groundwater table will fluctuate depending on climatic factors as well as the pumpage rate. The elevations given in Figure 8b are averaged from observations recorded from late summer of 1984 to early spring of 1985. The aquifer during the late summer is generally under the maximum stress (resulting from the high water consumption, high evapotranspiration and low precipitation) which extended the cone of depression and the recharge area. The rainfall in the summer of 1984 was, however, above normal, resulting in below normal pumpage and less required recharge area. The influence on the groundwater table illustrated in Figure 8b would extend further out from the city



(From Lippelt, Wisconsin Geological and Natural History Survey; September, 1981)

Figure 8. Regional Groundwater Elevation Map and Well Field Recharge Area.

supply wells during a dry year.

Pumpage Affects on Surrounding Groundwater Elevations

Figures 9 - 11 give the results from the continuous water level observations made from MW #1, the river stage; precipitation and pumpage records of the city supply wells. The groundwater surface elevation of Monitoring Well #1 was most dependent on the total pumpage (correlation coefficient of -.555 and at a significant level of .0001) and the river stage (correlation coefficient of .681 at a significant level of .0001).

Figure 12 illustrates the connection between the pumpage rate and the groundwater surface elevation in MW #1. By taking the difference between the river's stage and the water table elevation in MW #1, the effects of the river stage on the water level in MW #1 are minimized. As Figure 12 illustrates, there is a general correlation between pumpage and the difference in the water elevation of Monitoring Well #1 and the river's stage (correlation coefficient of .407 significant to the .0001 confidence level).

As Figure 12 illustrates, the groundwater surface of MW #1 stayed consistently below the river stage. This indicates that the induced cone of depression consistently extends to the river, and the river was consistently a source of recharge. This was the case until the 23rd of January when the river reached the winter base flow and the well pumpage was at an annual low. Another factor is that City Supply Well #6 was not operating from October 1984 through February 1985. Well #6 would have the strongest influence of the city supply wells on the groundwater elevation of MW #1.

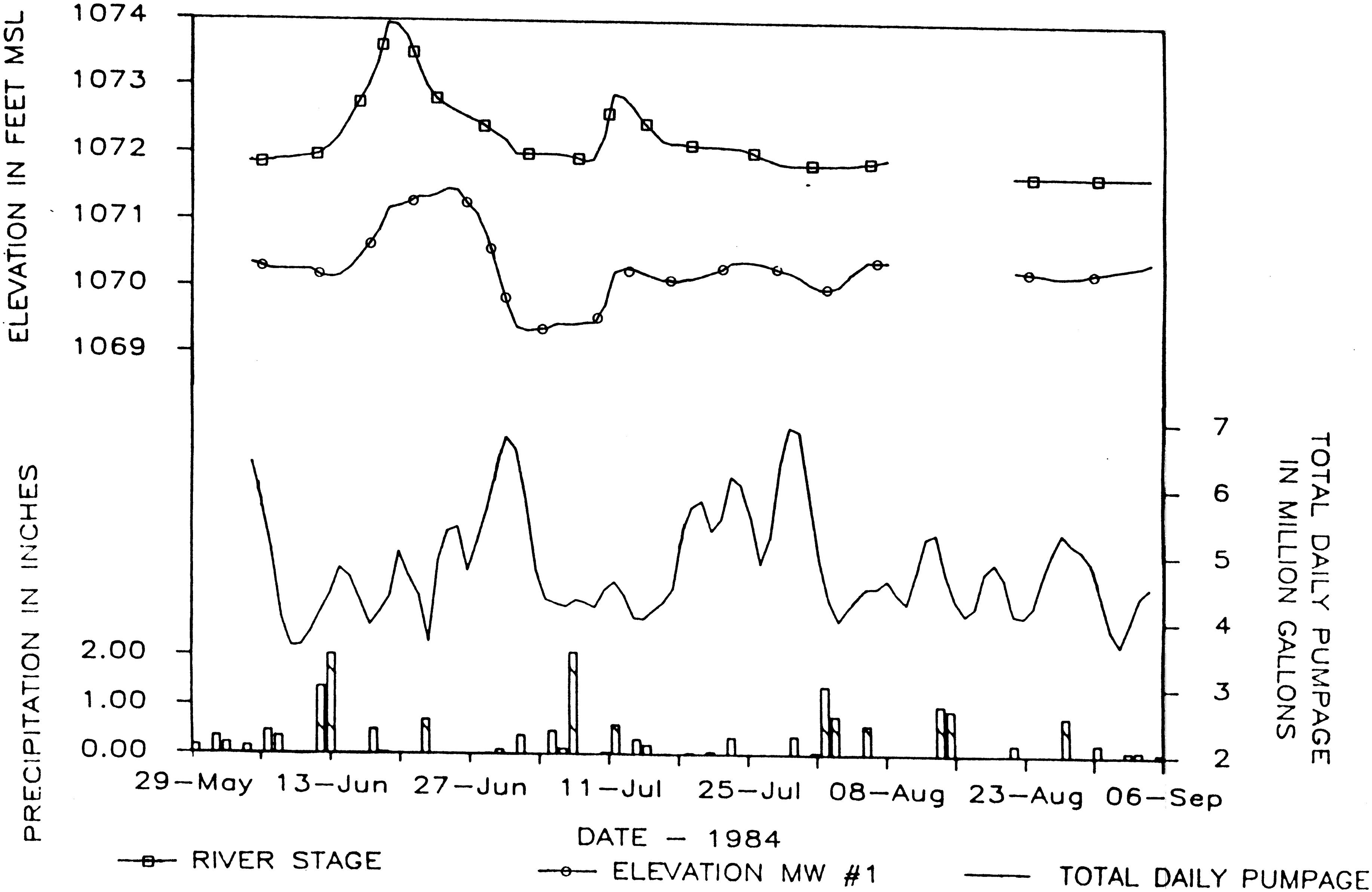


Figure 9 . River Stage, Elevation of Monitoring Well #1, Precipitation and Pumpage, May 29, - September 6,1984.

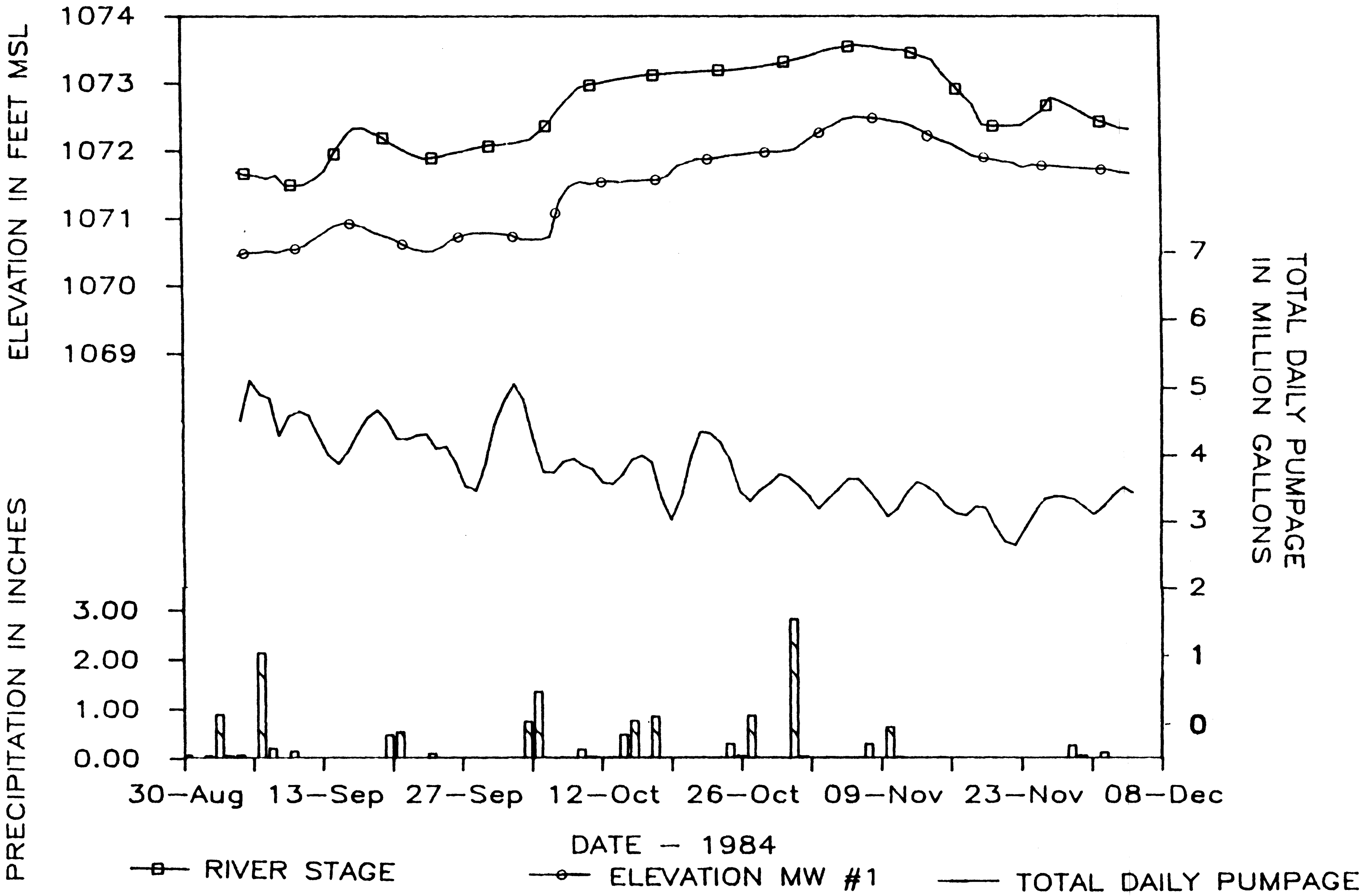


Figure 10 . River Stage, Elevation of Monitoring Well #1, Precipitation and Pumpage, August 30, - December 8, 1984.

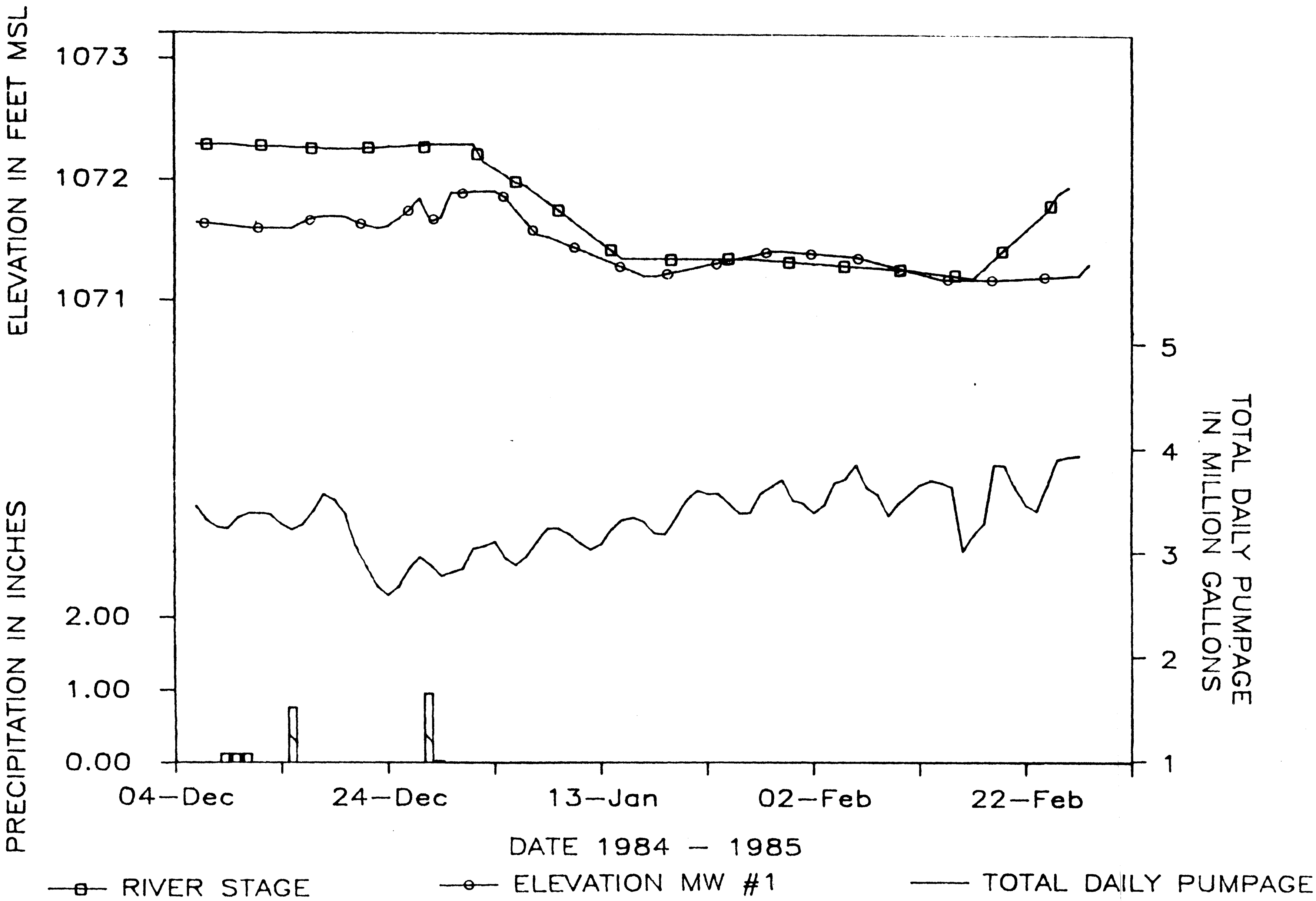


Figure 12. **River Stage, Elevation of Monitoring Well #1, Precipitation and Pumpage, December** 4,1984 **- Feb.** 22, 1985.

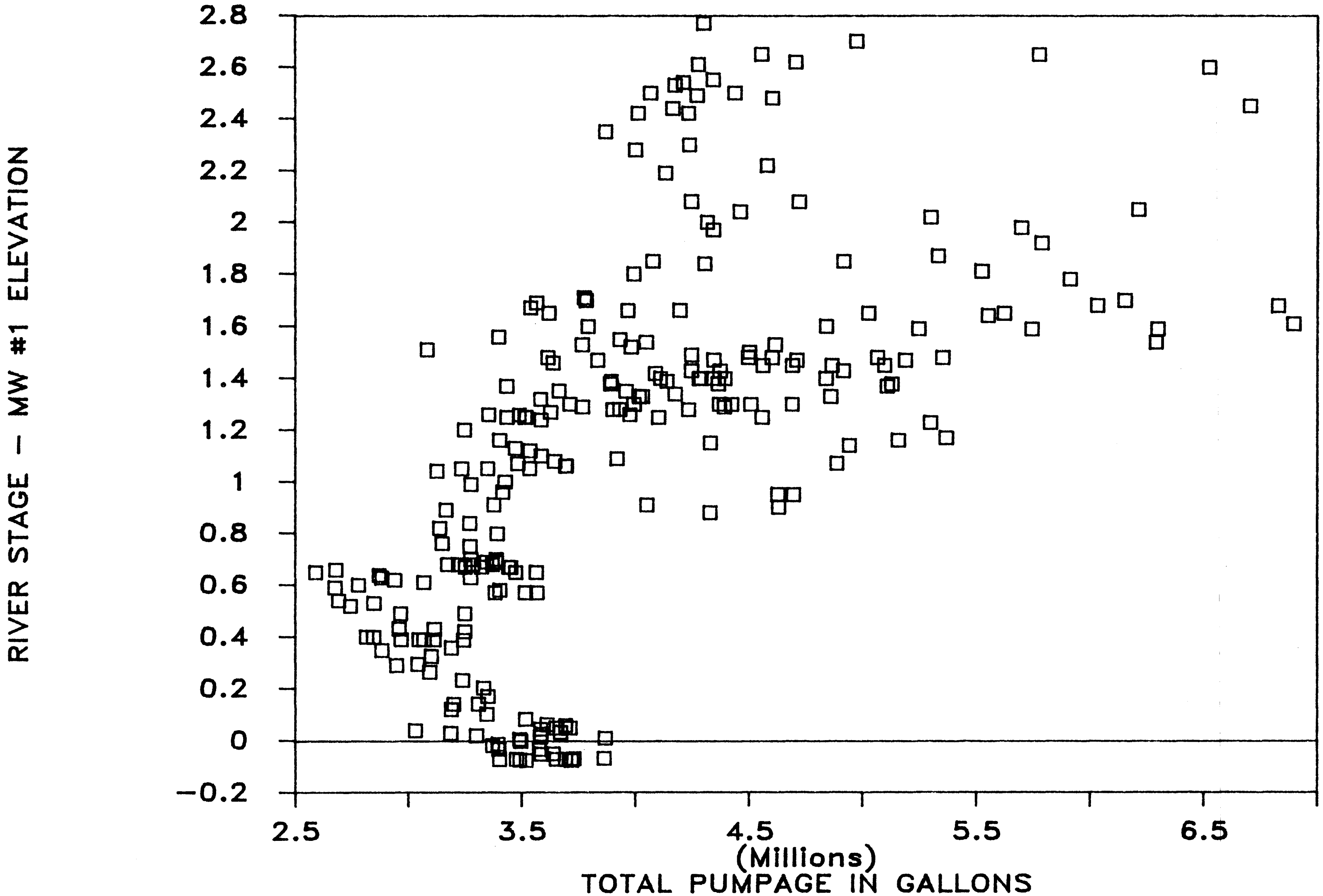


Figure 12. River Stage Minus Water Table of MW #1 vs. Total Daily Pumpage.

The piezometers placed within the river provided further evidence of the river contribution to the aquifer within the cone of depression. Table 3 gives the observed water table elevations within the river piezometers relative to the river's stage.

Table 3

Difference Between the Groundwater Elevations in the River Piezometers and The River Water Surface in Feet.

Date	Piezometer West	Piezometer East
09/24/84	0.6	
10/04/84	1.0	
11/14/84	0.6	
02/29/85	0.9	0.7
03/14/85		0.5

The reduced water elevation of the east piezometer (relative to the river stage) confirms that the cone of depression extends to the east of the river in the location of the piezometers. The observed water table elevations of February 29, 1985 also reveals that the river's recharge raised the piezometric potential about 0.2 feet across the width of the river (approximately 30 feet).

The Recharge Area

Observations from the nested well suggest consistent horizontal flow of the groundwater approaching the city supply wells. The absence of downward flow would suggest that the wells draw over the entire depth of the saturated aquifer. The nested systems to the east of the river (C and D) indicated that pumpage of the city supply wells was affecting the groundwater flow east of the Plover River.

Water table observations in wells between the city supply wells and the Plover River confirm that the cone of depression consistently extends to the river. The piezometers placed in the river also confirm that the river is contributing to the aquifer within the cone of depression. The amount contributed by the river could be significant. Application of Dacey's Law to a one-foot cross-section of the river at the location of the river piezometers results in a contribution to the aquifer of 47,000 gpd using the following input values:

* Transmissivity = 600,000 gallons per day/ft. (Hickok 1965)
* An aquifer depth of 90 feet, from City Supply Wells boring logs.
* Average head difference across the river channel = 0.7 ft.
* Applied over a length of 2.5 ft. The distance to the midpoint of the screen and the river bed.
* An average stream width of 25 feet.

Application of Dacey's Law on the river bed also assumes a good hydraulic connection between the river bed and the aquifer. This is felt to be an appropriate assumption when considering the scouring nature of the stream bed and the observed reduction of piezometric potential between the river piezometers (ie. drawdown was less to the east of the river than to the west due to recharge provided by the river). Observations at D-Nest relative to the river stage indicated that the cone of depression did not extend east of the river at that location, suggesting that the river contributed to the aquifer sufficiently to relieve the cone of depression.

The City of Stevens Point's total water yield for 1983 was 1.6 billion gallons. The average annual recharge to the aquifer is estimated to be 10 inches. (Holt 1965) This would result in a required area of recharge of about 9.0 square miles. A map showing the location of the required 9.0 square mile area closest to the well field that would be needed to recharge the city well field, is presented in Figure 13. This does not include recharge water from the Plover River, but does define the theoretical area needed for recharging the wells. Recharge to the river could originate further away as the river originates in Marathon County.

The influence that pumpage of the city supply wells has on the groundwater flow at depth both east and west of the river suggests that the city supply wells are partially recharged by the deeper aquifer. The water in the deeper aquifer most likely has originated from areas a significate distances from the well field, suggesting that the deep aquifer recharge to the city supply wells could originate from areas outside the immediate well field area but yet still within the theoretical recharge area presented in Figure 13.

Increasing pumpage from the city stand-by supply wells #4 and #5 would extend the required recharge area to the south of the area shown in Figures 8 and 13, to incorperate additional area and present concern for potential impacts to the water supply associated with these areas.

