An improved hydrogeologic model for the Token Creek Watershed: final report to the Wisconsin Department of Natural Resources, October 2001. 2001

Bahr, Jean Marie; Parent, Laura

Madison, Wisconsin: Wisconsin Department of Natural Resources, 2001

051419

Report Summary

Title: An Improved Hydrogeologic Model for the Token Creek Watershed

Project I.D.: WDNR #93325

Investigators: Principal Investigator: Professor Jean Bahr,
Department of Geology and Geophysics
University of Madison, Wisconsin

Research Assistant: Laura Parent
Department of Geology and Geophysics
University of Madison, Wisconsin

Period of Contract: 07/01/1999 through 06/30/01

Background/Need: The Token Creek watershed is an important contributor of water to the Yahara River and the Madison chain of lakes. Much of the baseflow for Token Creek comes from springs. These springs provide the cold baseflow that is important for aquatic habitats. However, the future of the springs is threatened by increased demand for groundwater due to local population growth. Development of an improved hydrogeologic model for this area is important both for estimating the impacts of increased groundwater pumping and for planning the placement of future wells to minimize this impact.

Objectives: To improve the local hydrogeologic model for the Token Creek watershed.

Methods: A field study was conducted at Culver Springs in the town of Token Creek from July 1999 to June of 2001. Groundwater level recording devices were placed in several shallow monitoring wells and recorded water levels continuously over a period of many months. Groundwater and surface water samples were taken and analyzed for major ions and stable isotopes. Three bedrock monitoring wells were drilled in order to obtain hydrostratigraphic information that would lead to a better understanding of the focusing mechanism for the springs.

Using data from the field study, the MODFLOW model for the Token Creek watershed was improved. Layers were added to better represent the local hydrostratigraphy, and high-discharge stream nodes were added to simulate the presence of springs in the watershed.

Results and Discussion: The field study revealed that there are several highly permeable layers in the bedrock that most likely provide the focusing mechanism for the springs. Adding these layers and high-discharge stream nodes to the MODLFOW model resulted in a good approximation to actual spring flow.

Conclusions/Implications/ Recommendations: The packer testing and modeling results from this project suggest that the focusing mechanism for Culver Springs is the existence of relatively thin, high permeability zones in the St. Lawrence/Tunnel City Formations. These high permeability zones provide fast flowpaths for the water, which can explain the high nitrate content of the water at Culver Springs. The existence of high permeability zones is thought to be the focusing mechanism for other springs complexes in Dane County, such as Nine Springs.

Modeling also shows that the impact of groundwater pumping on Culver Springs should be minimized by keeping pumping at a distance from the springs. However, while Sun Prairie wells are presently closest to the springs, the town of DeForest could have a great impact if pumping is moved closer to the springs.

Related Publications: Domber, 2000. An Improved Hydrogeologic Model for Groundwater Flow in the Token Creek Watershed. Master's Thesis, Department of Geology and Geophysics, University of Wisconsin, Madison, 78 p.

Key Words: springs, MODFLOW, groundwater modeling

Funding: This project was funded by the Wisconsin Department of Natural Resources

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

AN IMPROVED HYDROGEOLOGIC MODEL FOR THE TOKEN CREEK WATERSHED

Final Report to the Wisconsin Department of Natural Resources. October 2001

Principal Investigator: Jean Bahr
Research Assistant: Laura Parent

University of Wisconsin
Department of Geology and Geophysics
Weeks Hall
1215 W. Dayton St.
Madison, WI 53706

TABLE OF CONTENTS

FIGURES

TABLES

I. INTRODUCTION

A. Purpose

The Token Creek watershed lies in northeastern Dane County, Wisconsin. Token Creek's baseflow principally comes from several spring complexes, the largest of which is Culver Springs, located at the Tom and Edna Culver Preserve in the Town of Windsor. The cold baseflow provided by the springs makes this creek a prime candidate for restoration as a trout habitat. However, prior to 1994, a dam located at Portage Road impounded the water into a large pond (Token Creek Pond) before it was released to Token Creek. In 1994, the dam partially failed, and the pond drained, leaving a large wetland complex. Restoration efforts by the Wisconsin Department of Natural Resources, the U.S. Army Corps of Engineers and the Town of Windsor are underway. However, the surrounding area is undergoing rapid growth as the communities of Sun Prairie, DeForest and Windsor expand their populations. The increased demand for groundwater is a threat to the springs that supply the cold baseflow to Token Creek.

The purpose of this research, funded by the Wisconsin Department of Natural Resources, was to develop an improved numerical model of the Token Creek watershed using field data collected during the project. This model can be used to assess the impact of increased local groundwater pumping on the springs that supply the cold baseflow to Token Creek.