The current land practices within the recharge area consist largely of residential development, forested areas, and agriculture. Residential development is predominately to the north and east of the well field with increasing residential development to the east, east of the Plover River. Agricultural land-use is predominately to the east of city well field and the Plover River. Figure 14 gives the existing land uses for the immediate recharge area. Agriculture

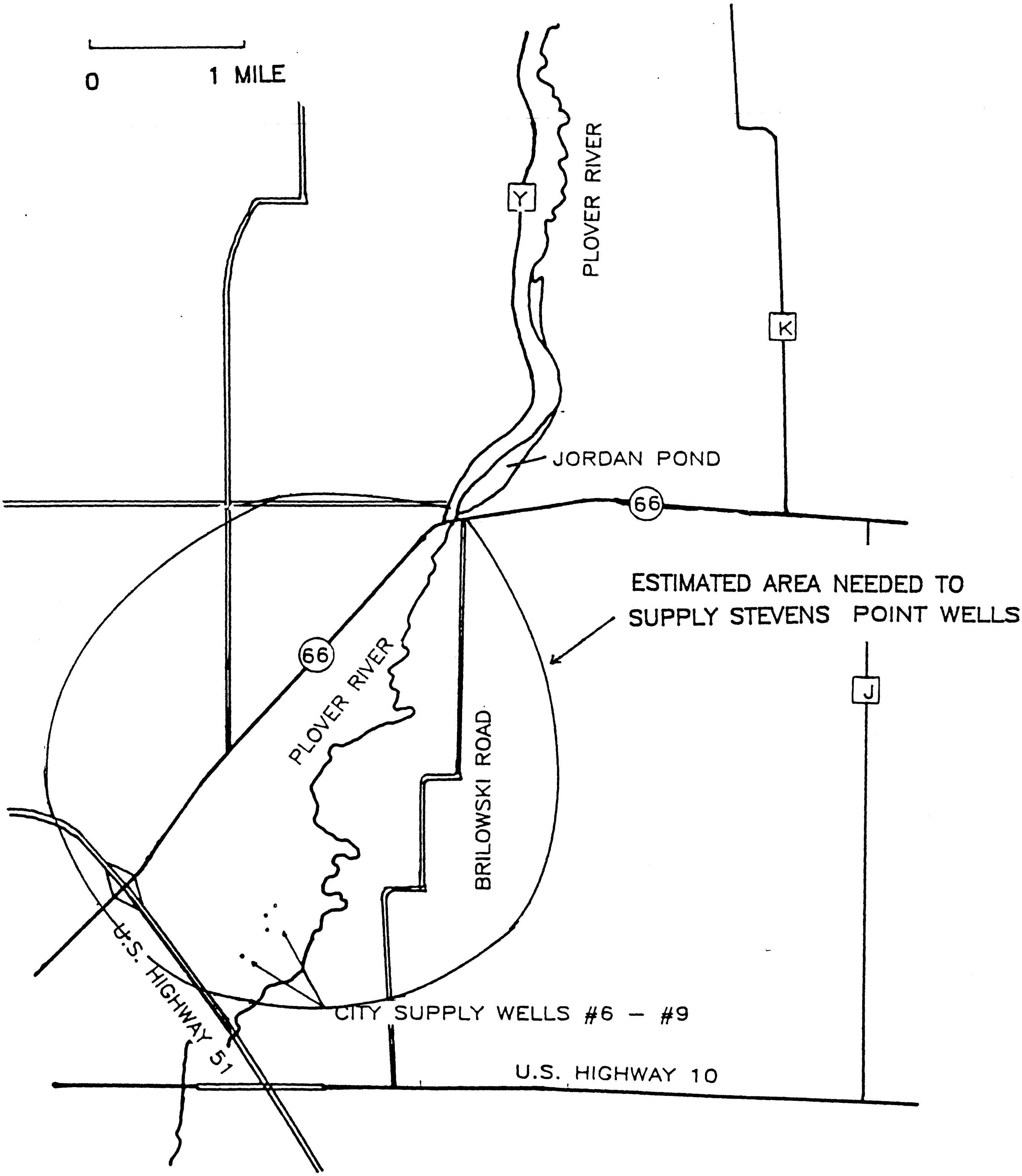


Figure 13. Estimated Area Needed to Recharge Stevens Point Water Supply Wells.

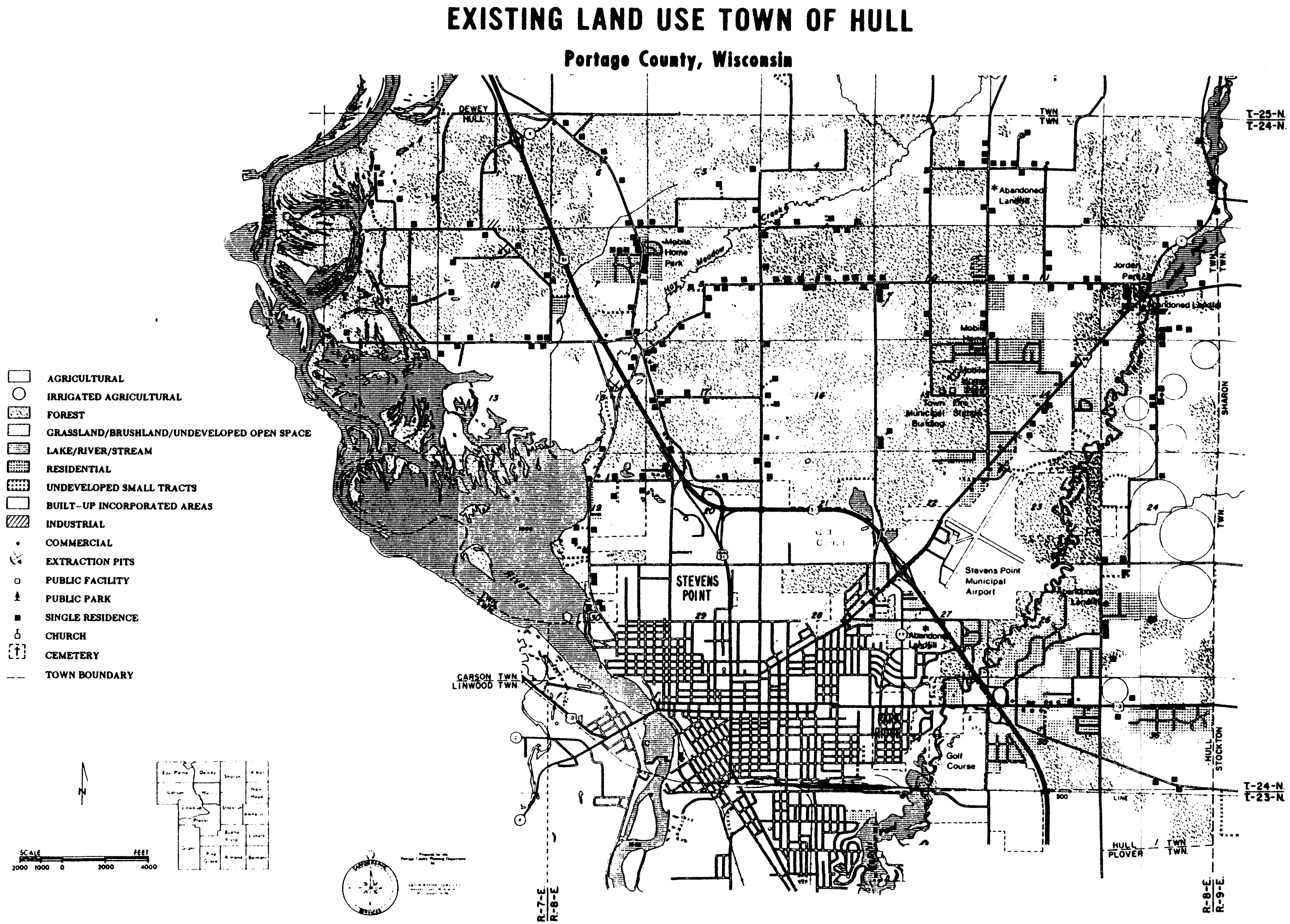


Figure 14. Existing Land Use of the Well Field Area.

continues as the predominate land -use east of the area shown in Figure 14.

V. Water Chemistry

The groundwater and surface water chemistry results can be found in the Appendix. The average values for each chemical constituent at each monitoring well, observation well, city supply well and the Plover River are also provided in Table 4.

All chemical data was used in developing the concentration contour maps presented in this section. Caution must be used in interpreting the maps in areas outside the sampling points, specifically areas up-flow of the sampling points, (i.e. east of Brilowski road, north and west of Highway 66 and south of Highway 10). The uncertainty of the interpolated data of these areas is illustrated by the use of the broken concentration line. Caution must also be used, as one well with an unusually high concentration of a chemical can result in affecting contour lines some distance from that point. This may influence the groundwater concentration plot to a greater extent than actually occurs. The high value may be due to a very local source and not affect groundwater in other directions from the source.

Each chemical constituent's concentrations distribution was analyzed at two aquifer depths, both within the unconsolidated outwash aquifer. The shallow wells were considered to be those within 45 feet of the ground surface, while deeper aquifer wells were those wells deeper than 45 feet. Monitoring wells #1 and #3-#5 were considered shallow wells. Monitoring Wells #3-#5 are screened

Table 4.

Average Chemistry Results for All Monitoring, Observation and City Supply Wells.

	K	Mg	Na	Fe	Mn	Alkalinity	Ca	Total Hardness	Conductivity	Cl	Sulfate	Nitrates	TKN	Ammonia	Reactive Phosphorus	Total Phosphorus	COD	Well Depth
A-60	1.5	18	2.8	.45	.02	165	74	177	336	7.0	8.5	0.2	.12	.08	.005	.115	12.6	60
A-40	1.5	18	1.9	.58	.02	154	71	173	324	8.9	10.8	0.2	.07	.02	.015	.072	12.6	40
A-20	1.4	19	2.7	.42	.02	160	38	178	337	5.5	11.0	0.2	.05	.02	.016	.020	4.3	20
B-60	1.4	22	2.0	.05	.02	176	77	209	384	6.8	18.0	0.2	.07	.02	.010	.116	6.9	66
B-40	1.0	19	2.3	.03	1.03	158	82	176	317	4.9	8.5	0.3	.26	.03	.020	.045	17.0	40
B-20	0.7	14	1.7	.03	.01	135	53	149	260	1.4	16.0	0.2	.06	.07	.003	.007	3.4	20
C-60	1.2	27	2.7	.29	.01	167	96	235	447	19.6	18.2	6.6	.29	.04	.005	.127	8.0	59
C-40	1.2	24	2.1	.08	.01	147	83	205	396	15.4	14.0	6.0	.15	.03	.005	.041	7.6	40
C-20	0.6	4	1.3	.02	.01	41	22	53	112	2.3	9.0	0.7	.09	.02	.011	.017	3.8	21
D-60	1.1	26	2.5	.09	.01	161	103	229	442	18.5	16.0	7.0	.25	.03	.004	.100	4.7	60
D-40	0.8	21	2.3	.05	.20	129	75	192	362	13.4	15.0	6.8	.30	.03	.010	.030	9.6	40
D-20	0.5	2	0.9	.05	.01	17	13	32	75	1.6	12.3	1.4	.07	.04	.005	.010	2.1	20
MW-1	0.6	6	0.9	.52	.02	79	17	113	175	1.0	13.0	0.2	.30	.06	.005	.011	26.0	6
MW-2	0.9	6	4.6		.30	66	19	82	176	5.5	8.5	1.8	.05		.060	.024	12.3	62
MW-3	1.0	9	2.6	.15	.10	84	21	100	194	4.0	6.2	0.2	.28	.28	.004	.018	7.5	40
MW-4	2.5	16	10.8	.24	.05	130	32	148	328	34.0	4.5	0.2	.29	.31	.002	.011	112.0	40
MW-5	1.6	12	19.0	.12	.40	112	28	128	469	5.6	12.0	0.2	.20	26.	1.20	2.30	42.4	37
OB-1	3.5	1	5.6	.12	.10	8	8	21	79	9.0	6.3	1.0	.01	.06	.026	.035	2.0	20
OB-2				.00	.02	134	10	22	320	2.5	16.0	0.6		.04				17
OB-3	1.0	1	1.9	.10	.02	20	11	29	56	1.0	7.0	0.5	.04	.12	.195	.20	33.5	23
OB-4	2.5	2	4.2	.20	.02	25	13	38	95	7.5	9.0	2.6	.01	.14	.185	.21	11.6	25
OB-5	1.6	7	1.5	.02	.02	70	29	78	145	1.0	5.7	0.5	.01	.06	.090	.08	2.0	36
#6	1.0		3.2	.02	.17	171	120	198	365	10.0	18.2	1.0	.03	.05	.004	.010	8.4	54-90
#7	0.8	19	2.7	.02	.32	152	85	169	317	7.3	11.3	0.5	.03	.03	.004	.009	3.2	54-80
#8	0.8	18	2.9	.02	.07	140	73	167	298	9.4	11.7	1.8	.02	.06	.004	.012	2.1	54-85
#9	0.7	14	3.1	.05	.01	105	62	138	267	10.0	14.8	1.5	.01	.04	.020	.042	2.9	48-80
River	1.0	16	2.8	.2	<.01	146	80	168	306	7.0	8.3	1.1	.54	.07	.009	.029	20.9	
River MW	1.4	11	2.4	.12	<.01	110	27	128	250	4.3	6.0	1.0	.21		.006	.002	20.5	
Range	0.5-3.5	1.0-27	.09-19	0-.58	.01-1.0	8-170	8-120	21-235	56-469	1.0-34	4.5-18	0.2-7.0	.01-.54	.02-26.	.002-1.2	.007-2.3	2.0-112	
Average	1.2	13	2.9	.15	.11	107	52	133	265	8.2	11.5	1.6	.14	.07	.028	.054	10.7	
Standard Deviation	.68	8.1	2.5	.17	.21	57	34	67	118	7.4	4.1	2.2	.14	.07	.052	.058	10.3	

Range, Average, and Standard Deviation of all Observation, Private and Monitoring Well Samples

	K	Mg	Na	Fe	Mn	Alkalinity	Ca	Total Hardness	Conductivity	Cl	Sulfate	Nitrates	TKN	Ammonia	Reactive Phosphorus	Total Phosphorus	COD
Range	.1-9.	.03-34	1.4-73	.0-7.3	.02-1.1	8-220	0-195	1-256	56-682	1.0-48	4.5-50	0.2-15.2	.01-40	.02-26	.002-2.3	.002-4.6	.1-112
Average	1.6	14.8	7.6	.25	.07	112	52	133	283	9.7	12.3	2.5	.93	.61	.063	.113	9.5
Standard Deviation	1.9	8.9	18.1	.78	.18	54	43	66	116	8.2	6.2	3.0	4.7	3.4	.296	.55	14.6

at a depth of about 40 feet. Monitoring Well #2 was used as a deep aquifer well with the screen at a depth between 60-65 feet.

The separate analysis based on depth of the aquifer is not to insinuate that there is no interaction between deep aquifer water and shallow aquifer water. The shallow aquifer sampling wells tend to be concentrated along Highway 66 because of the shallow depth to groundwater and bedrock.

Correlation coefficients were calculated to determine the degree of association between chemical constituents within a sample. Statistical correlation provides an indication of which chemical constituents are typically found in the same sample. This then may provide an indication as to which constituents move similarly, have similar sources, solubility and attenuation characteristics, and in situations in which there are several elevated constituents, the probable source of the contaminates. Table 5 provides a correlation matrix and the statistical significance of each correlation coefficient.

Figure 15 gives the sampling locations used in the shallow aquifer and deep aquifer analysis. Each of these locations was used in the chemical concentration plot found in this section. In cases where more than one sampling occurred at one location, the concentrations were averaged.

Nitrates

The most serious inorganic contamination threat to the Stevens Point Supply Wells is believed to be nitrate contamination. Nitrates in concentrations commonly reported in groundwater are not limited by

Table 5.

Correlation Coefficients and Statistical Significance Matrix of All Sampled chemical Parameters.

	K	Mg	Fe	pH	Cond	Alk	T. Hard	Ca	COD
K	1.0000 (71) .0000	.3983 (43) .0082**	.0368 (66) .7691	-.1748 (52) .2152	.0421 (71) .7271	-.1091 (71) .3649	.1499 (71) .2122	-.2085 (52) .1380	.1872 (66) .1322
Mg	.3983 (43) .0082**	1.0000 (55) .0000	-.0673 (49) .6457	.0650 (49) .6570	.5219 (55) .0000**	.5602 (55) .0000**	.8967 (55) .0000**	.8707 (55) .0000**	-.0114 (49) .9382
Fe	.0368 (66) .7691	-.0673 (49) .6457	1.0000 (103) .0000	.1205 (77) .2964	-.0584 (96) .5720	-.0626 (96) .5445	-.0166 (103) .8676	-.0579 (83) .6030	.0941 (103) .3445
pH	-.1748 (52) .2152	.0650 (49) .6570	.1205 (77) .2964	1.0000 (87) .0000	.1175 (87) .2783	.2487 (87) .0202*	.0826 (87) .4468	-.0167 (87) .8781	-.0366 (77) .7522
Cond	.0421 (71) .7271	.5219 (55) .0000**	-.0584 (96) .5720	.1175 (87) .2783	1.0000 (112) .0000	.8900 (112) .0000**	.7772 (112) .0000**	.4111 (93) .0000**	.0724 (96) .4832
Alk	-.1091 (71) .3649	.5602 (55) .0000**	-.0626 (96) .5445	.2487 (87) .0202*	.8900 (112) .0000**	1.0000 (112) .0000	.7968 (112) .0000**	.5477 (93) .0000**	.1206 (96) .2419
T. Hard	.1499 (71) .2122	.8967 (55) .0000**	-.0166 (103) .8676	.0826 (87) .4468	.7772 (112) .0000**	.7968 (112) .0000**	1.0000 (119) .0000	.5587 (99) .0000**	.0716 (103) .4725
Ca	-.2085 (52) .1380	.8707 (55) .0000**	-.0579 (83) .6030	-.0167 (87) .8781	.4111 (93) .0000**	.5477 (93) .0000**	.5587 (99) .0000**	1.0000 (99) .0000	-.0658 (83) .5543
COD	.1872 (66) .1322	-.0114 (49) .9382	.0941 (103) .3445	-.0366 (77) .7522	.0724 (96) .4832	.1206 (96) .2419	.0716 (103) .4725	-.0658 (83) .5543	1.0000 (103) .0000

	React P	Total P	Amn	Nitrate	TKN	Cl	Sulfate	Na	Mn
K	.2820 (71) .0172*	.2471 (62) .0529	.5646 (44) .0001**	.1551 (71) .1966	.4192 (62) .0007**	.3809 (71) .0010**	-.0589 (71) .6258	-.0494 (65) .6960	-.0849 (66) .4980
Mg	-.0315 (55) .8196	-.0196 (55) .8868	-.0634 (23) .7486	.2241 (55) .0999	-.0121 (54) .9309	.2555 (47) .0831	.1019 (55) .4591	-.2933 (48) .0431*	.0300 (53) .8309
Fe	.1501 (85) .1704	.0486 (68) .6940	.1617 (45) .2886	.0197 (83) .8596	.0349 (69) .7758	-.0457 (90) .6691	-.1113 (84) .3136	-.0471 (65) .7096	.0877 (72) .4637
pH	.1052 (75) .3693	-.1693 (49) .2448	-.3542 (36) .0340*	-.1450 (74) .2178	-.1302 (50) .3674	-.1852 (81) .0979	-.1024 (75) .3818	-.0363 (46) .8108	-.0074 (53) .9582
Cond	.2889 (100) .0036**	.5153 (74) .0000**	.5567 (61) .0000**	.2273 (99) .0236*	.3916 (74) .0006**	.5105 (104) .0000**	.4936 (100) .0000**	.3102 (71) .0085**	.0517 (76) .6571
Alk	.1307 (100) .1949	.3256 (74) .0046**	.3338 (61) .0076**	-.1072 (99) .2909	.2387 (74) .0405*	.2007 (104) .0411*	.3383 (100) .0006**	.0708 (71) .5573	.1871 (76) .1055
T. Hard	.0903 (100) .3713	.2556 (74) .0280*	.2696 (61) .0356*	.0908 (99) .3714	.1779 (74) .1295	.2823 (104) .0037**	.1407 (100) .1626	-.2675 (71) .0241*	.1134 (76) .3294
Ca	-.1328 (81) .2373	.0703 (55) .6098	-.0523 (42) .7420	-.0710 (80) .5313	.1182 (55) .3902	.1115 (85) .3097	.1242 (81) .2694	-.2762 (52) .0475*	.1755 (57) .1916
COD	.2669 (85) .0135*	.2136 (68) .0803	.3709 (45) .0121*	-.1330 (83) .2307	.1731 (69) .1550	.0735 (90) .4912	-.1562 (84) .1559	.0146 (65) .9083	.0955 (72) .4251

Correlation Coefficient
(Sample Size)
Significance Level

* Significance Level less than .05
** Significance Level less than .01

Table 5 (con't)

Correlation Coefficients and Statistical Significance Matrix of All Sampled Chemical Parameters.

	K	Mg	Fe	pH	Cond	Alk	T. Hard	Ca	COD	React P	Total P	Amn	Nitrate	TKN	Cl	Sulfate	Na	Mn
React P	.2820 (71) .0172 *	-.0315 (55) .8196	.1501 (85) .1704	.1052 (75) .3693	.2855 (100) .0035 **	.1307 (100) .1949	.0903 (100) .3713	-.1328 (81) .2373	.2669 (85) .0135	1.0000 (106) .0000	.9948 (74) .0000 **	.8646 (66) .0000 **	-.1133 (93) .2797	.9672 (74) .0000 **	-.1027 (92) .3302	.0353 (99) .7288	.2399 (71) .0439*	-.0746 (76) .5216
Total P	.2471 (62) .0529	-.0196 (55) .8666	.0486 (68) .6940	-.1693 (49) .2448	.5153 (74) .0000 **	.3258 (74) .0046 **	.2556 (74) .0280 *	.0703 (55) .6098	.2136 (68) .0803	.9948 (74) .0000**	1.0000 (74) .0000	.9936 (47) .0000 **	-.1213 (74) .3033	.9887 (73) .0000**	.0740 (66) .5546	.0905 (74) .4432	.2273 (67) .0644	-.0510 (72) .6708
Amn	.5646 (44) .0001**	-.0634 (23) .7486	.1617 (45) .2886	-.3542 (36) .0340 *	.5567 (61) .0000 **	.3389 (61) .0076 **	.2696 (61) .0356 *	-.0523 (42) .7420	.3709 (45) .0121 *	.8646 (66) .0000**	.9936 (47) .0000 **	1.0000 (67) .0000	-.1384 (67) .2639	.9984 (46) .0000 **	.3743 (53) .0056 **	.0610 (61) .6406	.2076 (44) .1763	-.0775 (49) .5964
Nitrate	.1551 (71) .1966	.2241 (55) .0999	.0197 (83) .8596	-.1450 (74) .2178	.2273 (99) .0236 *	-.1072 (99) .2909	.0908 (99) .3714	-.0710 (80) .5313	-.1330 (83) .2307	-.1133 (93) .2797	-.1213 (74) .3033	-.1384 (67) .2639	1.0000 (105) .0000	-.0735 (73) .5367	.4332 (91) .0000 **	.4063 (88) .0001 **	.3448 (71) .0032**	-.2119 (76) .0661
TKN	.4192 (62) .0007 **	-.0121 (54) .9309	.0349 (69) .7758	-.1302 (50) .3674	.3916 (74) .0006**	.2387 (74) .0405*	.1779 (74) .1295	.1182 (55) .3902	.1731 (69) .1550	.9672 (74) .0000 **	.9887 (73) .0000 **	.9984 (46) .0000 **	-.0735 (73) .5367	1.0000 (74) .0000	.1316 (67) .2864	.0612 (73) .6071	.1812 (66) .1454	-.0578 (72) .6299
Cl	.3809 (71) .0010*	.2555 (47) .0831	-.0457 (90) .6691	-.1852 (81) .0979	.5105 (104) .0000 **	.2007 (104) .0411 *	.2823 (104) .0037 **	.1115 (85) .3097	.0735 (90) .4912	-.1027 (92) .3302	.0740 (66) .5546	.3743 (53) .0055**	.4332 (91) .0000**	.1316 (67) .2864	1.0000 (104) .0000	.2415 (92) .0203*	.2822 (69) .0188 *	-.1370 (70) .2581
Sulfate	-.0589 (71) .6259	.1019 (55) .4591	-.1113 (84) .3136	-.1024 (75) .3818	.4936 (100) .0000 **	.3383 (100) .0006**	.1407 (100) .1626	.1242 (81) .2694	-.1562 (84) .1559	.0353 (99) .7288	.0905 (74) .4432	.0610 (61) .6406	.4063 (88) .0001**	.0612 (73) .6071	.2415 (92) .0203 *	1.0000 (100) .0000	.6203 (71) .0000 **	-.1504 (76) .1947
Na	-.0494 (65) .6960	-.2333 (48) .0431 *	-.0471 (65) .7096	-.0363 (46) .8108	.3102 (71) .0085 **	.0708 (71) .5573	-.2675 (71) .0241 *	-.2762 (52) .0475 *	.0146 (65) .9083	.2399 (71) .0439 *	.2273 (67) .0644	.2076 (44) .1763	.3448 (71) .0032**	.1812 (66) .1454	.2822 (69) .0188	.6203 (71) .0000 **	1.0000 (71) .0000	-.0992 (69) .4174
Mn	-.0849 (66) .4980	.0300 (53) .8309	.0877 (72) .4637	-.0074 (53) .9582	.0517 (76) .6571	.1871 (76) .1055	.1134 (76) .3294	.1755 (57) .1916	.0955 (72) .4251	-.0746 (76) .5216	-.0510 (72) .6708	-.0775 (49) .5964	-.2119 (76) .0661	-.0578 (72) .6299	-.1370 (70) .2581	-.1504 (76) .1947	-.0992 (69) .4174	1.0000 (76) .0000

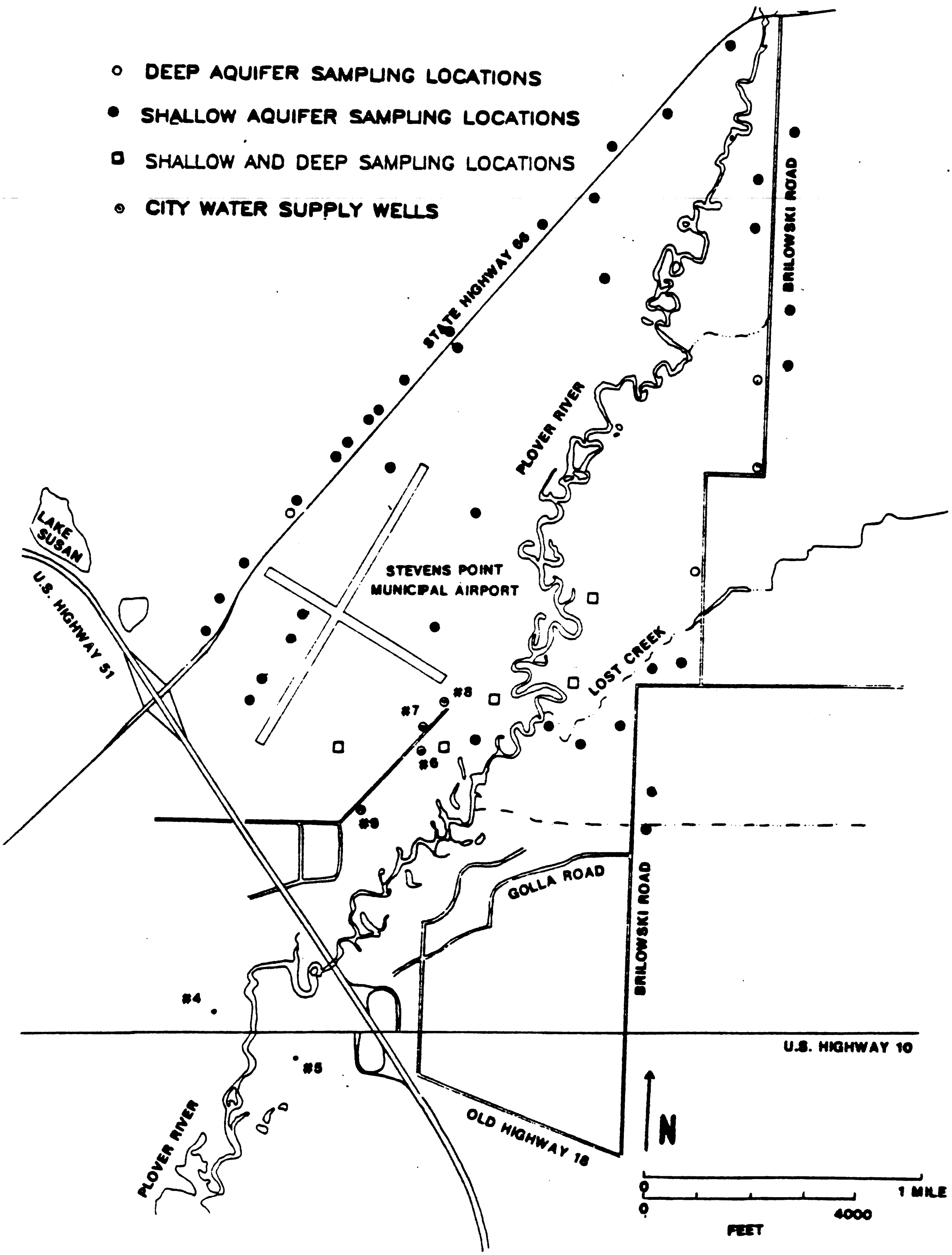


Figure 15. Groundwater Sampling Locations.

solubility constants. Because of the solubility and its anionic form, nitrates are very mobile in groundwater. (Cherry 1979)

The primary sources of nitrate contamination are agricultural fertilizers, livestock waste, private subsurface waste-water disposal systems and residential lawn fertilizing. The primary drinking water standard for nitrates is 10 mg/l (as elemental N). (Driscoll 1986)

Samples taken from the two deepest piezometers of the nested well systems to the east of the Plover River (C-60 and D-60), had consistently higher nitrate concentrations than the city supply wells, or monitoring wells to the west of the river. Table 6 gives the sampling dates and the nitrate concentration of the deepest piezometers in nested wells C and D.

Table 6.

Nitrate Concentration of Deepest Piezometers of Nested Well Systems C and D in mg/l as elemental N.

Date	C	D
7-18-84	6.5	6.6
8-29-84	6.8	7.0
11-15-84	6.5	7.5

High nitrate concentrations were also found in samples taken from private water supply wells along Highway 66 and Brilowski Road. The observation wells which are located between the city supply wells and the high nitrogen concentration groundwater near Highway 66 also showed some trace concentrations of nitrates ranging up to 2.6 mg/l in Observation Well #4.

Figures 16 & 17 give the well field in cross-section and illustrate the nitrate plumes of the deeper aquifer water to the

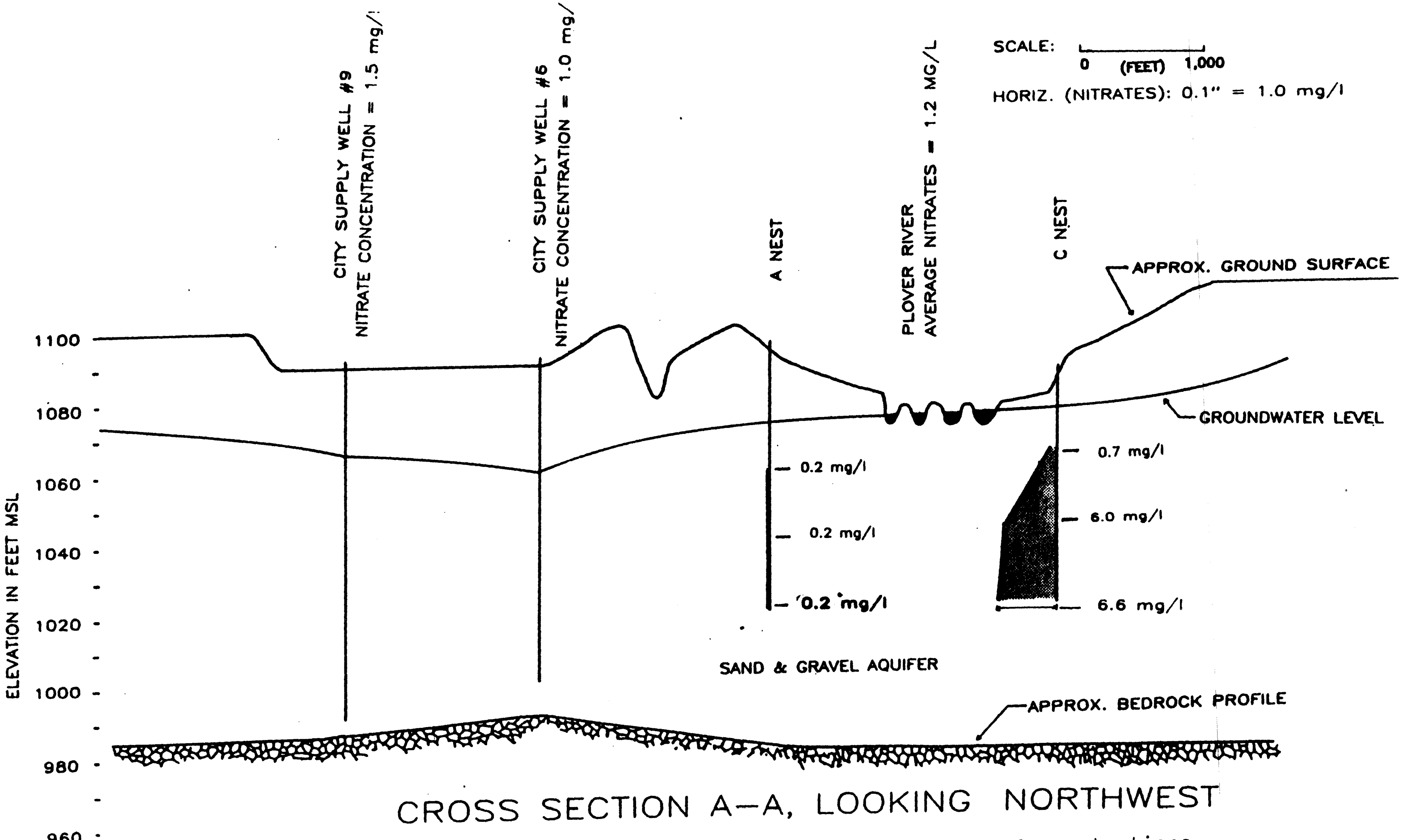


Figure 16. Cross-Section A-A of the Well Field Illustrating Nitrate Concentrations.

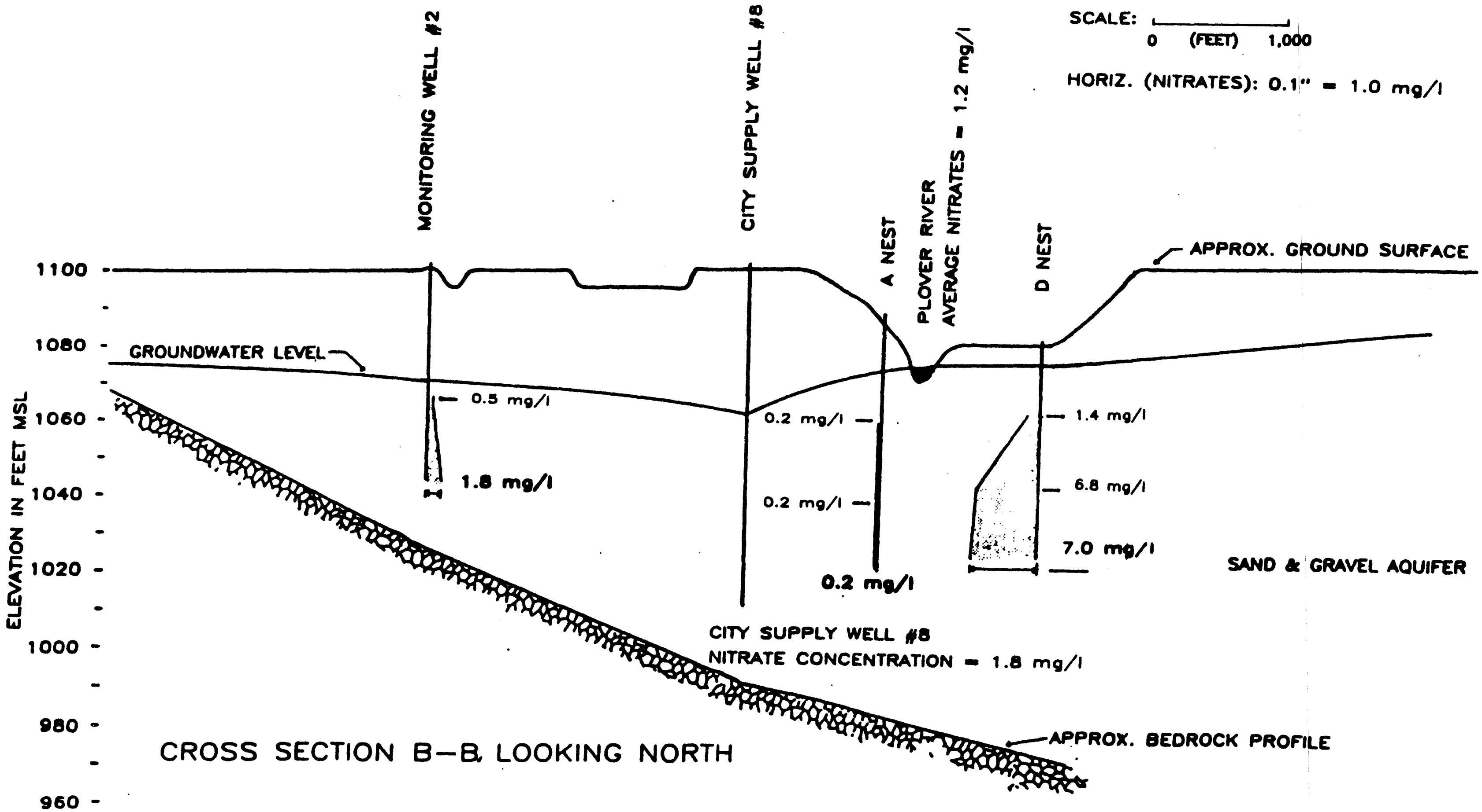


Figure 17. Cross-Section B-B of the Well Field Illustrating Nitrate Concentrations.

east of the Plover River. Figure 18, which illustrates the shallow aquifer nitrate concentration distribution, shows elevated nitrogen concentrations to the east of the well field, and to the west near the airport terminal. Figure 19 gives the deep aquifer plot of the nitrate concentrations.

The city supply wells were first sampled for nitrates in 1981, at which time a composite sample resulted in a nitrate concentration of 0.9 mg/l. (Murry 1984) Table 7 gives the average nitrate concentrations of the city supply wells #6 - #9 from six separate samplings in 1984 and 1985.

Table 7

Average Nitrate Concentrations in the City of Stevens Point Supply Wells in mg/l.

Well	#6	#7	#8	#9
Nitrate Concentration	1.0	0.5	1.8	1.5

The present (1984-1985) composite nitrate level is at about the same concentration as the 1981 sampling. It appears that there has been very little, if any, increase in the overall nitrate levels in the Stevens Point supply wells. However, the city wells do show some elevated concentrations of nitrates over background concentrations.

The high nitrate concentration east of the river, and the measured flow direction at these locations, presents conditions in which nitrates could be potentially introduced from this region to the city supply wells. The nitrates detected in the city supply

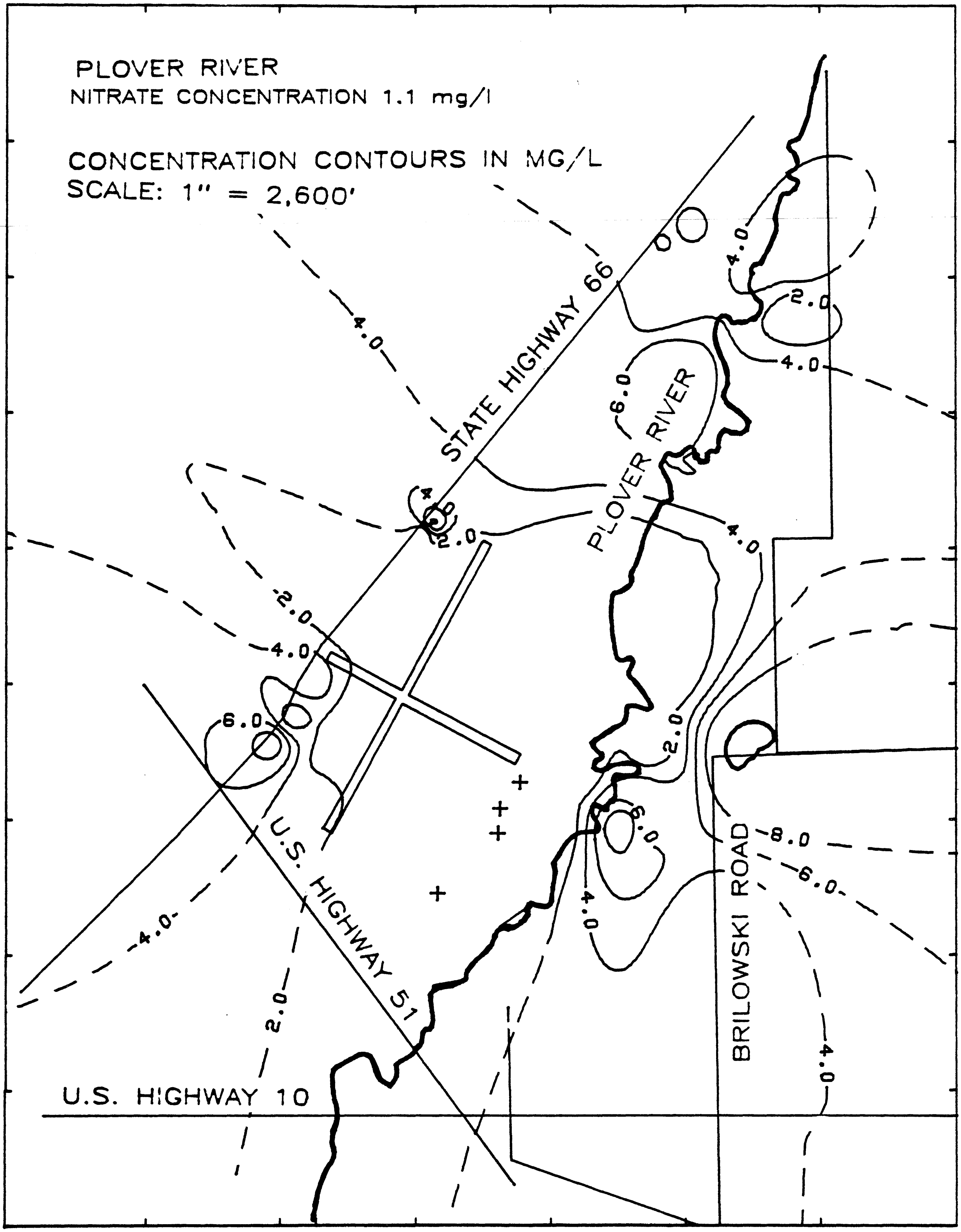


Figure 18. Shallow Aquifer Nitrate Concentration Contours.