B. Token Creek Watershed

The Token Creek watershed is a 27 square mile area that extends north to the Dane-Columbia county border, east to Sun Prairie, and south to Cherokee Marsh (Figure 1). Token Creek is a major contributor to the Yahara River, which empties into Lake Mendota. Baseflow per square mile of the watershed is much greater than for the neighboring Yahara River, which suggests that Token Creek has a larger groundwater basin than the surface watershed (WRM 1997). The watershed area was glaciated during the most recent Wisconsin glacial advance, while most of the upland areas are only covered with a thin sheet of glacial material. In some locations glacial cover can reach 200 feet or more. The glacial deposits are underlain by 800 to 1000 feet of Ordovician and Cambrian dolomite and sandstone over Precambrian crystalline rock.

The northern portion of the watershed consists of a plateau that reaches into southern Columbia county. The site of the old millpond is a glaciated valley that was once part of glacial lake Yahara. Drilling done in 1997 suggests that the glacial valley is very steep sided at the location of the Culver Springs complex (WRM 1997).

C. Culver Springs Complex

Culver Springs is a complex of several large springs and boils. The largest of the springs are impounded by berms into 4 small ponds. The overflow from these ponds flows via culverts into a tributary to Token Creek (hereafter referred to as the Spring Tributary). Smaller boils and seeps also exist in the bed of the old Token Creek Pond, especially between the spring ponds and the confluence of the Culver Tributary and Token Creek. Figure 2 shows these features on a recent aerial photo.

Stream gaging done in 1997, 1999 and again for this study shows that Culver Springs contributes approximately 6 cfs to the baseflow of Token Creek, or approximately 1/3 of its total baseflow before it enters the Yahara River.

II. BEDROCK MONITORING WELLS

A. Well Location and Installation

Three bedrock monitoring wells were installed in the Token Creek Watershed in June 2000. All three wells were located on Town of Windsor property. The first well was installed near Mueller Road, several miles north of the Culver Springs complex. The purpose of installing this well was to examine the stratigraphy in the recharge area for the springs. The second and third wells were installed at Culver Preserve in order to examine the stratigraphy near the springs. Figure 3 shows the location of the wells.

The wells were drilled by a local well drilling company (Water Wells, Inc.). Samples were collected every 5 feet for all three wells, and are on file at the Wisconsin Geologic and Natural History Survey (WGNHS). The Mueller Road well (DN-1434) was drilled using the mud rotary method to a depth of 37 feet below ground surface (bgs), then 5 inch steel casing was set and grouted. A 5 inch borehole was then drilled a further 333 feet using the air hammer method, for a total well depth of 370 feet bgs. This borehole is open to the Prarie du Chien , Jordan, St. Lawrence, Tunnel City, and Wonewoc Formations. Because the shaley facies of the Eau Claire Formation is absent in this area, the contact between the Wonewoc and the Mt. Simon Formations is difficult to detect. Therefore, a small portion of the upper Mt. Simon Formation may also be present in the lowest 10 feet of the borehole.

The first well at Culver Preserve (CP 1, DN 1435) was drilled using mud rotary to a depth of 35 feet bgs, then 6 inch steel casing was installed. A further 250 feet was drilled using air hammer and 4 inch casing was set and grouted. Finally, a 4 inch borehole was drilled a further 25 feet to give a total well depth of 310 feet bgs. The 4 inch borehole is open to the lower Wonewoc/upper Mt. Simon.

The second well at Culver Preserve (CP 2, DN 1436) was drilled using mud rotary to a depth of 35 feet, then 5 inch steel casing was set. A 5 inch borehole was then drilled a further 165 feet for a total well depth of 200 feet bgs. The borehole is open to the St. Lawrence, Tunnel City and upper Wonewoc Formations.

The Well Construction Reports and Monitoring Well Construction Reports for these wells are included in Appendix A.

B. Borehole Geophysics

In June and July of 2000, CP1, the Mueller Road monitoring well and a private well on Mueller Road were logged using borehole geophysical tools. In March of 2001, CP2 was also logged. Natural gamma, caliper, single point resistance, and spontaneous potential logs were completed at the Mueller Road monitoring well, Mueller Road private well, and CP2. In addition, a fluid temperature log was competed at CP2. Temperature logs were not collected at Mueller road or at CP1 because the temperature probe was not functioning at the time those wells were logged. Natural gamma, single point resistance and spontaneous potential logs were completed to a depth of 285 feet bgs at CP1 before the well was cased.

Geophysical logs are included in Appendix B. Gamma logs are the most useful in identifying lithology in the wells, since they detect the presence of clay and shale, which have a higher natural gamma radioactivity than clean sandstone or dolomite. The Wonewoc Formation is a fine to medium grained clean sandstone, and has a low gamma intensity. The Jordan and St. Lawrence Formations and the Tunnel City Group contain more clay and shale, and can be identified by their higher gamma intensities.