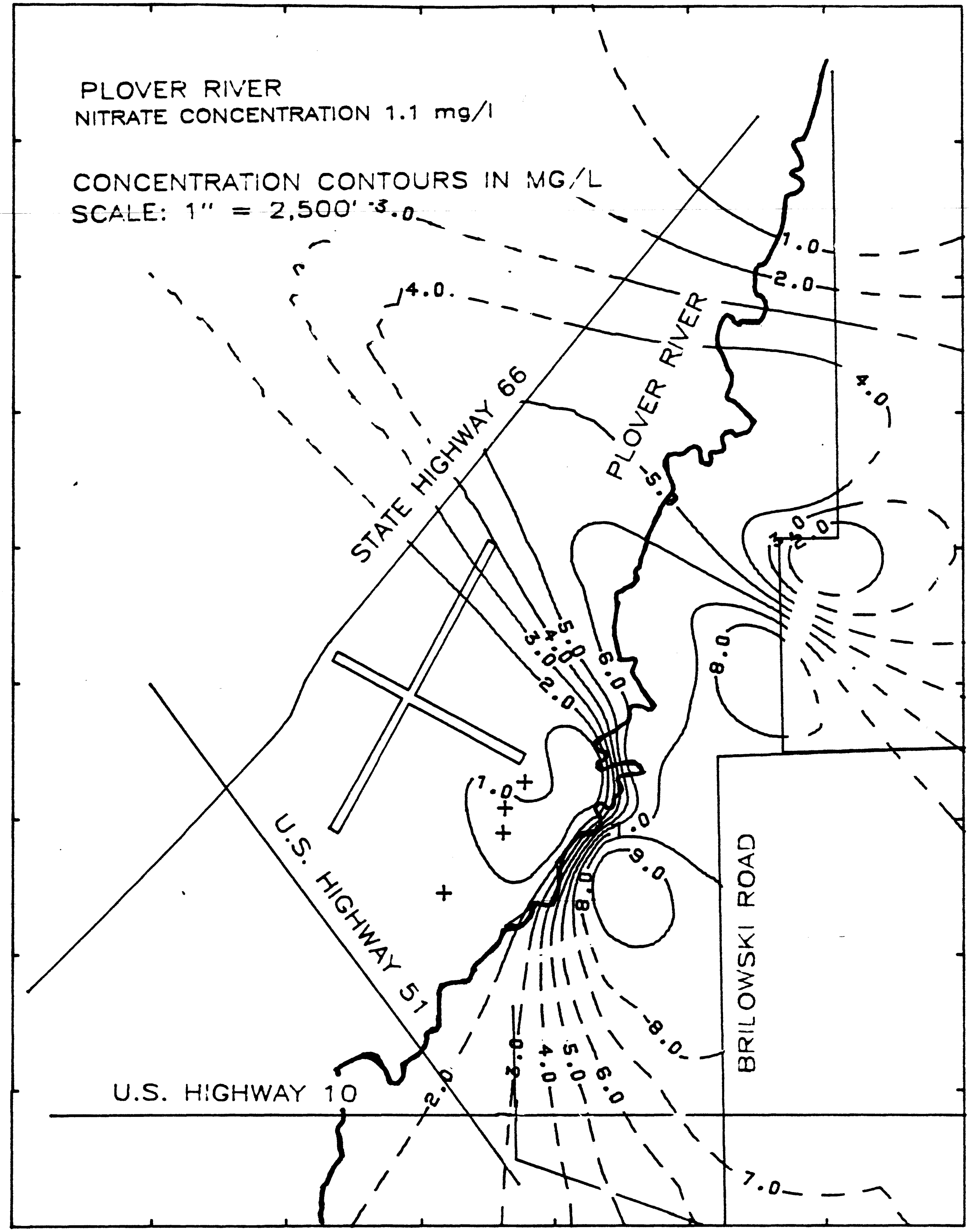


Figure 19. Deep Aquifer Nitrate Concentration Contours.

water could also be in part from the higher nitrate groundwater from the area northwest of the well field. It would appear that the relatively low nitrate concentration in the immediate recharge area and the Plover River is a contributing factor in diluting high nitrate water and maintaining the relatively low nitrate concentrations in the city supply wells. The Plover River nitrate concentration ranged from 0.4 - 2.0 mg/l over 10 separate samplings.

It is the author's opinion that a small volume of high nitrate water from the east of the Plover River, as well as the high nitrate water along Highway 66, is used in recharging the city wells. However, the high nitrate water is sufficiently diluted with water lower in nitrates to reduce the overall nitrate levels to well below the drinking water standards.

Increases in nitrates due to residential development in the recharge area north, east and west of the well field could cause increases in the future as more of this area is exposed to private waste disposal systems.

The presence of nitrates in the groundwater was associated with sulfates and chloride ions with correlation coefficients of .41 and .43, respectively. Since nitrates, sulfate and chloride ions all have low background concentrations, within the Plover River Aquifer, these chemical constituents most likely result from the same contaminating sources. Agriculture fertilizer, septic systems, and animal wastes are believed to be the primary sources of nitrates in the well field area.

Total Kjeldahl Nitrogen and Ammonia

The Total Kjeldahl Nitrogen (TKN) is a measurement of nitrogen in the NH (ammonia) and organic nitrogen forms. Nitrogen in these forms are for the most part not found in natural groundwater and thus a good indication of man's impact on the groundwater. Currently, drinking water standards do not exist for Ammonia and TKN. High values of ammonia are most likely to occur in water which is lacking in oxygen and where prercolating recharge water has passed through decomposing organic matter; from septic systems, or animal wastes. The shallow aquifer concentration plot of TKN given in Figure 20 shows some areas of elevated concentrations of TKN.

The deep aquifer concentration plot given in Figure 21 shows some higher TKN concentrations northeast of the well field. This groundwater apparently doesn't reach the city wells in sufficient volume to affect the water quality of the city wells.

The Ammonia concentrations illustrated in Figure 22 and 23 show much the same pattern as the TKN, with some isolated areas of higher ammonia concentrations. The shallow aquifer concentration plot illustrates localized groundwater impacts concentrated along Highway 66. The probable sources of these impacts are due to septic systems, animal waste or other waste disposal. A very high concentration of ammonia detected at MW #5 (May 10, 1985) was not incorporated into Figure 22, due to the exaggerated influence on the regional concentration distribution. This high ammonia value is believed to be result of septic system discharge from facilities on the Izaak Walton League Land.

Ammonia was correlated with TKN (correlation coefficient of

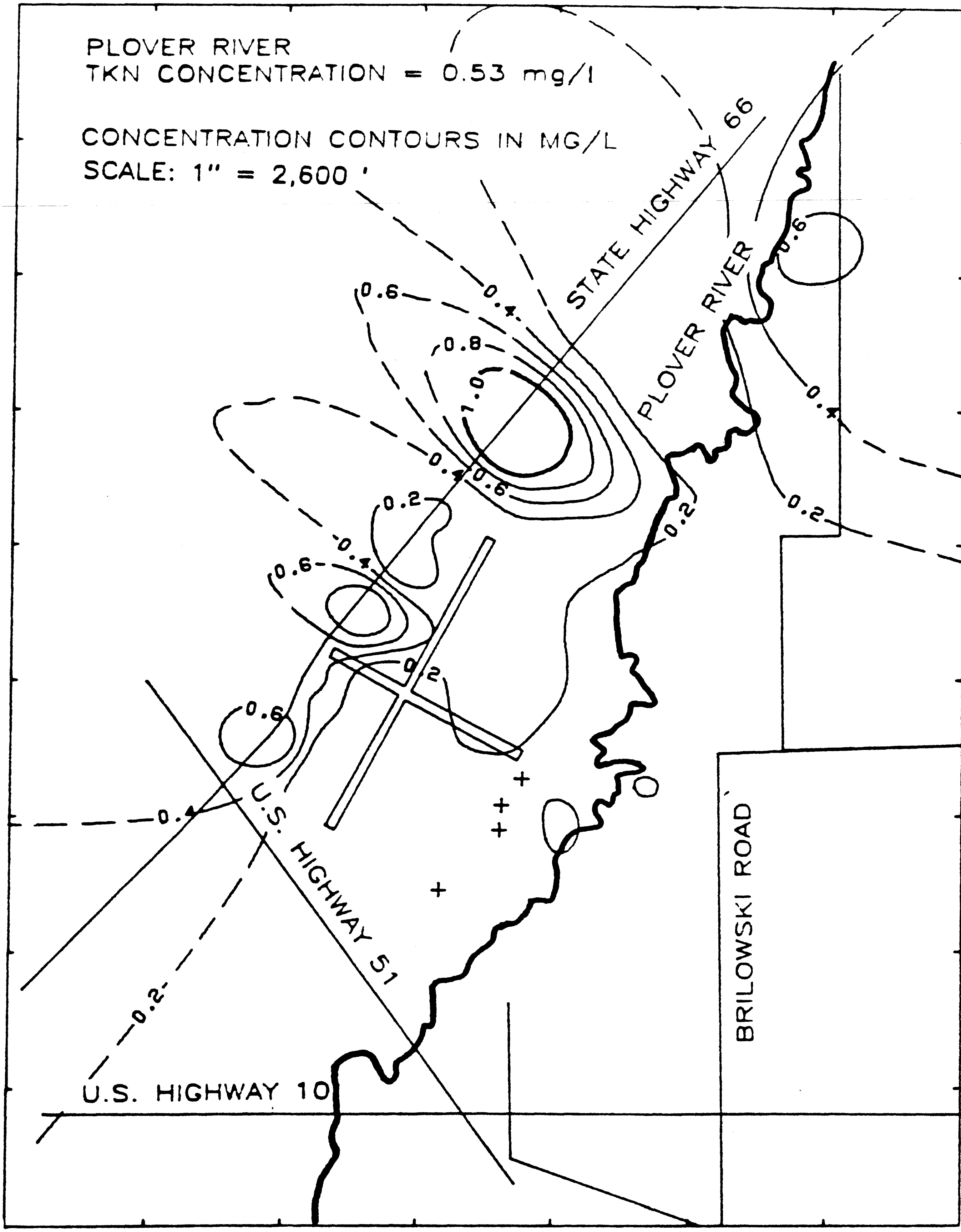


Figure 20 . Shallow Aquifer TKN Concentration Contours.

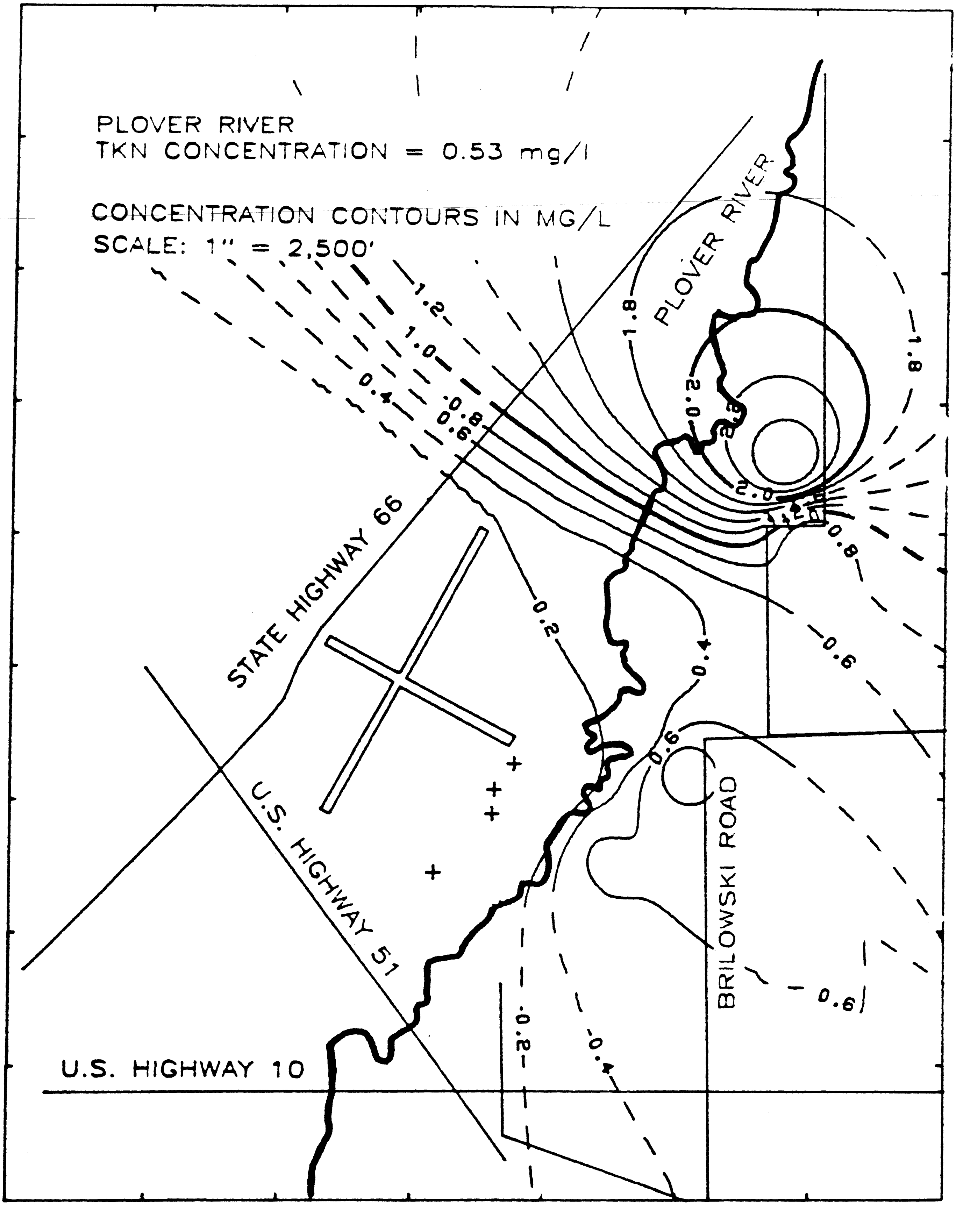


Figure 21. Deep Aquifer TKN Concentration Countours.

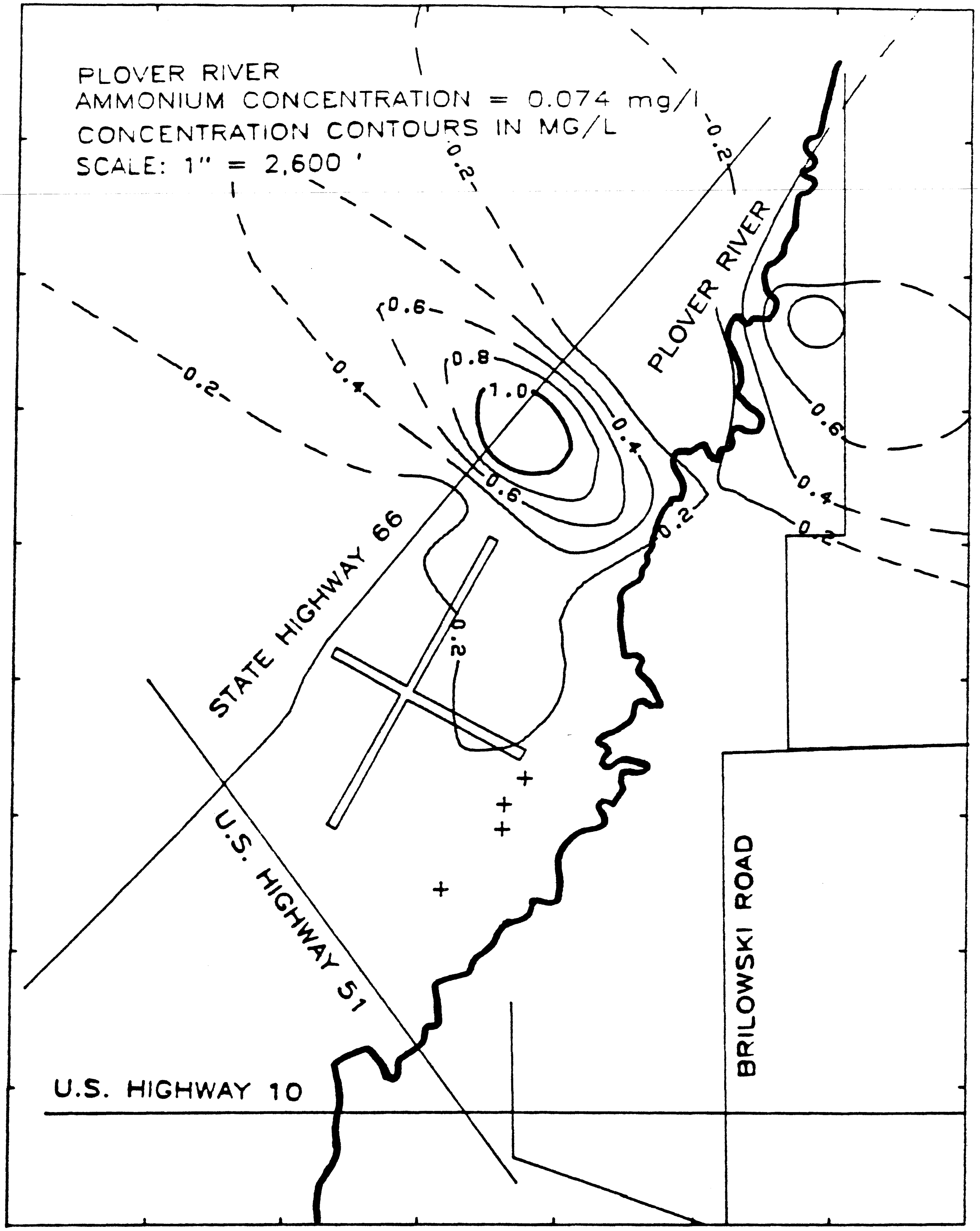


Figure 22. Shallow Aquifer Ammonia Concentration Contours.

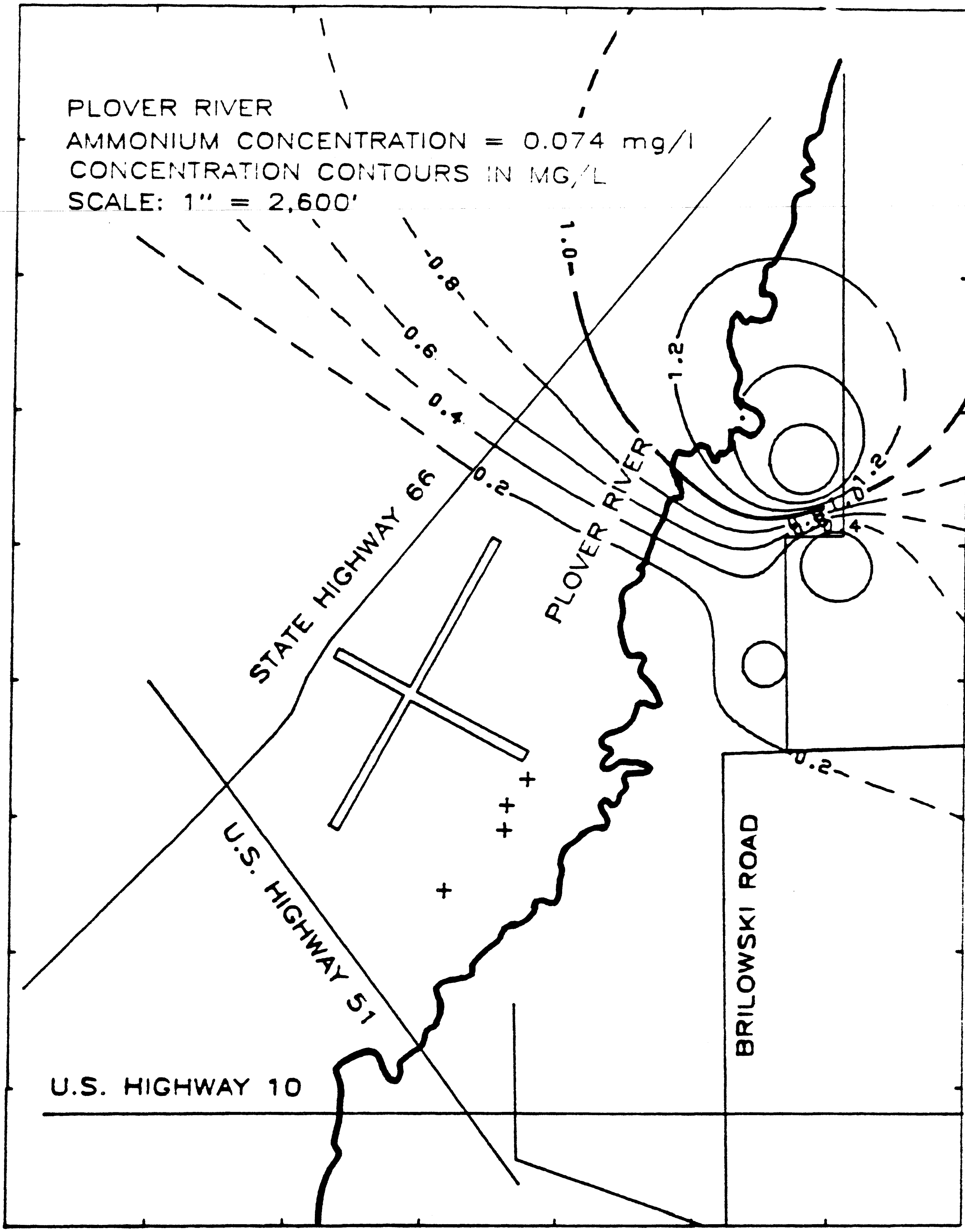


Figure 23. Deep Aquifer Ammonia Concentration Contours.

.998), conductivity (correlation coefficient of.557), potassium (correlation coefficient of .567), reactive phosphorus (correlation coefficient of .865) and total phosphorus (correlation coefficient .994). TKN was correlated with ammonia (.998), potassium (.419), conductivity (.392), reactive phosphorus (.967), and total phosphorus (.989).

The strong association of Ammonia and TKN with phosphorous and conductivity is indication that these constituents are introduced to the aquifer by animal waste and private septic system wastes.

Sulfates

Sulfates can be present in groundwater from natural sources, but also can be introduced as a result of fertilizer use or waste disposal. The Secondary Drinking Water Standard for sulfate is 250 mg/l. (Driscoll 1986) Figure 24 gives the shallow aquifer concentration plot while Figure 25 gives the deep aquifer concentration plot. The range in sulfate concentrations was from 4.5 to 50 mg/l. The average concentration in the city supply wells was 14 mg/l. The presence of sulfates correlated strongly with conductivity (correlation coefficient of 0.49), chloride (.24), sodium (.62) and nitrates (.41). The correlation with nitrates would suggest that sulfates are introduced along with nitrates through agricultal fertilizing and animal wastes predominately east of the Plover River. Sulfates were also present along Highway 66, where application of roadsalts and private septic systems have impacted groundwater.

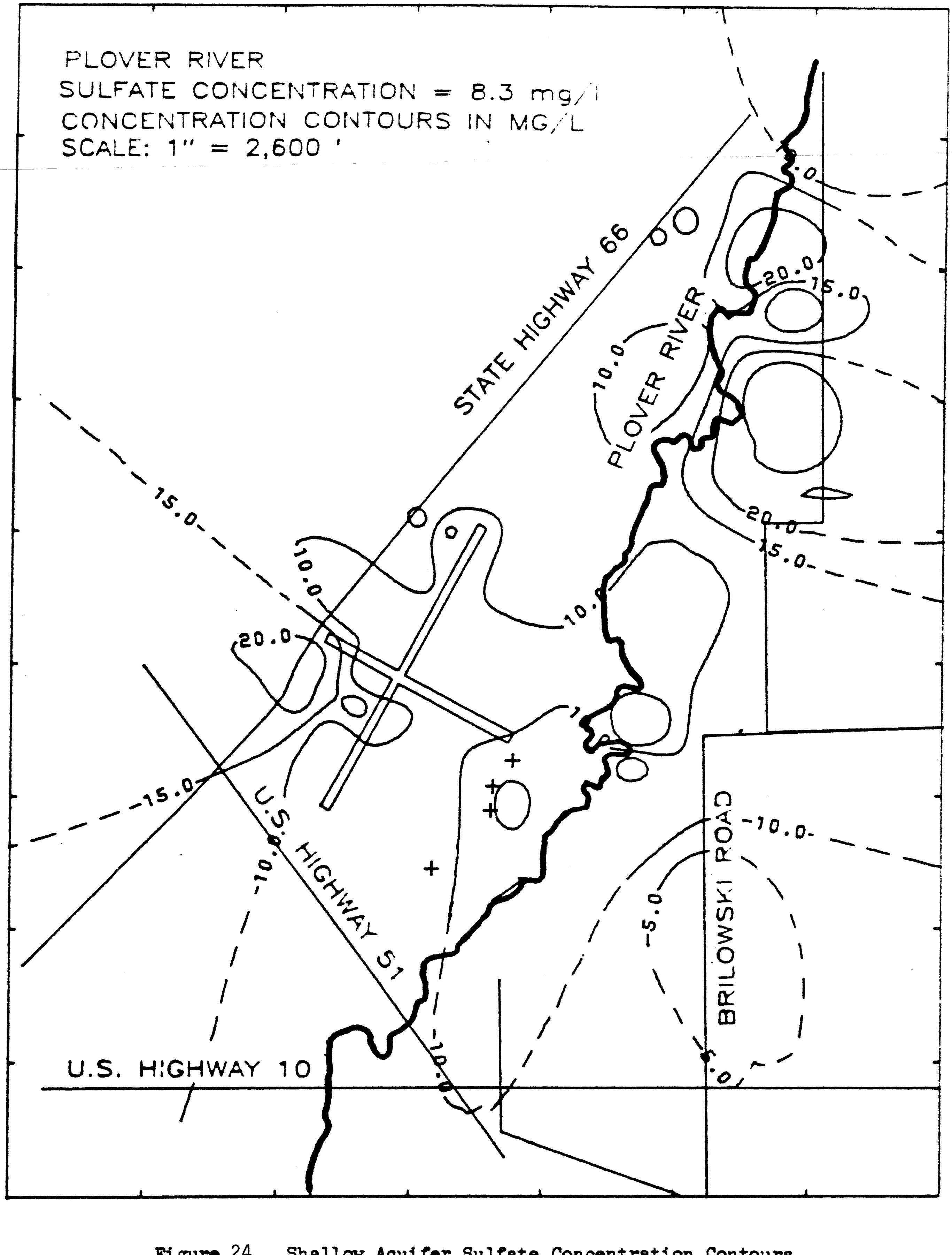


Figure 24, Shallow Aquifer Sulfate Concentration Contours.

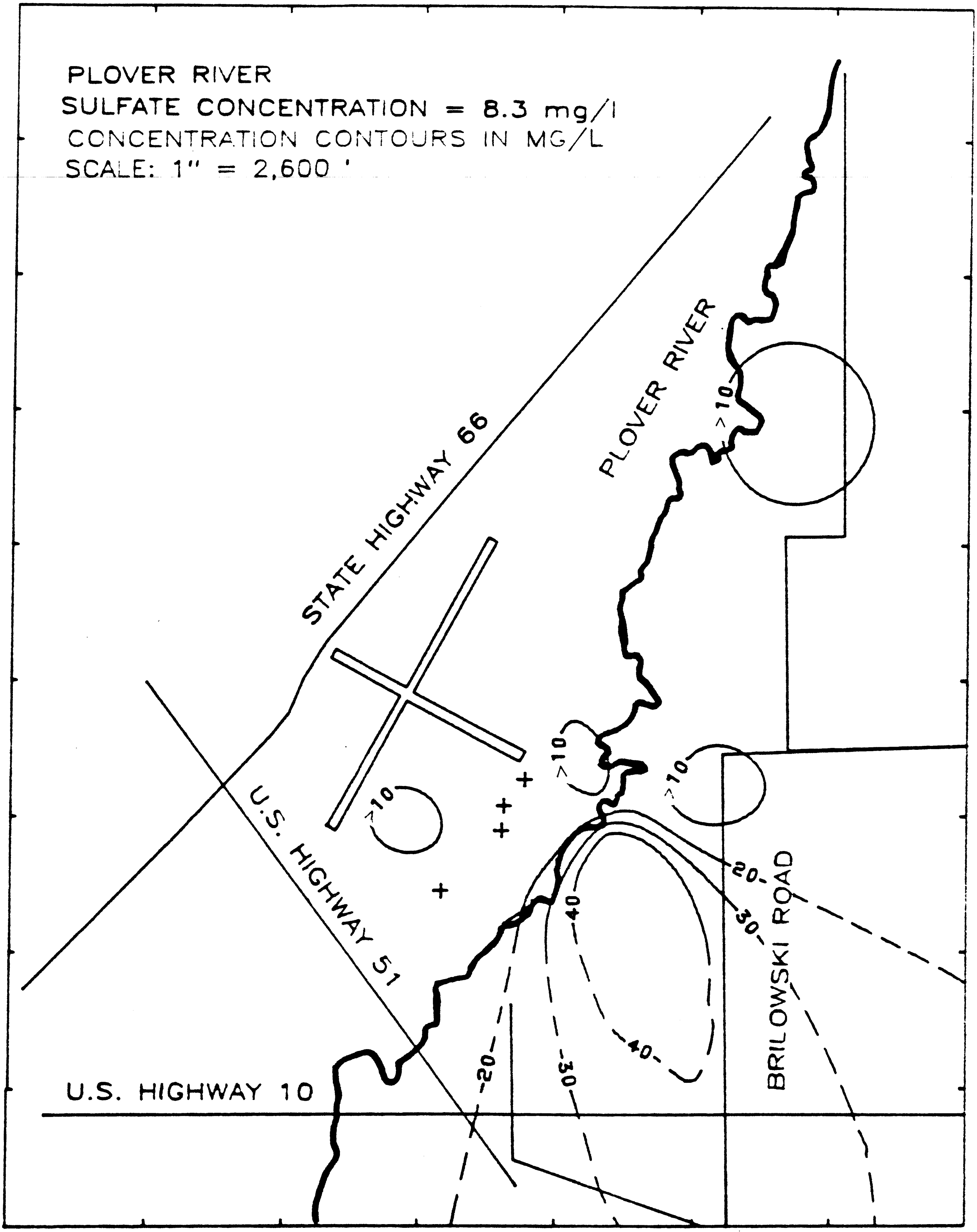


Figure 25. Deep Aquifer Sulfate Concentration Contours.

Chloride

Chloride in groundwater is often associated with human impact and is a very conservative ion; and is therefore a good indication of contamination resulting from man's activity. Chloride concentrations over 250 mg/l are generally objectionable for water supply purposes. (Drischoll 1986) Figure 26 gives the shallow aquifer concentrations of chloride and illustrates the region of elevated chloride concentrations northeast of the well field. The abrupt change in chloride concentration suggests that the high chloride concentrations along Highway 66 are readily diluted as the groundwater approaches the city supply wells.

The deep aquifer groundwater chloride concentrations given in Figure 27 illustrate higher chloride concentrations east of the Plover River. The high chloride concentrations groundwater is diluted sufficiently as to not impact the city supply wells.

The presence of chloride in the deep aquifer east of the Plover River is apparently the result of fertilizer use as demonstated with the association between chloride and nitrates (correlation coefficient of .433). The presence of chloride in the shallow aquifer along Highway 66 is attributed to roadsalt and impacts from septic systems.

Alkalinity

Alkalinity indicates the presence of anions (largely HCO_3^- carbonate) which possess the ability to neutralize acids. Alkalinity is generally lowest in the sand and gravel aquifers in the northern portion of the State of Wisconsin where the aquifers lies directly on Precambrain rocks, which are primary silicates. Higher alkalinities are found in the Silurian and Sandstone aquifers

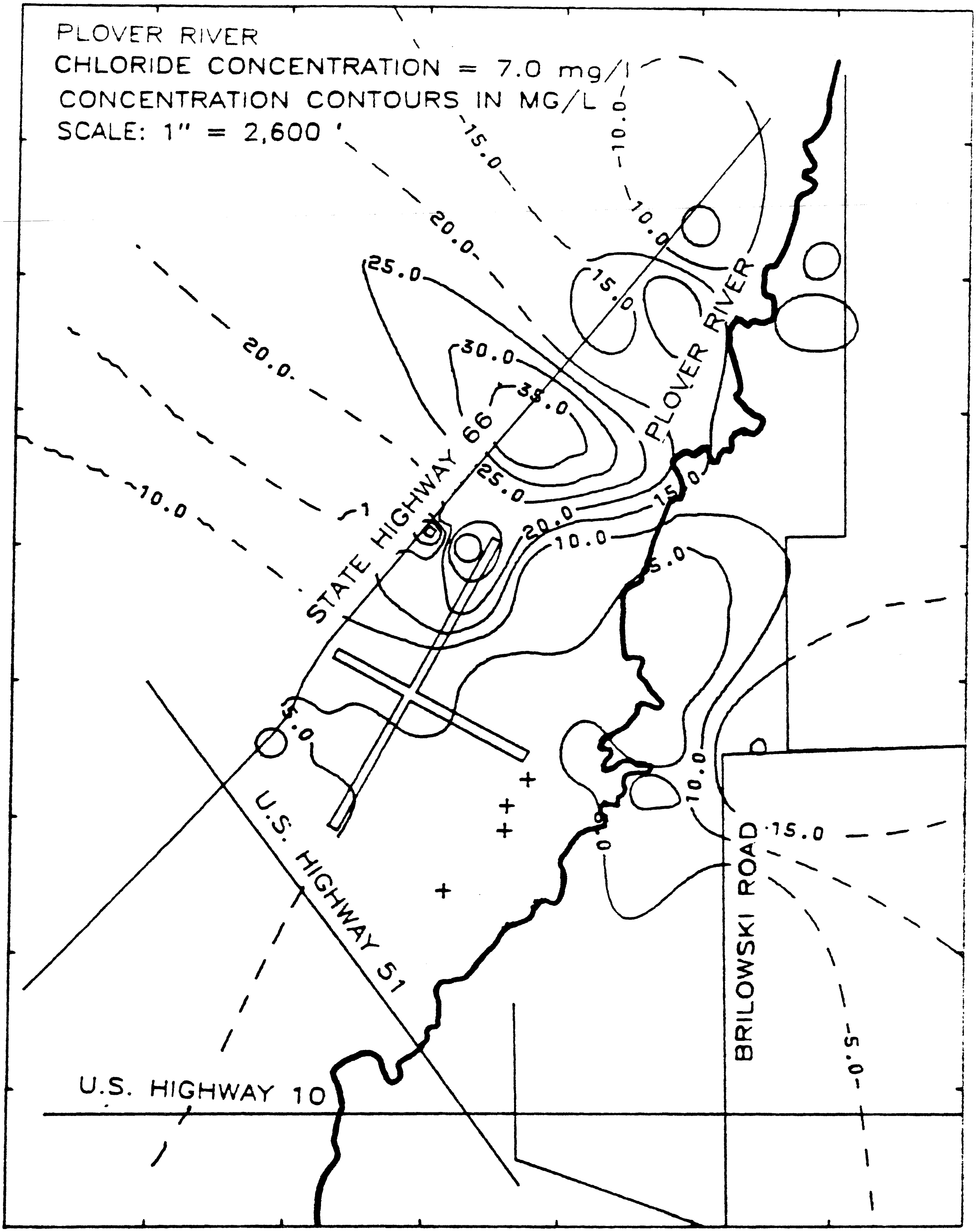


Figure 26. Shallow Aquifer Chloride Concentration Contours.

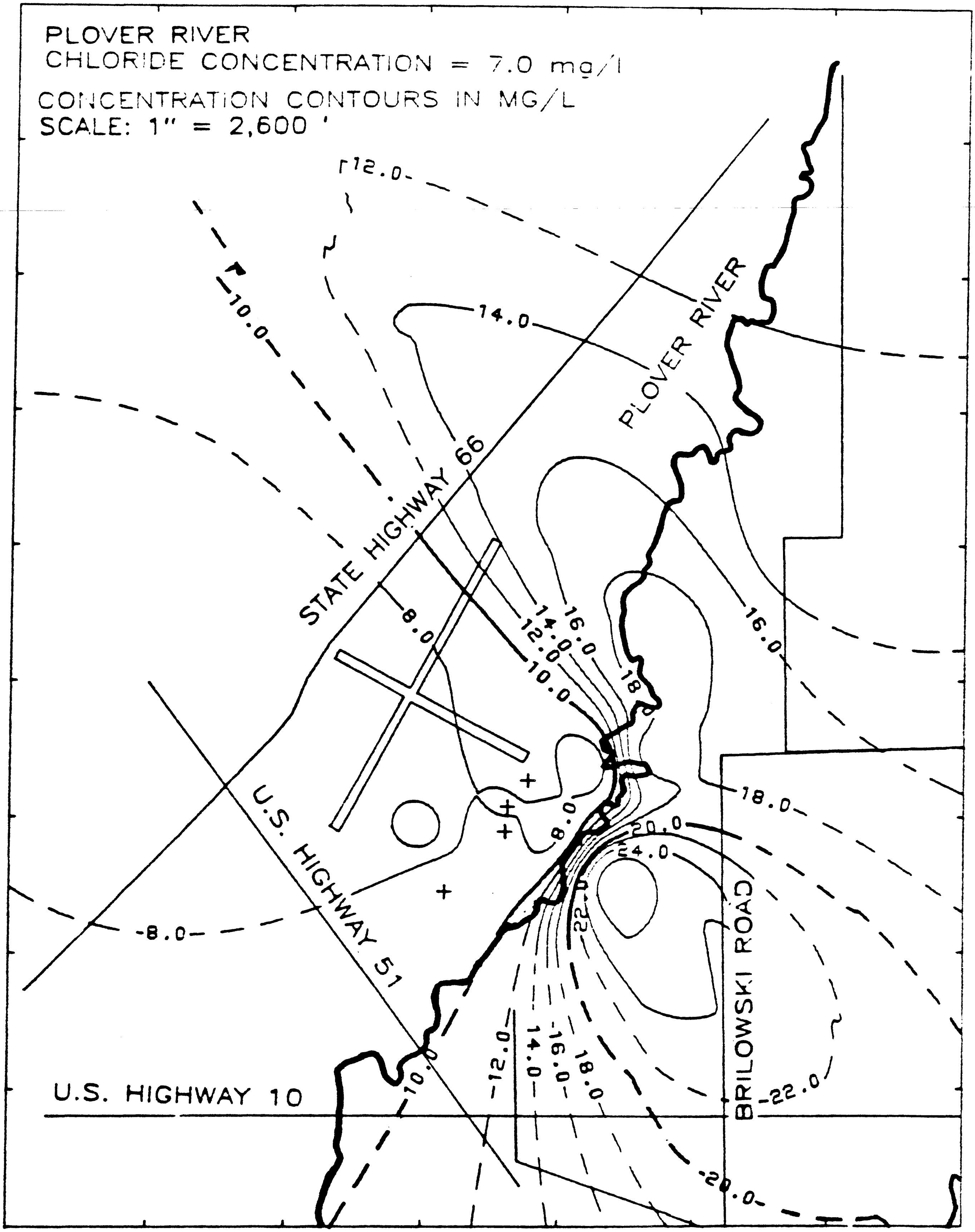


Figure 27. Deep Aquifer Chloride Concentration Contours.

where carbonate minerals are abundant and contribute to alkalinity. (Kammerer 1981) High alkalinity and hardness is found in much of the groundwater east of Stevens Point due to the presence of carbonate minerals in the glacial till and outwash. Sources of alkalinity are similar to hardness and follow a similar pattern with depth. No established standard exists for an acceptable upper limit of alkalinity in surface water or groundwater.

The shallow aquifer concentration plot is given in Figure 28, while the deep aquifer concentration plot is given in Figure 29. Shallow piezometers between the Plover River and the city supply wells (A-20 and B-20 averaged 147 mg/l) were much higher than the shallow piezometers in Nest C and D (averaged 29 mg/l). This may in part be due to recharge from the Plover River which has an alkalinity of 146 mg/l. A similar pattern occurs for hardness calcium and magnesium. This pattern does not occur for nitrates, chloride or COD which indicates the elevated values noted in the shallow piezometers west of the river are most likely the result of local mineralogy as well as input from the river.

Manganese

Manganese is an undesirable impurity in water supplies, largely due to the tendency to form black precipitate and black oxide stains rather than any toxic effects. (Hem 1985) The recommended upper limit for manganese in public water supplies in the United States is .05 ppm (secondary drinking water standard). (NAS-NAE 1972) No mandatory limit is specified for this element by the U.S. Environmental Protection Agency.

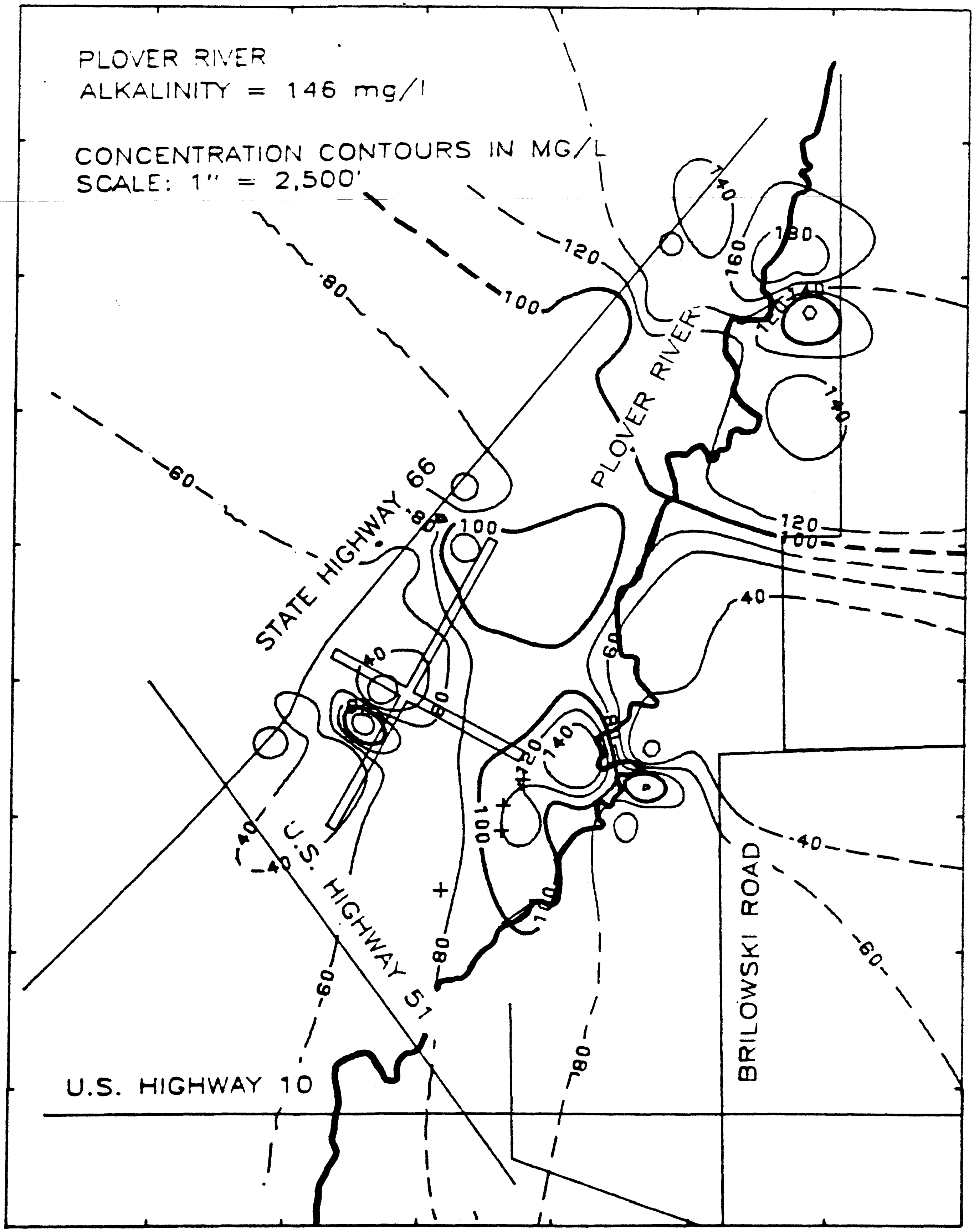


Figure 28. Shallow Aquifer Alkalinity Concentration Contours.