Caliper logs for the 4 wells all show variability in the size of the borehole. Many of these caliper "spikes" may be fractures or voids that extend outwards into the formation. The fluid temperature log for CP2 shows discrete increases that correspond with caliper spikes, suggesting that significant amounts of water are entering the borehole at these intervals.

C. Straddle Packer Testing

In April of 2001, packer testing took place in CP2. A straddle packer assemblage designed by William Batten of the WGNHS, shown in Figure 4, was used to isolate 3.7 ft intervals in order to perform slug tests on the intervals. Slug test that gave non-oscillating results were analyzed using the Hvorslev method. Oscillating results were analyzed using the method of McElwee et al. (1992).

The results of the slug tests are listed in Table 1. Hydraulic conductivity ranges from over 1000 ft/day to less than 1 ft/day. The St. Lawrence, upper Tunnel City and lowest Tunnel City have the highest hydraulic conductivity values, while the middle Tunnel City and Wonewoc have the lowest.

Figure 5 presents the results from the slug tests along with caliper and temperature measurements taken during geophysical logging. The intervals with the highest values (at 750, 805, 825, 855 and 865 feet) correspond to fractures detected by the caliper. Temperature "jumps" on the fluid temperature logs are also intervals where high conductivity was measured. This suggests that these intervals have a high rate of flow through.

III. MAJOR ION AND STABLE ISOTOPE GEOCHEMISTRY

A. Sampling Methods

Geochemical sampling of shallow monitoring wells and surface waters was done in March, June and September of 2000, and April/May 2001. Samples were also taken from private wells in June and September of 2000, and from bedrock monitoring well CP1 and selected intervals in CP2 during packer testing in April/May 2001. Sample locations for shallow wells and surface water at Culver Preserve are shown in Figure 6 and locations for Big Hill, private wells and the deep monitoring wells in Figure 7. All samples were analyzed for temperature, conductivity, alkalinity, pH and dissolved oxygen in the field. Samples were taken in clean 250 ml bottles, one each for metals and nutrients, and isotope samples were taken in clean 50 ml bottles. Metal samples were filtered and preserved in the field. Major ion samples were stored on ice, then delivered to the State Lab of Hygiene for analysis, while stable isotope samples were sent to Southern Methodist University. The complete data from the samples are included as Appendix C.

B. Discussion-Shallow Wells And Surface Water

Average values for each sampling location were used to divide samples into groups. These groupings are shown in Table 2. Group 1 has high nitrogen (>10 mg/l) and generally high chloride (>20 mg/l) and sodium (>6 mg/l). Also, these values are fairly consistent between sampling rounds. The high nitrate, chloride and sodium are probably due to human use of fertilizer and road salt. However, the consistent values of the samples suggest that the water travels along long flowpaths, resulting in the damping of any seasonal variations.

Group 2 consists of two shallow wells, which show marked variation between sampling rounds, especially in nitrate. These wells are both adjacent to a cultivated field. It is interesting to note that one of the wells shows a higher value in March, while the second well shows a higher value in June. The variability of these samples suggests that the water is travelling along short flowpaths.

Group 3 has low conductivity, nitrate, chloride and sodium. This group may contain a greater proportion of surface water. Two of these samples are from shallow wells in the former Token Creek Pond bed, the third is from a spring on Big Hill.

Group 4 has very high conductivity and alkalinity, and low dissolved oxygen and nitrate. These samples probably represent waters with fairly long residence times in glacial materials. This group consists of shallow wells on Big Hill and a shallow well in glacial material near Culver Springs.

Stable isotope results for shallow monitoring wells and surface waters are shown in Figure 8, along with the local meteoric water line from Hunt et al. (1998). Most samples from the springs (Seep, Big Pond, Big Hill and Pond 4) and samples from shallow.wells in the bed of the old Token Creek Pond(3 and 5) are clustered in the lower left, and show the influence of deep groundwater. Deep groundwater has lower del D and del O18 than surface water. Samples from upland wells are mostly clustered in the upper right on the chart, and indicate the predominance of surface water. Well 6A, which is a fairly deep well (40 ft) is placed between the two clusters, which indicates mixing of deep groundwater and surface water in that well. However, it still shows a greater influence of surface water than the nearby springs in Big Pond and Pond 4.

C. Discussion-Deep Wells

Table 3 shows the results from geochemical sampling of private wells and bedrock monitoring wells. Samples are presented in order of increasing depth. The shallowest samples have higher sulfate, chloride and nitrogen than the deepest samples, as expected. pH is above 7 in all samples

Figure 9 shows stable isotope results for deep wells. All samples show the predominance of deep groundwater, except one private well, which has a mixing signature between surface water and deep groundwater.