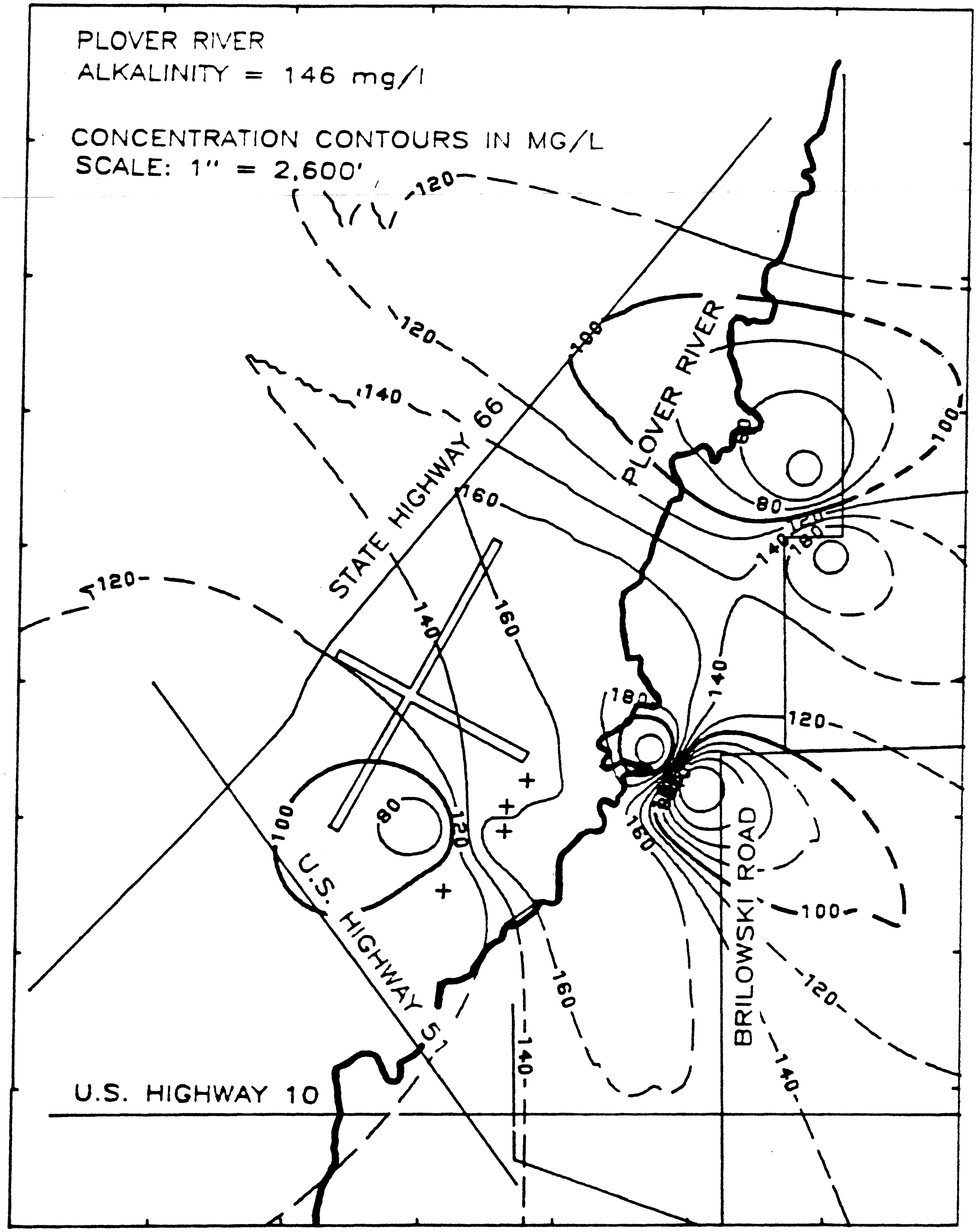


Figure 29. Deep Aquifer Alkalinity Concentration Contours.

The presence of manganese in the city supply wells has reached the point of becoming somewhat of a problem. The average manganese concentrations in each of the city supply wells over five samplings is given in Table 8.

Table 8

Average Manganese Concentration in the City of Stevens Point Supply Wells in mg/l

Well	#6	#7	#8	#9
Manganese Concentration	.17	.32	.07	.01

The presence of manganese seems to be a very localized phenomenon. The most significant concentration occurred in the intermediate depth piezometer of B - nest, with an average over several samplings of 1.03 mg/l. This is significantly higher than the manganese concentration averaged over all the sampling points of 0.06 mg/l.

One shallow aquifer monitoring well to the north of the city wells also showed elevated levels of manganese. Figure 30 gives the shallow groundwater manganese concentrations and illustrates the elevated concentrations in MW #5. Figure 31 gives the deeper aquifer concentrations. The higher concentrations of manganese near the B nest are the most likely source of the manganese found in the city supply wells. City supply wells #6 and #7 seem to be the major contributing wells to the manganese concentration to the city's drinking water. The overall manganese concentration of the city drinking water could most likely be reduced if the use of wells #6 and #7 would be reduced, particularly during periods of low

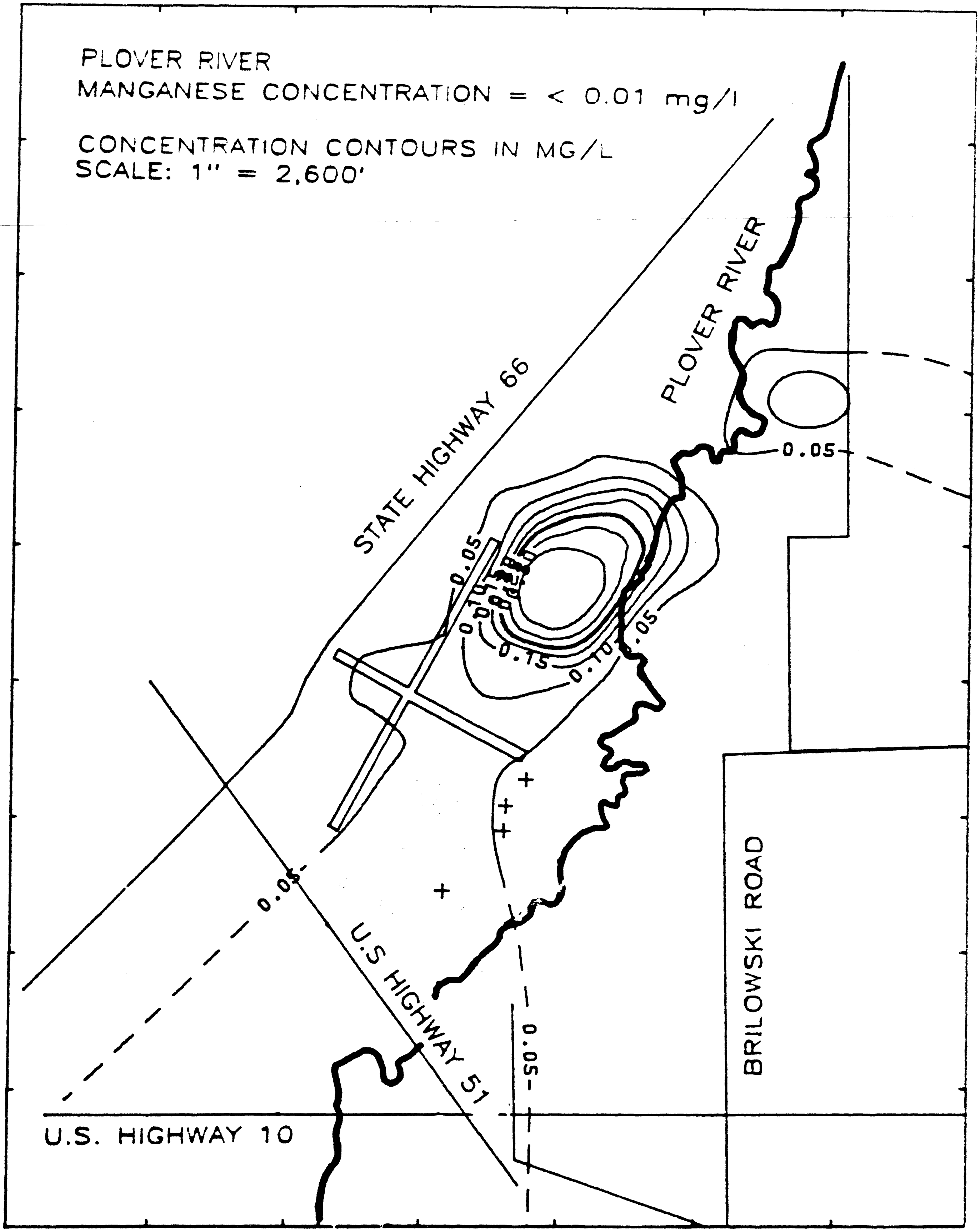


Figure 30. Shallow Aquifer Manganese Concentration Contours.

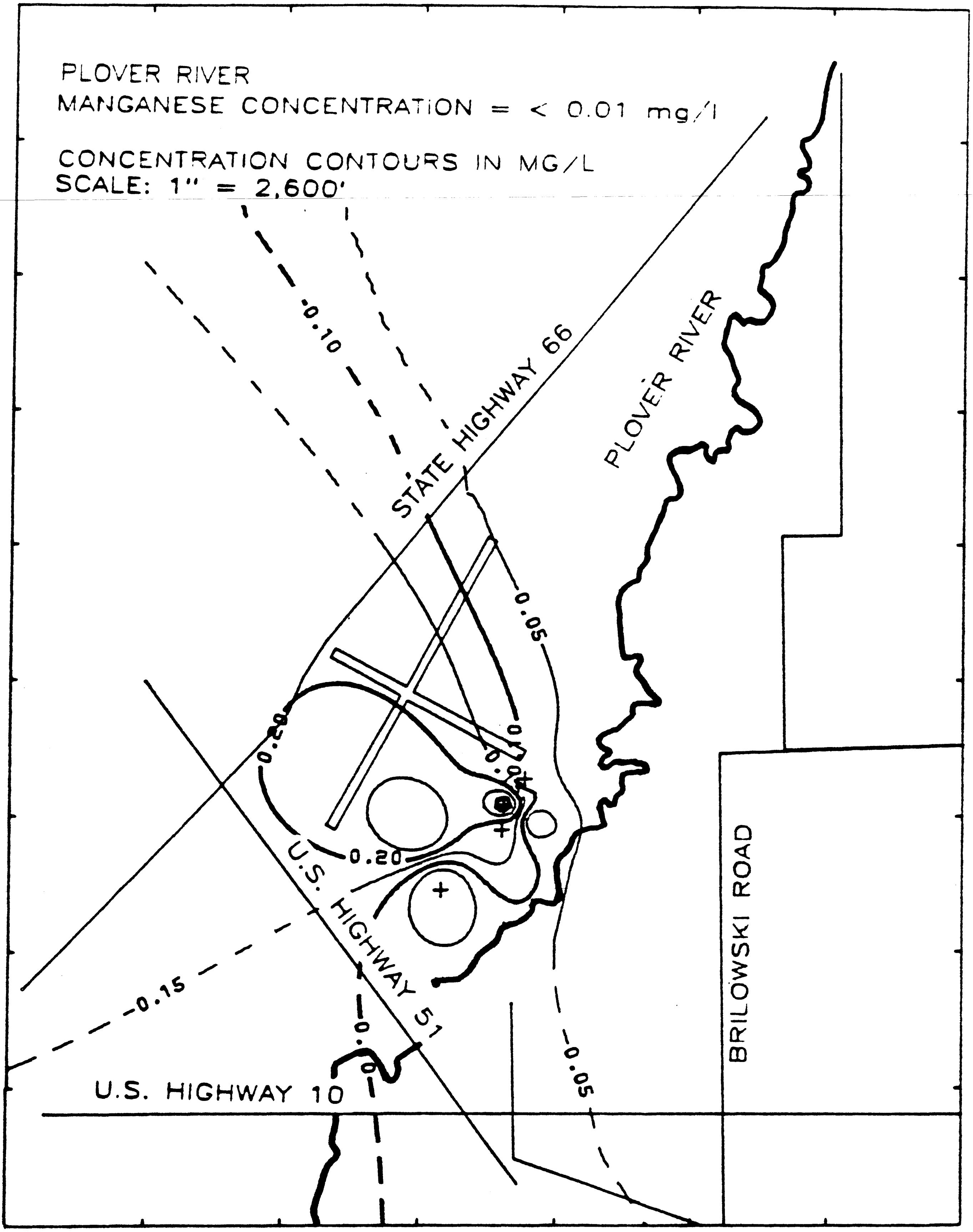


Figure 31. Deep Aquifer Manganese Concentration Contours.

consumption when there is less water taken from other wells to dilute the higher manganese concentrations of wells #6 and #7. The B nested wells system is located near an abandoned river bed and existing flood plain. The previous streambed material may include sand grains and pebbles having manganese oxide coating. (Hem 1985) Recharge through the existing wet organic soils could remove dissolved oxygen existing in the recharge water creating reducing conditions that allows available manganese to go into solution.

Iron

Iron chemistry is very similar to Manganese, usually occurring in significant concentrations in acid water or water without any oxygen. High iron concentrations (> 0.3 mg/l) can form red oxyhydroxide precipitates that stain laundry and plumbing fixtures and therefore, is an objectionable impurity in domestic water supplies. The occurrence of iron is only partially associated with the minerals which comprise the aquifer. More important are the oxidation conditions of the recharge water in conjunction with the rate of groundwater movement. (Holt 1965) Iron to date has not been a problem in the Stevens Point Municipal Well System.

Figure 32 gives the iron concentration plots of the shallow aquifer groundwater, and Figure 33 gives the iron concentration of the deep aquifer groundwater. Higher concentations were detected within all of the piezometers in A - Nest. The source could be derived from water which contacted the high organic soils within the adjacent flood plain east of the river. The western bank of the river in this region is an upland area with little in organic

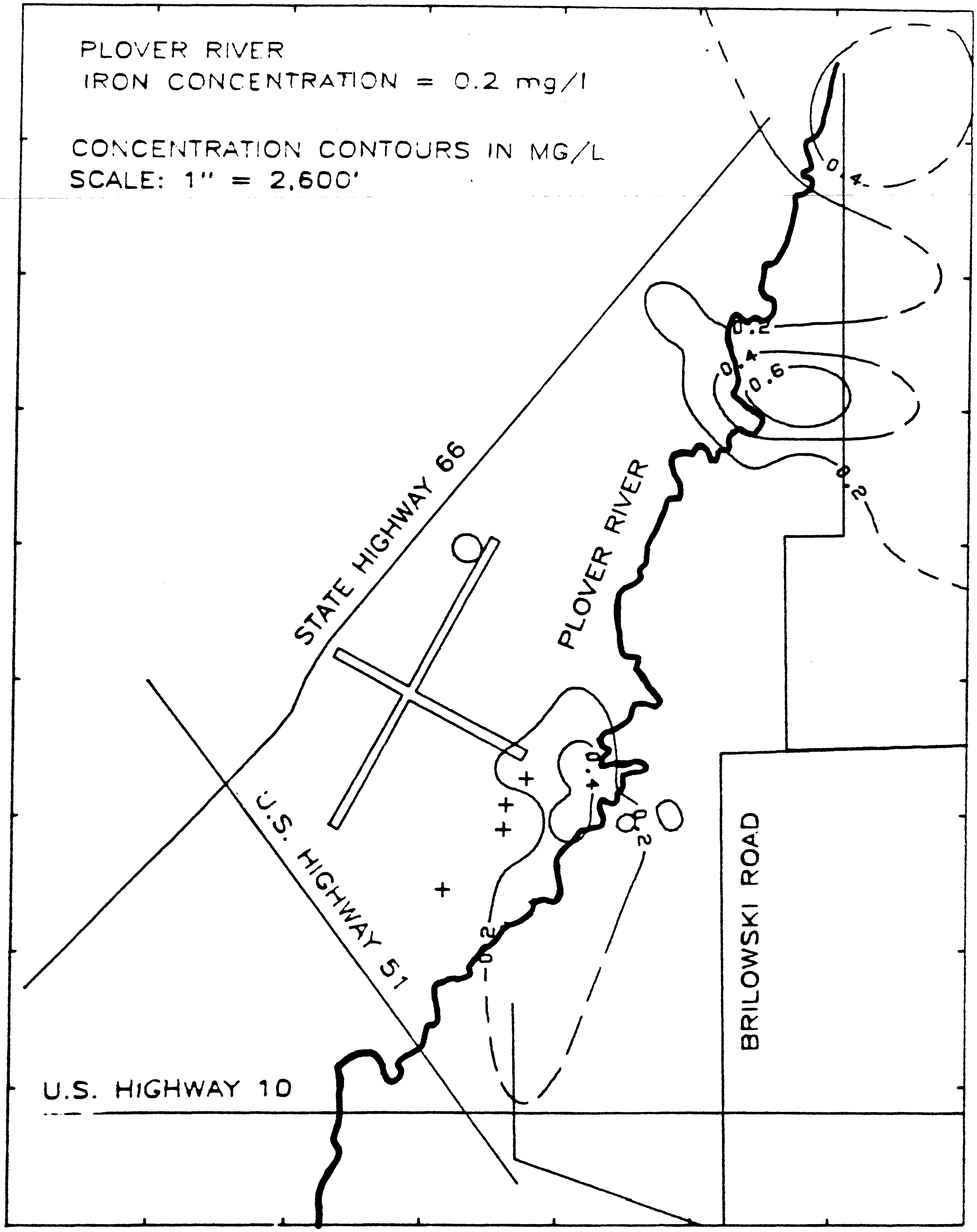


Figure 32. Shallow Aquifer Iron Concentration Contours.

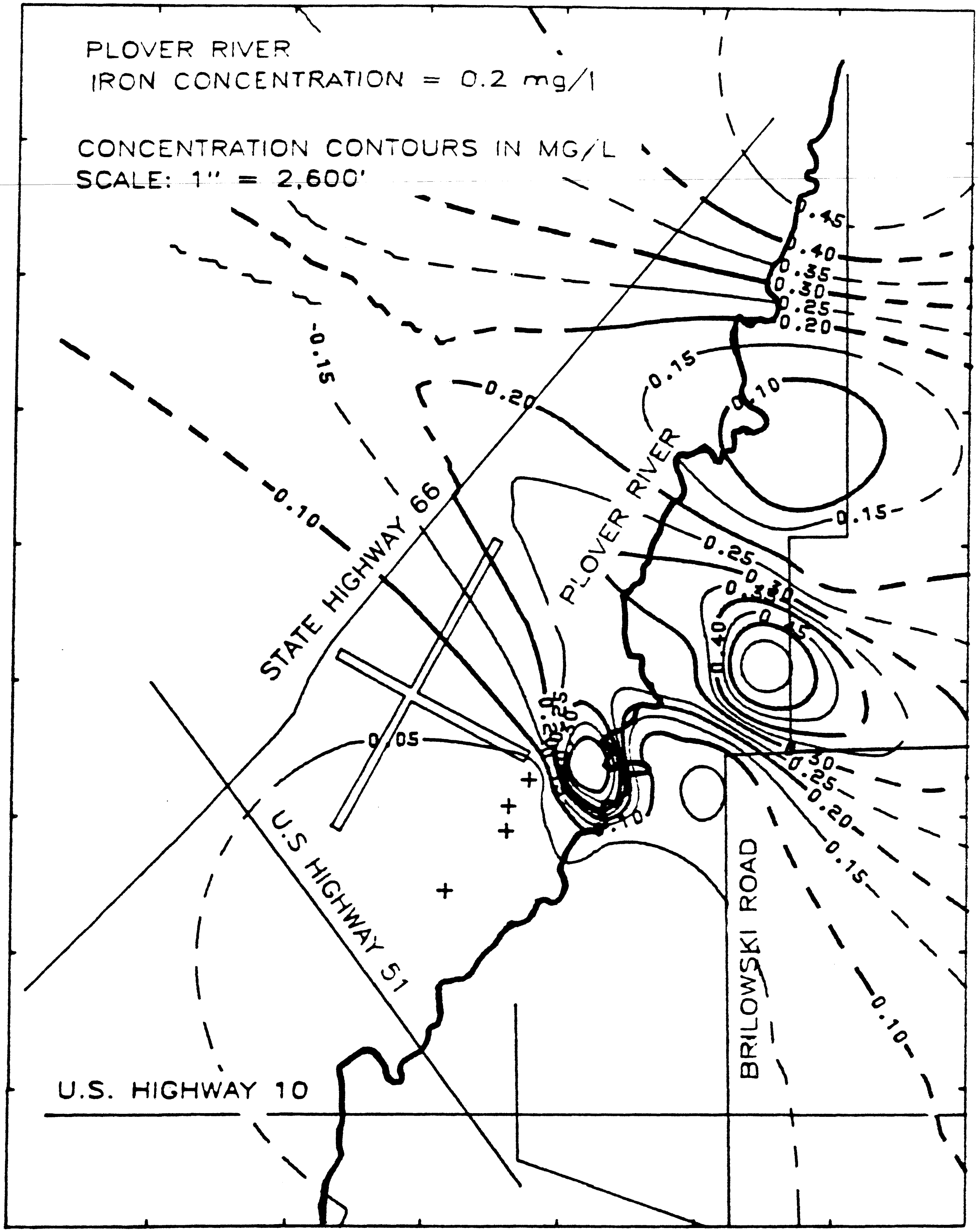


Figure 33 . Deep Aquifer Iron Concentration Contours.

matter in the soils. The resulting reducing conditions east of the river could then convert the iron minerals within the aquifer into more soluble ferrous ion. Pumpage from the city supply wells could potentially pull recharge water from this area beneath the river towards the A nested wells. A second possible source of the higher iron concentration near A nest is the potentially reducing conditions as water from the river is used to recharge the aquifer. Changes in the water chemistry as the water leaves the river and is drawn through the aquifer may result in conditions more favorable for the conversion of iron-bearing minerals within the aquifer to more soluble ferrous ion.

Total Hardness

Hardness measures the total quality of multivalent cations in a sample and is typically expressed in mg/l of calcium carbonate equivalent (McGinley 1984). Calcium (correlation coeficient of .559) and Magnesium (correlation coeffiecent of .897) make up most of water hardness. The main water quality problem caused by excessive hardness of water is the formation of insoluble residues when hard water comes in contact with soap or is heated. For ordinary domestic purposes, hardness less than about 100 mg/l as $CaCO_3$ is generally not objectionable. (Hem 1985)

The hardness generally increased with depth and to the east of the Plover River. The hardness of samples taken from the city supply wells suggests that a significant amount of the recharge is from the deeper aquifer or that the groundwater at depths greater than the deepest piezometers is yet harder and is diluted by the softer shallow aquifer groundwater.

Sodium

Current drinking water regulations (Environmental Protection Agency, 1975) do not specify a maximum sodium concentration. Sodium is not particularly abundant in sedimentary rocks of the type that constitutes the State's principal bedrock aquifers, or in the sand and gravel aquifers of Portage County. Because of its high solubility in water, sodium tends to remain in solution after it comes in contact with groundwater. Sodium concentrations in groundwater may, however, increase or decrease through interaction with clay. (Kammerer 1981) Sodium may be introduced to the groundwater through the salt used in road deicing, septic system discharge or animal waste.

The shallow groundwater plot is given in Figure 34 which shows somewhat higher concentrations than the deep aquifer concentration plot given in Figure 35. It appears that the presence of sodium in the deep groundwater is the result of the shallow aquifer sodium plume pulled deeper from the influence of the city wells. The significant differences in concentration between the deep aquifer groundwater and shallow aquifer groundwater, would indicate that the high sodium plume is significantly diluted by the lower sodium recharge from the deeper aquifer and the Plover River. The presence of sodium in the groundwater sampled as a result of this study was highly correlated with sulfates (correlation coefficient of 0.62), suggesting that the presence of sodium is the result of septic system impacts occurring along Highway 66. The presence of sodium was only mildly associated with the presence of chloride ions which is commonly detected in areas of roadsalt impacts.

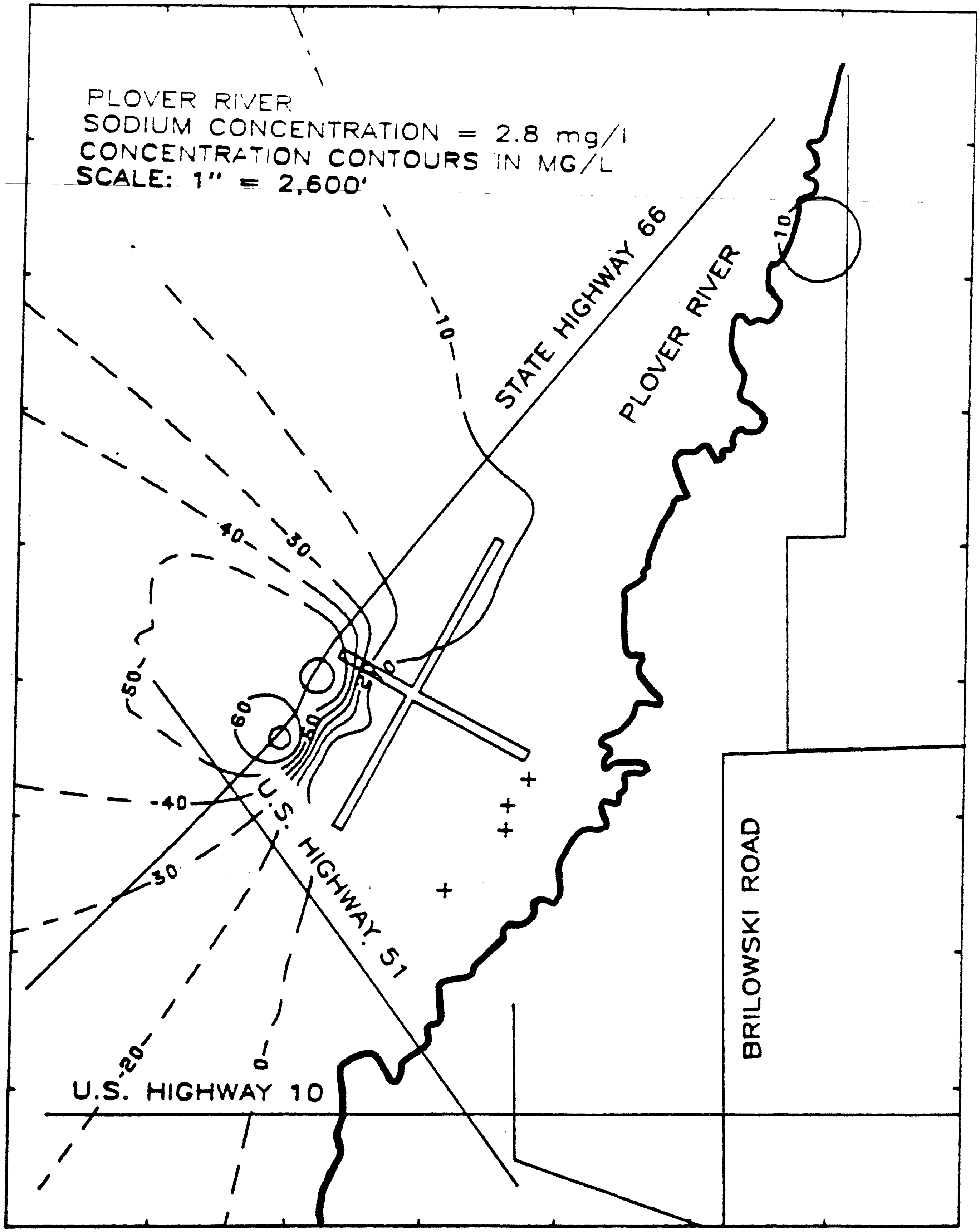


Figure 34. Shallow Aquifer Sodium Concentration Contours.

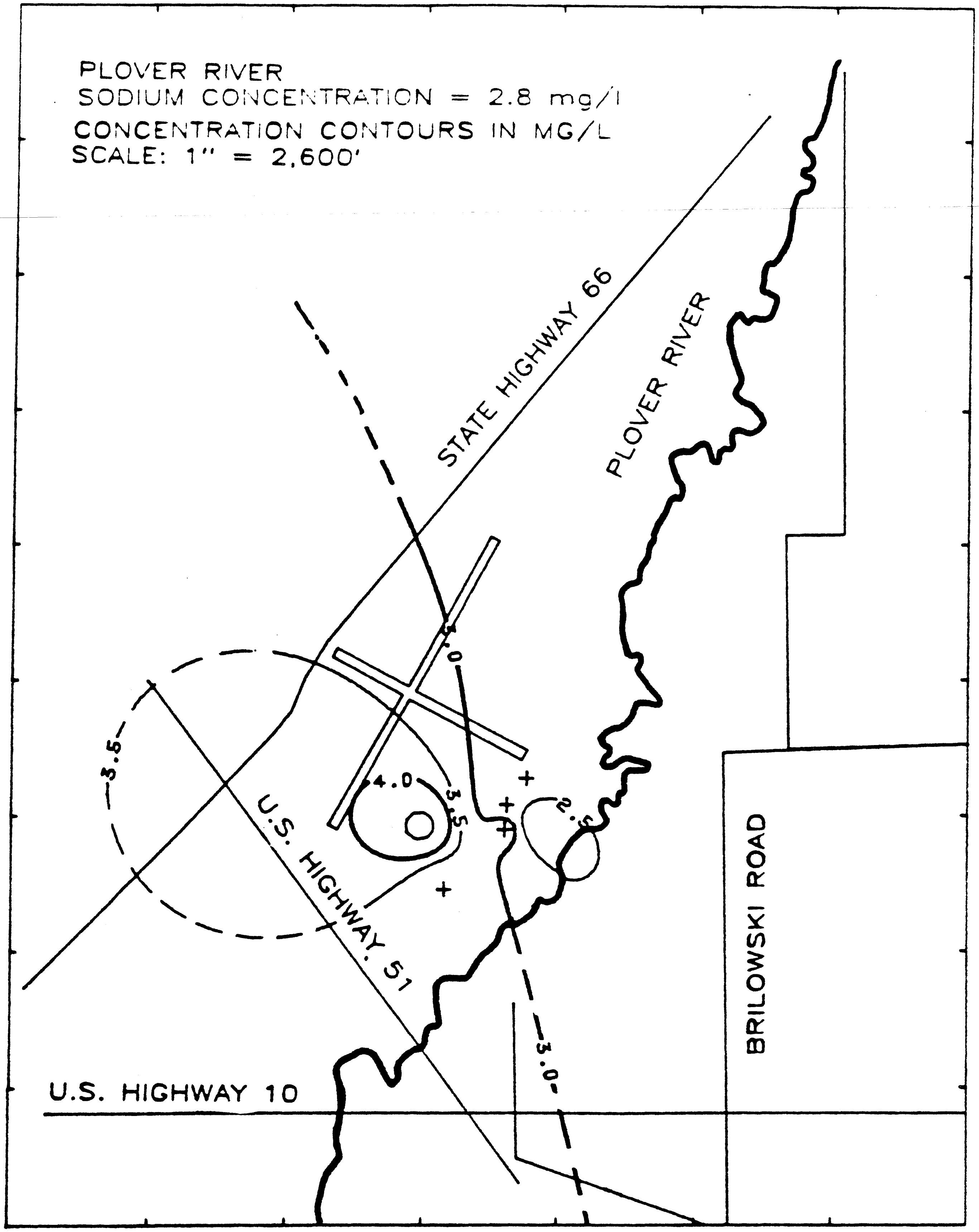


Figure 35. Deep Aquifer Sodium Concentration Contours.

Chemical Oxygen Demand

The Chemical Oxygen Demand is a measure of oxygen that would be required to oxidize the organic matter content in a sample. Natural groundwater contains very little organic matter and thus has a low COD usually less than 5 mg/l. The high CODs are possibly due to contamination during sampling. COD concentrations of the river water is naturally greater than most groundwater, averaging 21.5 mg/l while groundwater averaged 9.9 mg/l. The samples taken from the city wells averaged 3.7 mg/l, indicating presence of some dissolved organic chemicals. The primary concern with the presence of organics is that toxic chlorinated organic (like chloroform) could be formed during chlorination. More recharge from the Plover River or a significant change in the Plover River water quality could raise the COD of the city supply wells.

Tritium

Since the 1950's, Tritium has been introduced into the atmosphere and precipitation by man's activity with nuclear power and atmospheric testing of atomic weapons. Tritium is the only radioisotope of hydrogen. The radioactive H ion decays by pure beta emission with a half life of 12.3 years.

Figure 36 gives the tritium activity in precipitation since 1952. As Figure 36 illustrates, the atmospheric atomic testing of weapons during the 1950s - 1960s resulted in a peak tritium activity in precipitation during the early 1960s. By measuring the tritium activity in groundwater samples the general age of the precipitation recharge can be determined by comparing the tritium activity of the groundwater sample

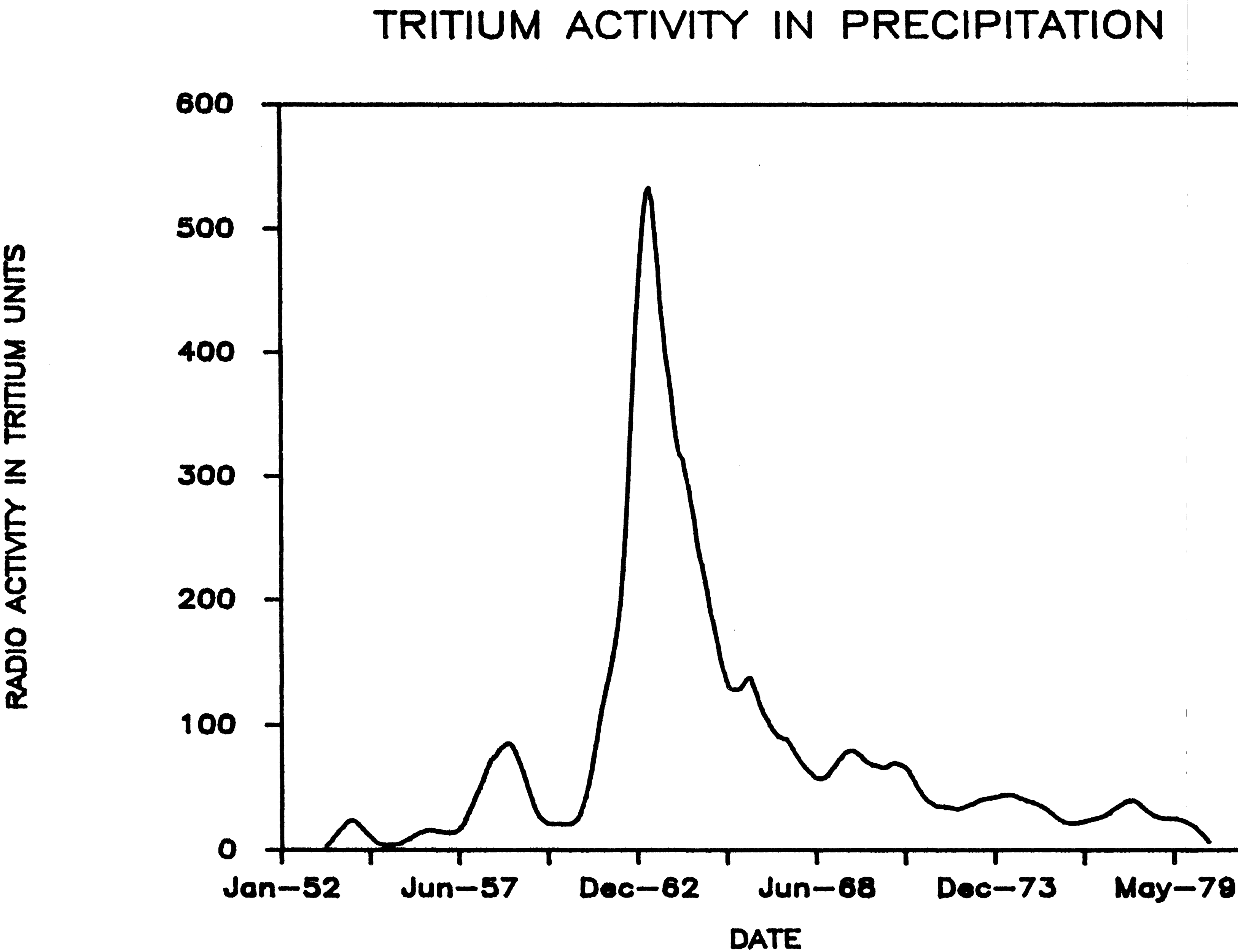


Figure 36. Tritium Activity in Precipitation.

to that of the tritium activity of the historic precipitation. Groundwater that is the result of precipitation from a per 1960's precipitation will have near zero tritium activity, while groundwater with a radioactive tritium activity of 100 TU (One Tritium Unit equals 1 atom of tritium per 10^{18} atoms of hydrogen.) or more is the result of precipitation recharge during the early 1960's. Current precipitation and groundwater recharge would contain about 30 TU. Samples taken from the monitoring wells, observation wells and city supply wells were analyzed for tritium activity. All of the samples showed similar activity levels (ranging from 42-82 TU), indicating that the area sampled contains largely post 1960's water and that any precipitation recharge during the early 1960s is diluted within the aquifer. This relatively short time from recharge to discharge provides a limited safety factor for attenuation or remediation of impacts to recharge water.

VI. Summary and Conclusions

Observations from the nested well systems installed as part of this study demonstrated that the groundwater flow near the city supply wells is predominately horizontal, suggesting that the groundwater flow was dominated by the pumpage from the city supply wells. The nested wells to the east of the Plover River demonstrated horizontal or slightly downward gradients as exhibited in the deeper piezometers of C - Nest. This would suggest that the grounwater flow in this area is dominated by pumpage from the city supply wells and that the city supply wells are acting as the predominate discharge source for the region, resulting in groundwater flow from east of the river beneath the river to the city supply wells. The absence of downward flow near the city supply wells (nests A and B) and the balanced chemistry of the city supply wells suggests that the city supply wells are extracting water over the entire saturated depth of the unconsolidated aquifer. This may be significant in that defining the recharge source of the deeper aquifer is very difficult. The groundwater found in the deeper aquifer is potentially water which recharged from regions a significant distants from the city well field.

Monitoring wells within the cone of depression and within the Plover River bed demonstrated that the Plover River is a significant source of recharge to the city supply wells. The river monitoring wells also illustrated that the cone of depression extends beyond the Plover River. This presents the concern that changes in the water quality of the Plover River could affect the city water supply. In addition,it must also be stressed that changes to the flow characteristics of the river and resulting river bed hydraulic conductivity would affect the ability for the river to contribute to the aquifer within the cone of depression. If the river was to be impounded within the cone of depression this would most likely interfere with the hydraulic connection between the river and the aquifer and require an additional recharge demand on other areas of the aquifer.

Elevated levels of nitrates, sulfates and chloride ion within the deep aquifer east of the river clearly identify impacts to the groundwater. The groundwater flow observations demonstrate that this area of impacted groundwater is in a position to recharge the city supply wells and potentially impact the city water supply.

Similarly elevated concentrations of nitrates, sulfates and chlorides were identified along Highway 66 northwest of the well field. Increased development in this area could potentially provide greater impacts to the groundwater in this region and effect the water quality of the city water supply.

Each of several recharge regions provided elevated concentrations of some chemical constituent. Yet in each case the high values were significantly diluted as the city wells withdrew water from the other regions. For example, the high nitrogen plume from east to the Plover River and in some wells along Highway 66 was diluted sufficiently to reduce the overall nitrogen content in the city supply wells, to well within the drinking water standard. While this will aid in protecting the city's water source from inorganic contaminents, other contaminates which may exceed water quality standards at trace concentrations may still present a potential threat to the city's water supply. The agricultural practices to the east of the Plover River and the suburban development along Highway 66 present the greatest potential for trace organic contamination along with gas tanks on the airport property.

The groundwater flow patterns near the well field makes it impossible to delineate the absolute recharge area. The theoretical recharge area presented in Figure 8 and 13 presents the area which is most likely to contribute to the city water supply. Areas outside of the recharge area presented in Figure 8 and 13 could conceivably contribute to the recharge of the city supply wells but it is felt that sufficient dilution and attenuation of contaminates would occur prior to arriving at the city supply wells and therefore provides an acceptable margin of safety. The City is fortunate to have its well field located in an are with undeveloped area along the Plover River to buffer and dilute water inputs from more developed areas. It is also fortunate that the Plover River is presently of good water quality with few municipal or industrial discharges upstream from the well field.

Recomondations

The present study provides a water quality data base that should continue to be monitored for changes. The area along Highway 66 needs further evaluation to determine its potential impacts to the well field as does the deep aquifer east of the Plover River. Both of these areas are experiencing develpement that could adversely impact future water quality. All effort should be made to maintain the natural undeveloped ares along the Plover River north and east of the well field to prevent future developement in teh most cutiecal part of the recharge area.

VIII. REFERENCES

American Public Health Association. 1985. Standard Methods for the Examination of Water and Wastewater. 16th Edition.