IV. GROUNDWATER AND SURFACE WATER MONITORING

A. Groundwater Levels

Groundwater levels were measured in several shallow wells and the two deep monitoring wells at Culver Springs. Groundwater levels were recorded with Global Water Waterloggers, which took readings at 30 minute intervals over periods of many months. Selected data are shown in Figures 10, 11 and 12. Figure 10 shows groundwater levels in spring of 2000 in a nested pair of shallow monitoring wells, 6A and 6B. These wells are located just to the east of the spring ponds (see Figure 6 for locations). The screened inteval of the shallower well, 6B is at approximately 13 feet, while 6A is screened at 40 feet below ground surface. As can be seen in the figure, there is a strong upward gradient between the two wells: water levels in 6A, the deeper well, are about 3 feet higher than in the shallow well. In fact, water levels in this well are above the level of the ground surface. In addition, a strong response to rainfall events at 4/19/00 and 5/17/00 can be seen in the shallower well, with a more damped response in the deep well, as expected. The sudden drop-off of water levels in wells 6A and 6B on 5/1/00 may be due to a drop in the level of the nearest spring pond. The drop in pond water levels was most likely due to removal of blockage from the pond's outlets.

Figure 11 shows data from another nested well pair, 8A and 8B from August and September 2000. These wells are south of the old Token Creek Pond (see Figure 6 for locations). Well 8B is screened at 11 feet and well 8A is screened at 46 feet. There is an upward gradient between the two wells, but it is not as strong as at the 6A and 6B pair. Both wells exhibit similar responses to rainfall events on 8/4/00 and 8/16/00, but shallow well 8B also shows a strong daily ET signal.

Figure 12 has data from the two bedrock monitoring wells at Culver Preserve, CP 1 and 2. Note that there are two different Y-axes on this chart, since water levels in CP1 are about 9-10 feet higher than in CP2. The deeper of the two wells, CP1, is open only in the lowest 20 feet of the well, from 290 to 310 feet below ground surface. CP 2 is open from 40 to 200 feet bgs. CP1 shows daily fluctuations that, at this depth, are probably due to daily cycles of groundwater pumping.. CP1 also shows variations over several days that are probably due to longer term groundwater pumping cycles. CP2 displays a more damped response to groundwater pumping.

B. Surface Water Temperatures

Surface water temperatures were measured with Hobo temperature gages in the Spring Tributary and in one of the boils in the Big Pond in May and June of 2000. The results are shown in Figure 13. Temperatures at the boil are very constant, at approximately 9.5 °C. Temperatures in the Spring Tributary respond to solar heating and to rainfall events. However, the water temperature in the Spring Tributary consistently returns to 9.5 °C, the same as that of water coming from the boil. One question of importance to the restoration of Token Creek is whether or not the Spring Ponds are causing significant.heating of the spring water before it is released into the Spring Tributary. These results suggest that there is not significant heating, since warming in the Spring Ponds would lead to sustained temperature elevation in the Spring Tributary, which is not seen.

C. Stream Gaging

In the summer of 2001, two stream gaging stations were placed in the Spring Tributary. The stations each had a stilling well with a waterlogger and a staff gage. The waterlogger data were correlated to the staff gage, and the staff gages were surveyed relative to each other, in order to obtain the gradient between the gages. The data from the waterloggers are shown in Figure 14. The upstream waterlogger is approximately 500 feet from the downstream gage, and the gradient is .1 feet per 500 feet, or .0002. As can be seen in the figure, response to several rainstorm events is rapid. A gradual increase in stage takes place starting on June 20th due to the growth of vegetation in the stream bed, rather than change in baseflow. Daily fluctuations in stage are also evident, and may be due to ET or may be a response to groundwater pumping.

A stage discharge curve was attempted for the Spring Tributary. However, no correlation was found between stage and discharge

V. NUMERICAL MODEL IMPROVEMENTS

A. Description of Original Model

The main goal of this project was to improve the numerical model of Token Creek developed by Steve Domber and described in his thesis (Domber, 2000). This is a finite-difference MODFLOW model, developed using the Groundwater Vistas pre- and post-processor. The model was created by the Telescopic Mesh Refinement (TMR) method from the regional scale Dane County model. TMR allows a new model to be created from a portion of a larger model, in order to focus on local features. Boundary conditions for the local model are determined by the larger model.

The initial TMR model was further refined by adding layers representing local stratigraphy, refining the grid, and calibrating to added head targets. Calibration was achieved by varying recharge rates, adding stream nodes and varying hydraulic conductivity in the model layers. A full description of this process is presented in Domber (2000).

In the present project, the TMR model was further improved by adding a layer to represent the Tunnel City formation, adding stream nodes to represent the focused flow at Culver Springs, and by adjusting hydraulic conductivities in some of the layers to reflect the findings from the straddle packer slug tests.

In the original TMR model the Tunnel City and Wonewoc formations were represented by a single layer with a hydraulic conductivity of 5 ft/day. In the improved model, this single layer was split into two, the upper portion representing the Tunnel City formation with a hydraulic conductivity of 20 ft/day and a lower portion representing the Wonewoc, which remained at 5 ft/day.

The St. Lawrence formation, which had a hydraulic conductivity of 5 ft/day in the original model, was changed to 250 ft/day to reflect the high hydraulic conductivity values obtained in the slug tests. Stream nodes were then placed in this layer at the site of Culver Springs to represent the focused flow at the springs. The springs have a flow of 6-8 cfs; the model simulated flow of 6 cfs at these stream nodes. The original TMR model did not reproduce any of the spring flow at Culver Springs, so this represents a significant improvement in calibration. These changes did not significantly affect the calibration of the initial model to head targets.

The particle tracing program, MODPATH was used to delineate the groundwater basin for upper Token Creek and its tributaries in the refined model. Particles were placed in Token Creek grid cells and traced upgradient to their recharge sources by the program. Figure 16 shows the groundwater basin, which extends north into Columbia County and southeast into Sun Prairie. Note that the inclusion of a high permeability layer extends the groundwater basin past the northern edge of the model. A cross section (Figure 17) shows that the high permeablilty layer lengthens flow paths. Figure 18 shows the groundwater basin for Culver Springs alone. The basin also extends north past the model boundary into Columbia County. The long flow paths for the springs mean that response to recharge events will be damped, which agrees with the field evidence of constant flow coming from the springs.

B. Simulations

The refined Token Creek model was used to examine the effects of well location and increased pumping rates on Culver Springs and Token Creek. These simulations tested proposed new wells and pumping increases for the City of Sun Prairie and the Village of DeForest. The first simulation was run with the existing pumping rates taken from the Dane County model and imported into the original Token Creek TMR model. This simulation was run as a comparison to later simulations. The second simulation includes Sun Prairie Well number 7, which was not included in the original Token Creek model. For this simulation, well 7 was pumped at the same rate as well 5. The third simulation includes a proposed new well for Sun Prairie, which is also pumped at the same rate as wells 5 and 7. The fourth simulation tests a proposed well for DeForest, which is pumped at the same rate as Sun Prairie wells 5 and 7. In this fourth simulation, the proposed new Sun Prairie well is not included. Figure 19 shows the locations of the wells and the reporting stations for streamflow in the model.

The results of the simulations are presented in Table 4. Stream flow results are reported at 5 stations: Culver Springs(A), Token Creek at the confluence with the Spring Tributary (B), and the Spring Tributary at the confluence with Token Creek (C), Token Creek at the old pond dam (D) and Token Creek at the Yahara River (E). The two Sun Prairie wells have the greatest effect on flow in Token Creek before it reaches the Spring Tributary, while the DeForest well has a greater effect on the Spring Tributary. All have similar effects on the total flow of Token Creek when it empties into the Yahara River, and on flow from Culver Springs. In addition, all have similar effects on spring flow, with the Deforest well having only slightly more impact on the springs than the Sun Prairie wells.

VI. CONCLUSIONS

The packer testing and modeling results from this project suggest that the focusing mechanism for Culver Springs is the existence of relatively thin, high permeability zones in the St. Lawrence/Tunnel City Formations. These high permeability zones provide fast flowpaths for the water, which can explain the high nitrate content of the water at Culver Springs. The existence of high permeability zones is thought to be the focusing mechanism for other springs complexes in Dane County, such as Nine Springs (Swanson and Bahr, 2000).

Modeling also shows that the impact of groundwater pumping on Culver Springs should be minimized by keeping pumping at a distance from the springs. However, while Sun Prairie wells are presently closest to the springs, the town of DeForest could have a great impact if pumping is moved closer to the springs.

VII. REFERENCES

Domber, 2000. An Improved Hydrogeologic Model for Groundwater Flow in the Token Creek Watershed. Master's Thesis, Department of Geology and Geophysics, University of Wisconsin, Madison, 78 p.

Hunt, R.J., Bullen, T.D., Krabbenhoft, D.P., Kendall, C., 1998, Using stable isotopes of water and strontium to investigate the hydrology of a natural and a constructed wetland: Ground Water, Vol 36, No. 3, p. 434-443

McElwee, C.D., Butler, J.J., Jr., and Bohling, G.C. 1992. Nonlinear analysis of slug test in highly permeable aquifers using a Hvorslev-type approach, Kansas Geological Survey Open File Report 92-39

Swanson and Bahr, 2000. An Investigation of the Hydrogeologic Conditions Responsible for Springs in a Glaciated Terrain, Final Report to the Wisconsin Department of Natural Resources, 17 p.