Cherry, J. A. and Freeze, R. A. 1979. Groundwater. Prentice-Hall, New Jersey.

Donohue and Associates, Consulting Engineers. October 1980. Comprehensive Water Study.

Driscoll, F. G. 1986. Groundwater and Wells. Johnson Division, St. Paul, Minnesota.

Hem, J.D. 1985. Study and Interpretation of Chemical Characteristics of Natural Water. Third Edition. United States Geological Survey Water-supply Paper 2254.

Hickok, Eugene, A. and Associates. November, 1965. Ground Water Investigation At City of Stevens Point, Wisconsin.

Hickok, Eugene, A. and Associates. January 1981. Hydrogeolgic Study Airport Well Field.

Holt, C. L. R. 1965. Geology and Water Resources of Portage County Wisconsin. Geological Survey Water-Supply Paper 1796.

Kammerer, Phil, A. Jr. 1981. Groundwater Quality Atlas of Wisconsin.

McGinley, Paul, M. and Kmet, Peter. August 1984. Formation, Characteristics, Treatment and Disposal of Leachate from Municipal Solid Waste Landfills. Wisconsin Department of Natural Resources, Wisconsin.

Murray Lloyd. Oral Communication in February, 1985.

National Academy of Sciences and National Academy of Engineering. 1972 Water Quality Criteria. Report of Committee on Water Quality Criteria, U.S. Environmental Protection Agency, Washington D.C.

Shaw, Byron. Oral Communication in January, 1984.

Strand, John, A. and Associates. April 20, 1965. Reconnaissance Groundwater Investigation for the City of Stevens Point, Wisconsin.

APPENDIXES

CHEMISTRY DATA. ALL VALUES IN MG/L UNLESS OTHERWISE NOTED

Well	K	Mg	Fe	pH	Cond in UMHOS	Alk	Hardness	Ca	COD	React P	Total P	Amn	Nitrates	TKN	Cl	Sulfate	Na	Mn	Tritium Activity in TU
SAMPLED ON JANUARY 30, 1984																			
CSW #6	1.00		0.00	7.7	333	168	178	106	12.0	0.002		0.06	0.0		5.5	6.8	2.4	0.17	
CSW #7	1.00		0.00	7.7	325	154	168	102	3.0	0.005		0.02	0.4		7.7	6.8	3.0	0.25	
CSW #8	0.80		0.00	7.7	247	108	128	72	0.1	0.002		0.12	1.0		6.6	8.2	2.8	0.00	
CSW #9	0.60		0.00	8.1	282	112	145	84	3.0	0.010		0.03	1.3		9.0	11.2	3.0	0.00	
SAMPLED ON JULY 9, 1984																			
CSW #6	0.01			7.6	349	168	20	133		0.006		0.08	1.0		14.0	21.5			
CSW #7	0.03			7.5	295	154	168	114		0.002		0.04	0.5		9.7	10.5			
CSW #8	0.02			7.7	302	149	175	108		0.005		0.04	1.6		13.2	13.0			
CSW #9	0.14			7.9	242	104	136	71		0.020		0.06	1.5		13.3	15.5			
OB #1				6.7	73	12	22	10		0.100		0.06	1.0		8.5	6.5			
OB #2				9.6	320	134	22	10				0.04	0.6		2.5	16.0			
OB #3				8.3	74	32	48	1		1.800		0.12	0.8		0.0	8.5			
OB #4				7.0	99	23	41	1		0.002		0.14	3.6		5.3	16.0			
OB #5	1.00	7	0.05	8.5	152	70	74	18	2.0										
PLOVER RI	0.33			8.2	320	170	196	108		0.020		0.14	1.0		9.1	12.5			
SAMPLED ON JULY 18, 1984																			
A-60			0.70	7.7	318	158	171	106	16.0	0.015				6.10	10.5				
A-40			0.56	7.7	333	154	175	104	13.6	0.015					10.2	12.0			
B-60			0.10	7.6	380	182	214	106	8.0	0.020					5.2	22.0			
B-40			0.06	7.8	315	156	186	126	20.9	0.062					5.8	10.5			
B-20			0.04	8.2	254	120	143	75	4.9	0.008					2.1	16.0			
C-60			0.43	7.3	447	168	237	145	10.5	0.008					19.3	17.0			
C-40			0.15	7.5	390	140	208	122	5.5	0.006					15.6	14.0			
C-20			0.02	8.6	114	42	59	31	9.2	0.025					2.8	9.0			
D-60			0.10	7.4	440	164	233	157	3.7	0.005					21.2	16.0			
D-40			0.08	7.4	360	130	190	110	20.3	0.032					13.6	15.0			
D-20			0.03	7.1	76	18	37	18	3.7	0.010					1.2	10.5			
MW #1			0.32	7.3	184	74	102	49	28.3	0.005					1.1	16.0			
PLOVER RI			0.40	8.1	299	144	165	102	35.1	0.002					5.8	8.5			
SAMPLED ON AUGUST 29, 1984																			
CSW #4										0.005		0.05	2.4						
CSW #5										0.006		0.04	3.5						
CSW #6										0.002		0.05	1.0						
CSW #7										0.002		0.04	0.5						
CSW #8										0.004		0.02	2.2						
CSW #9										0.012		0.13	1.5						

A-60 = WELL NEST A, DEEP PIEZOMETER (60 FEET)
OB = AIRPORT OBSERVATION WELLS
MW = SINGLE DEPTH MONIORING WELLS
CSW = CITY SUPPLY WELL

CHEMISTRY DATA. ALL VALUES IN MG/L UNLESS OTHERWISE NOTED

	K	Mg	Fe	pH	Cond UMHOS	Alk	Hardness	Ca	COD	React P	Total P	Amn	Nitrates	TKN	Cl	Sulfate	Na	Mn	Tritium Activity TU
SAMPLED ON OCTOBER 18, 1984																			
PLOVER RI		12		7.9	260	110	124	70	37.6	0.002	0.048	0.08	0.4	0.88	7.8	8.0			
SAMPLED ON OCTOBER 29, 1984																			
CSW #6	0.90		0.00		412	176	210		4.8	0.004	0.010	0.02	1.0	0.03	10.4	26.5	2.1	0.14	43
CSW #7	0.90		0.00		314	144	165		1.2	0.005	0.008	0.04	0.5	0.03	7.1	13.0	2.6	0.30	42
CSW #8	1.10		0.00		371	158	196		1.2	0.002	0.015	0.03	2.5	0.02	11.0	14.5	2.7	0.06	54
CSW #9	1.00		0.02		264	100	133		2.4	0.068	0.075	0.02	1.5	0.00	10.6	16.0	3.3	0.00	56
A-60	1.50		0.25		347	160	179		10.8	0.000	0.225	0.04	0.0	0.19	6.5	8.0	2.5	0.00	53
A-40	1.60		0.60		332	154	173		3.6	0.005	0.134	0.00	0.0	0.12	6.3	12.0	2.4	0.00	49
A-20	2.10		0.44		338	156	175		1.8	0.008	0.028	0.02	0.0	0.06	6.1	12.0	2.6	0.02	48
B-60	1.50		0.04		388	174	208		3.0	0.000	0.220	0.01	0.0	0.14	9.2	21.0	1.9	0.02	53
B-40	1.10		0.02		319	158	171		9.6	0.000	0.088	0.04	0.0	0.35	5.8	6.0	2.1	1.06	51
B-20	0.80		0.06		267	120	157		0.6	0.000	0.012	0.10	0.0	0.11	0.0	16.5	1.6	0.00	53
C-60	1.90		0.22		456	170	239		6.6	0.000	0.248	0.02	6.8	0.38	22.8	17.5	2.7	0.00	58
C-40	1.20		0.06		409	150	208		12.0	0.010	0.070	0.00	6.2	0.14	17.2	15.0	2.1	0.00	55
C-20	0.70		0.00		112	42	51		0.1	0.005	0.026	0.00	0.5	0.14	1.8	9.0	1.2	0.00	49
D-60	1.20		0.06		454	162	231		3.0	0.000	0.155	0.01	7.0	0.24	18.5	16.5	2.4	0.00	53
D-40	0.90		0.04		365	130	186		1.8	0.000	0.052	0.01	6.8	0.38	13.7	15.5	2.4	0.20	63
D-20	0.60		0.10		74	18	29		0.6	0.000	0.016	0.01	1.2	0.13	0.0	11.0	1.0	0.00	58
MW #1	0.70		0.33		196	94	108		26.4	0.004	0.016	0.04	0.0	0.36	0.0	11.0	0.9	0.01	85
POLVER RI	1.70		0.12		338	152	182		14.4	0.000	0.045	0.04	0.8	0.54	6.1	7.5	2.4	0.00	47
POLVER RI	1.00		0.10		351	172	196		12.6	0.000	0.035	0.10	1.0	0.49	7.8	9.5	3.9	0.00	62
SAMPLED ON NOVERMBER 15, 1984																			
CSW #7	0.60	19	0.00	7.8	335	156	174	41	5.4	0.005	0.010		0.0	0.03	4.7	11.0	2.6	0.40	
CSW #8	0.70	18	0.00	7.8	330	144	170	40	4.1	0.006	0.005		1.5	0.01	6.6	11.0	3.3	0.05	
CSW #9	0.50	14	0.00	8.3	274	104	136	32	3.4	0.010	0.010		1.5	0.00	7.1	16.5	3.0	0.00	
A-60	1.50	18	0.40	7.8	343	168	180	41	10.9	0.000	0.006		0.0	0.06	5.3	7.0	3.0	0.02	
A-40	1.50	18	0.58	7.7	324	154	170	37	7.5	0.025	0.010		0.0	0.01	4.6	8.5	2.7	0.00	
A-20	0.60	19	0.41	7.9	335	164	180	38	6.8	0.012	0.004		0.0	0.04	4.8	10.0	2.8	0.02	
B-60	1.20	22	0.02	7.6	384	172	206	47	9.6	0.010	0.012		0.0	0.00	6.1	24.0	2.2	0.02	
B-40	1.00	19	0.02	7.6	317	160	172	38	20.5	0.000	0.000		0.0	0.16	3.0	9.0	2.5	1.00	
B-20	0.60	14	0.06	8.1	259	122	140	31	4.8	0.000	0.000		0.0	0.00	1.1	16.5	1.8	0.00	
C-60	0.70	27	0.22	7.4	437	164	228	50	6.8	0.005	0.005		6.5	0.20	16.8	16.0	2.7	0.00	
C-40	0.90	24	0.02	7.5	390	150	200	44	5.4	0.002	0.012		6.2	0.16	13.5	12.5	2.1	0.00	
C-20	0.50	4	0.00	8.8	109	38	50	12	2.0	0.005	0.008		1.0	0.04	2.3	8.0	1.4	0.00	
D-60	1.00	26	0.10	7.4	433	158	222	48	7.5	0.004	0.050		7.5	0.26	15.8	16.0	2.6	0.00	
D-40	0.60	21	0.02	7.6	361	128	182	40	6.8	0.002	0.008		7.0	0.21	12.9	14.0	2.2	0.20	
D-20	0.50	2	0.02	7.1	74	16	30	8	2.0	0.005	0.005		1.5	0.00	0.0	15.5	0.8	0.00	
MW #1	0.40	6	0.91	7.2	146	64	76	17	23.2	0.005	0.005		0.0	0.30	0.0	11.0	0.9	0.02	
MW #2	0.90	6	7.30	8.2	176	66	82	19	12.3	0.060	0.024		1.8	0.05	5.5	8.5	4.6	0.30	
MW #3	1.00	8	0.15	7.9	194	88	100	21	7.5	0.005	0.024		0.0	0.25	2.2	7.0	2.6	0.02	
MW #4	2.50	15	0.24	7.6	328	134	148	32	112.0	0.002	0.015		0.0	0.36	19.9	2.0	10.2	0.05	
MW #5	1.60	11	0.12	7.6	254	112	128	28	42.4	0.000	0.020		0.0	0.20	5.6	8.5	4.0	0.40	
OB #1	3.50	1	0.12	6.1	85	4	20	5	2.0	0.026	0.035		1.0	0.00	9.4	6.0	5.6	0.10	
OB #3	0.50	0.5	0.10	7.0	39	8	12	4	33.5	0.195	0.200		0.0	0.04	11.1	5.0	1.9	0.00	
OB #4	1.00	2	0.20	6.9	92	26	34	8	11.6	0.185	0.210		1.6	0.00	1.5	7.0	4.2	0.00	
OB #5	1.00	7	0.05	8.6	152	70	74	18	2.0	0.090	0.080		0.5	0.00	0.0	5.0	1.5	0.00	
RIVER MW	1.40	11	0.12	7.8	250	110	128	27	20.5	0.006	0.002		1.0	0.21	4.3	6.0	2.4	0.00	
PLOVER RI	1.00	13	0.14	8.0	264	120	136	31	19.1	0.005	0.008		1.0	0.34	4.4	6.5	2.6	0.00	
PLOVER RI	1.00	14	0.20	8.1	267	122	140	31	19.8	0.000	0.005		1.5	0.24	5.6	8.0	2.7	0.02	

CHEMISTRY DATA. ALL VALUES IN MG/L INLESS OTHERWISE NOTED

	K	Mg	Fe	pH	Cond UMHOS	Alk	Hardness	Ca	COD	React P	Total P	Amn	Nitrates	TKN	Cl	Sulfate	Na	Mn	Tritium Activity TU
SAMPLED JANUARY 29, 1985																			
PLOVER RI				7.4	376	174	224	132	6.5	0.010	0.025	0.02	2.0	0.46	8.6	9.6	3.5	0.03	
SAMPLED FEBRUARY 18, 1985																			
CSW #6																		0.23	
CSW #7																		0.34	
CSW #8																		0.08	
CSW #9																		0.01	
SAMPLED ON MARCH 1, 1985																			
CSW #6																		0.14	
CSW #7																		0.31	
CSW #8																		0.14	
SAMPLED ON MAY 10, 1985																			
MW #3		10			195	80	92	20		0.002	0.012	0.28	0.0	0.32	6.0	5.5	2.5	0.19	
MW #4		17			372	126	160	33		0.000	0.006	0.31	0.0	0.23	48.0	7.0	11.5	0.05	
MW #5		14			684	220	240	33		2.300	4.650	26.00	0.0			15.5	32.5		

A-60 = WELL NEST A, DEEP PIEZOMETER (60 FEET)
OB = AIRPORT OBSERVATION WELLS
MW = SINGLE DEPTH MONIORING WELLS
CSW = CITY SUPPLY WELL

Deep Private Wells

	K	Mg	Na	Fe	Mn	Alkalinity	Ca	Total Hardness	Conductivity	Cl	Sulfate	Nitrates	TKN	Ammonia	Reactive Phosphorus	Total Phosphorus	COD	Well Depth
Sampled on February 22, 1985																		
SW1/4, NE1/4 Sec. 26	0.7	8.4		.03	.02	176	14	74	563	27	50.	9.5	.61	.08	.005	.015	13.2	70
NE1/4, NE1/4 Sec. 26		6.4		.04	.02	22	10	72	154		6.5	7.5	.88	.06	.006	.025	4.4	80
NW1/4, SW1/4 Sec. 24	8.0	29.0	2.6	.58	.05	184	41	210	365	16	13.	9.0	.44	.42	.022	.050	8.0	66
SE1/4, NW1/4 Sec. 24	6.5	34.3	2.7	.18	.05	184	50	256	413	12	16.5	1.0	.65	.06	.005	.005	31.4	63
SE1/4, SW1/4 Sec. 13		9.0		.05	.02	36	20	88	182		8.0	5.0	2.5	1.8	.004	.010	4.4	64
Sampled on April 24, 1984																		
SW1/4, NE1/4 Sec. 22				7.2	.41													80
NW1/4, SE1/4 Sec. 12				.48	.02	140	120	153	303	10.2	5.0	.2					.1	70
Range	0.7-8.0	6.4-34.3	2.6-2.7	.03-7.2	.02-.41	22-184	10-120	72-256	154-563	10.2-27	5.0-50	0.2-9.5	.44-2.5	.06-1.8	.004-.022	.005-.05	.1-31.4	
Average	5.1	17.4	2.65	1.2	.08	124	43	142	330	16.3	16.5	5.4	1.0	.48	.008	.021	10.3	
Standard Deviation	4.1	11.7	.07	2.6	.14	75	41	78	152	7.5	17.0	4.0	.84	.75	.008	.018	11.2	

Shallow Private Wells

	K	Mg	Na	Fe	Mn	Alkalinity	Ca	Total Hardness	Conductivity	Cl	Sulfate	Nitrates	TKN	Ammonia	Reactive Phosphorus	Total Phosphorus	COD	Well Depth
Sampled on February 22, 1985																		
SW1/4, NE1/4 Sec. 26		24.		.44	.02	54	25	138	268		14.	10.0	.02	.03	.005	.010	2.9	32
NW1/4, SW1/4 Sec. 25	1.2	11.	1.4	.16	.02	72	14	96	168	2	16.	3.0	.12	.03	.006	.006	3.6	44
NE1/4, NE1/4 Sec. 26	2.6	24.	8.4	.02	.02	122	20	180	326	12.	17.	4.5	.22	.06	.160	.168	2.9	30
SW1/4, SW1/4 Sec. 24 *	1.2	18.	2.7	.08	.02	18	31	148	301	26.	18.	15.2	.01	.08	.008	.008	5.1	32
SE1/4, NW1/4 Sec. 13	6.5	16.	6.0	.20	.02	78	16	108	186	7.	6.	.5	.42	.91	.002	.005	14.6	43
SE1/4, NW1/4 Sec. 13	0.2	.04	125	.03	.02	186	0	1	459	17.	22.	5.0	.71	.41	.002	.010	20.5	40
NE1/4, NE1/4 Sec. 14		34.		.02	.02	166	50	232	392		16.	4.2	.02	.01	.005	.005	3.6	40
SW1/4, NE1/4 Sec. 14	6.5	20.	11.5	.02	.02	88	25	132	264	13.	11.	5.6	.12	.10	.005	.010	2.2	
SE1/4, SW1/4 Sec. 14	3.5	20.	6.8	.11	.02	88	32	164	345	38.	11.	5.6	1.2	1.16	.002	.002	2.9	23
NE1/4, SE1/4 Sec. 14		20.		2.8	.02	102	29	158	318		7.5	7.0	.01	.03	.004	.005	2.9	25
NW1/4, NW1/4 Sec. 23	2.6	24.	20.	.02	.02	102	28	154	339	22.	14.	8.5	.18	.08	.006	.015	1.4	22
NE1/4, NE1/4 Sec. 22	9.0	14.	20.	.03	.02	68	17	100	244	28.	12.5	1.0	.05	.20	.005	.002	2.9	31
SW1/4, NE1/4 Sec. 22		7.4		.02	.02	58	15	72	130		6.5	.2	.94	.01	.005	.018	2.2	
NE1/4, SE1/4 Sec. 22	0.1	.03	63.	.02	.02	60	3	1	223	10	21.	5.0	.41	.07	.030	.035	7.3	27
SE1/4, SW1/4 Sec. 22	0.2	.04	73.	.03	.02	66	3	1	265	11.	16.	9.0	.75	.05	.115	.120	6.6	18
Sampled on April 24, 1984																	.1	30
NE1/4, NE1/4 Sec. 26				.02	.02	20		20										
SE1/4, NW1/4 Sec. 22				.14	.02	24	27	35	117	2.5	23.	1.2					2.2	23
NE1/4, NE1/4 Sec. 22				.06	.02	20	18	27	76	2.8	12.	.2					.1	22
NE1/4, NE1/4 Sec. 22				.04	.02	68	65	80	158	1.8	16.	.4					.1	25
SW1/4, SW1/4 Sec. 14				.02	.02	54	57	71	215	24.	13.	2.5					.1	25
NE1/4, SW1/4 Sec. 14				.02	.02		65	112										22
SW1/4, NE1/4 Sec. 14				.26	.06	148	143	188	375	24.	13.	2.0					2.7	
SW1/4, SW1/4 Sec. 12				.02	.02	120	100	129	246	4.0	9.	1.5					.1	28
SE1/4, SE1/4 Sec. 14				.02	.02		47	86										35
NW1/4, NE1/4 Sec. 13				.04	.02	190	196	240	445	9.6	24.	4.8					13.5	25
NW1/4, SE1/4 Sec. 13				.74	.12	144	155	208	395	13.4	28.	5.5					1.6	32
SW1/4, NE1/4 Sec. 13				.12	.02		55	94										40
SW1/4, SW1/4 Sec. 24 *				.12	.02	26	37	59	148	13.	9.	5.0					.1	42
SW1/4, SW1/4 Sec. 24				.02	.02		45	78										37
SW1/4, NW1/4 Sec. 25				.02	.02		102	147										27
NE1/4, NE1/4 Sec. 26				.02	.02	66	71	100	212	9.4	11.	5.0						44
NE1/4, NE1/4 Sec. 26				.32	.02		57	88										
Range	.1-6.5	.03-34	1.4-73	.02-2.8	.02-.12	20-190	0-196	1-240	76-459	1.8-38	6-28	.2-15.2	.2-1.2	.01-1.16	.002-.16	.002-.168	.1-20.5	
Average	3.1	15.5	21.3	.19	.025	85	50	118	265	13.8	15.	4.5	.35	.22	.024	.028	4.1	
Standard Deviation	3.0	10.1	25.5	.51	.019	50	47	57	104	9.9	5.7	3.6	.38	.35	.047	.049	5.1	