Water Resources Management Practicum (WRM), 1997. Water Resources Atlas for Token Creek: Institute for Environmental Studies, University of Wisconsin-Madison, 140 p.

FIGURES

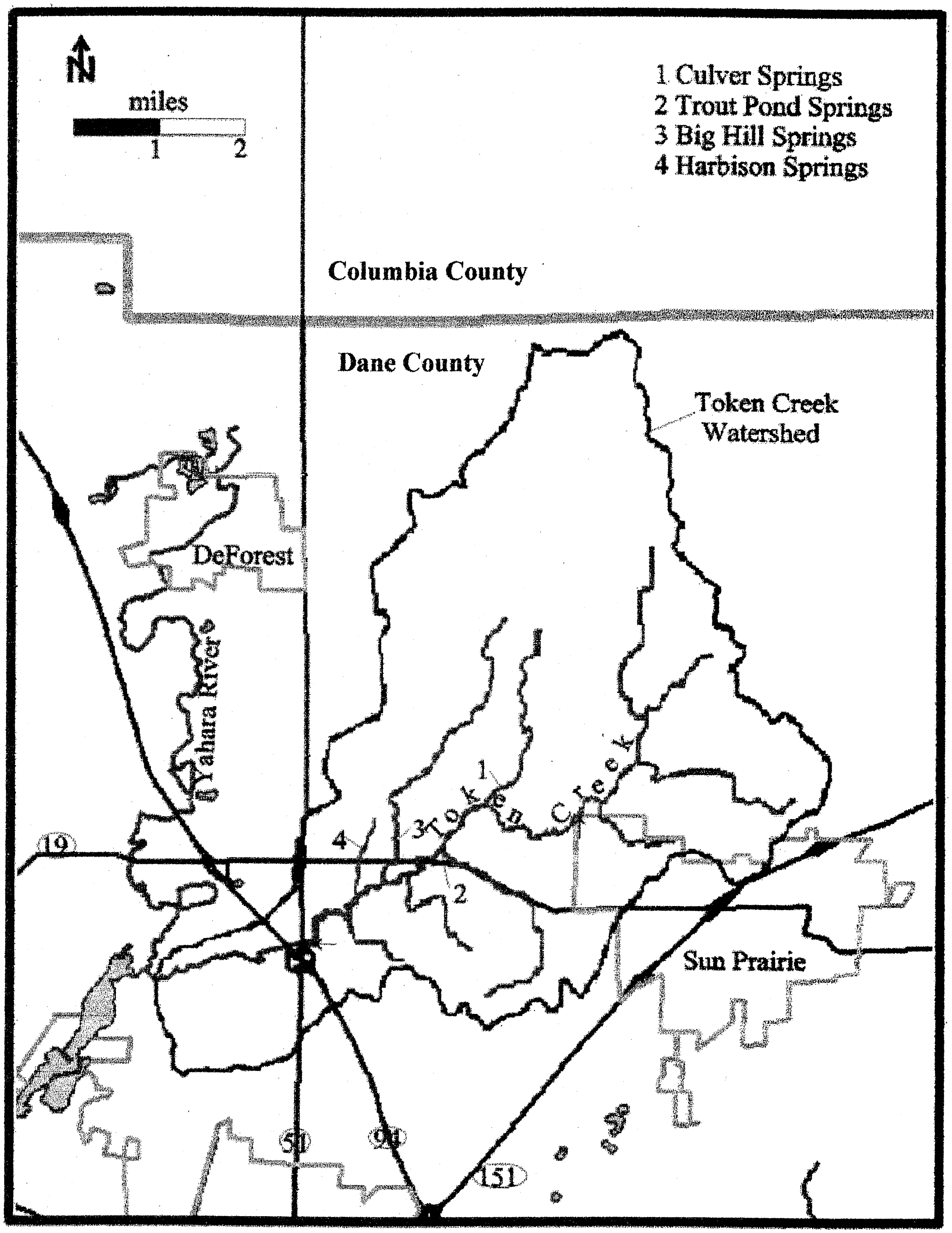


Figure 1. Token Creek watershed and spring locations (from Domber 2000)

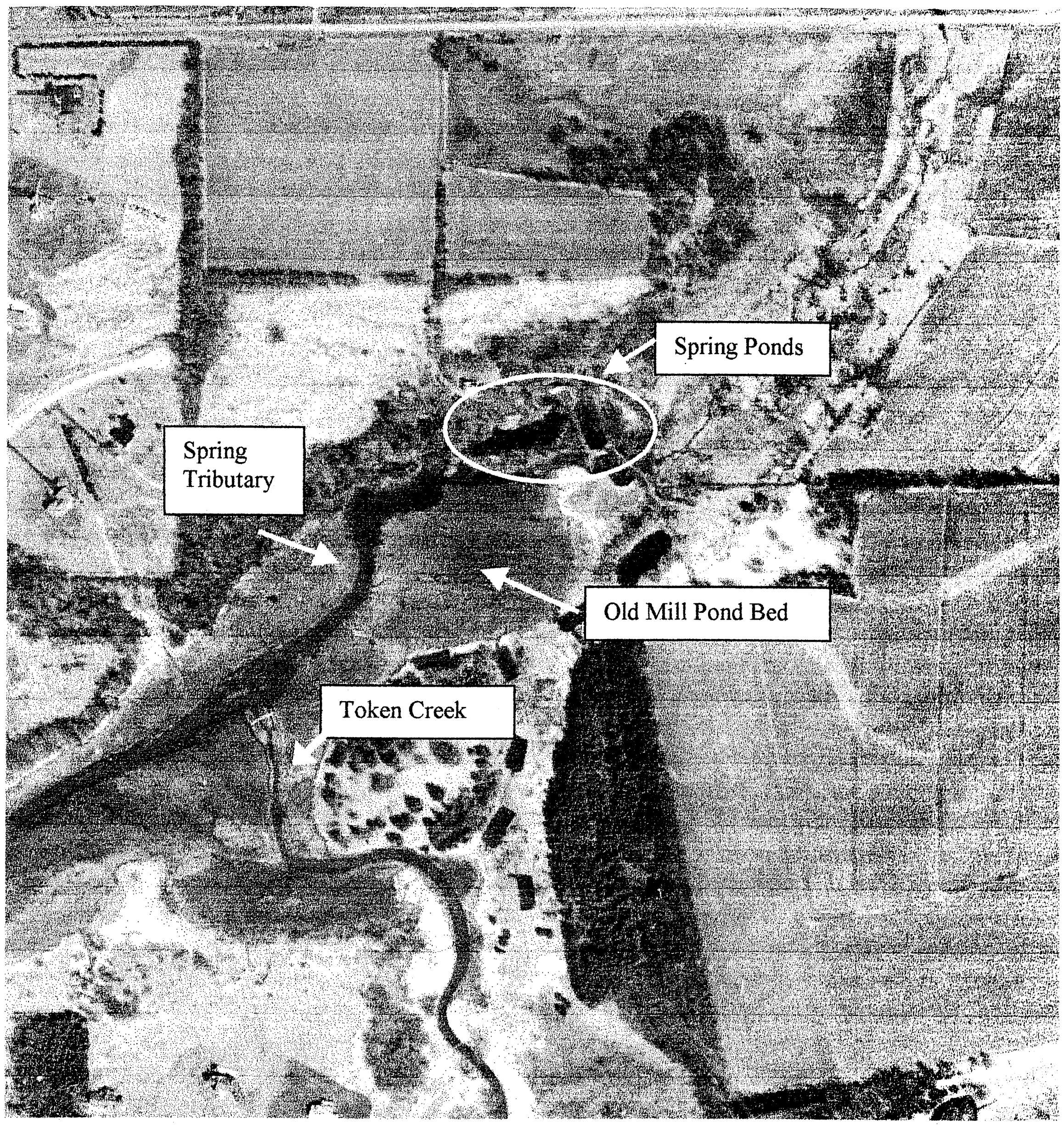


Figure 2. Features near the Culver Spring Complex

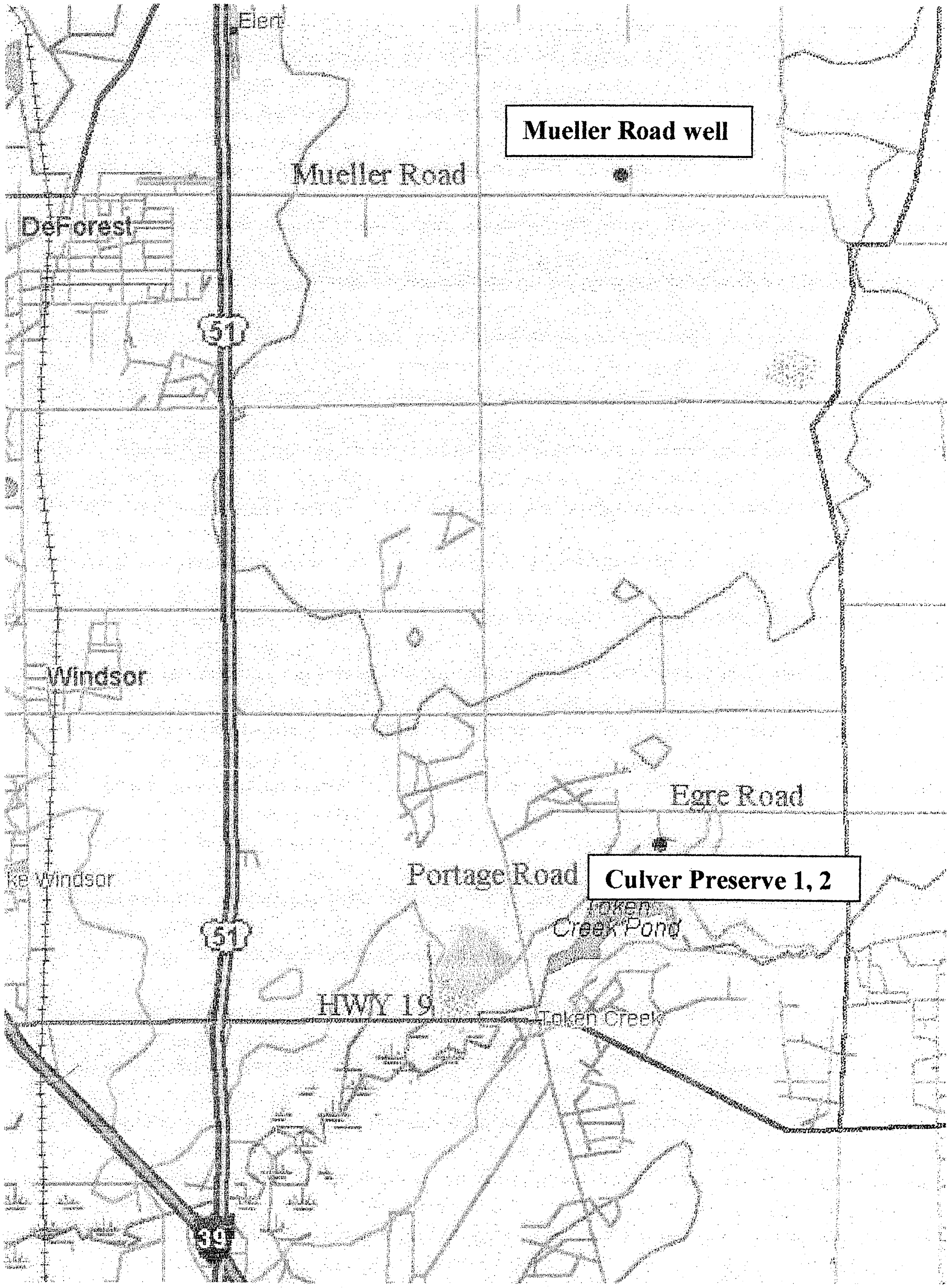


Figure 3. Location of bedrock monitoring wells

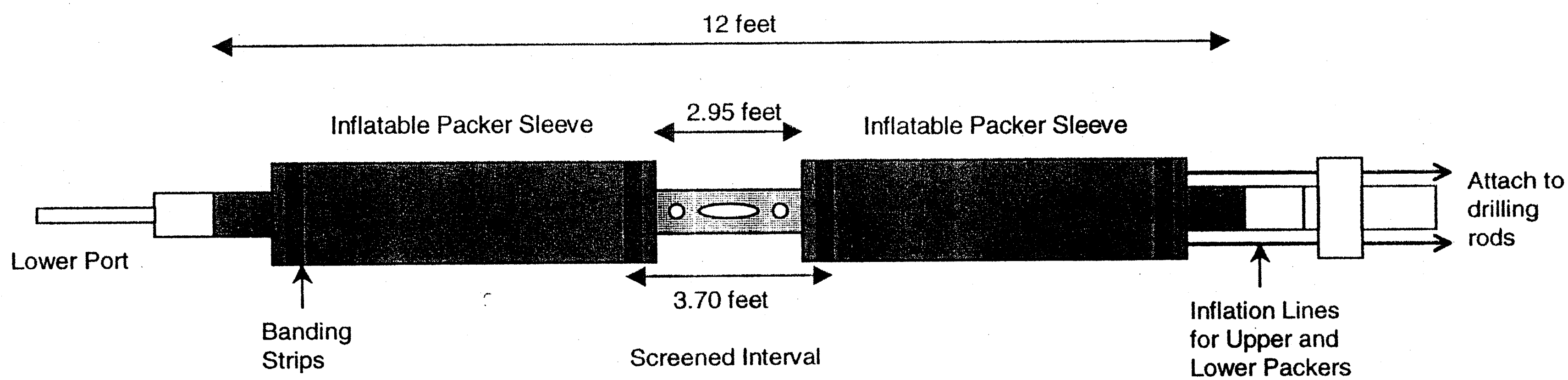


Figure 4. Straddle Packer Assemblage (from Swanson and Bahr, 2000)

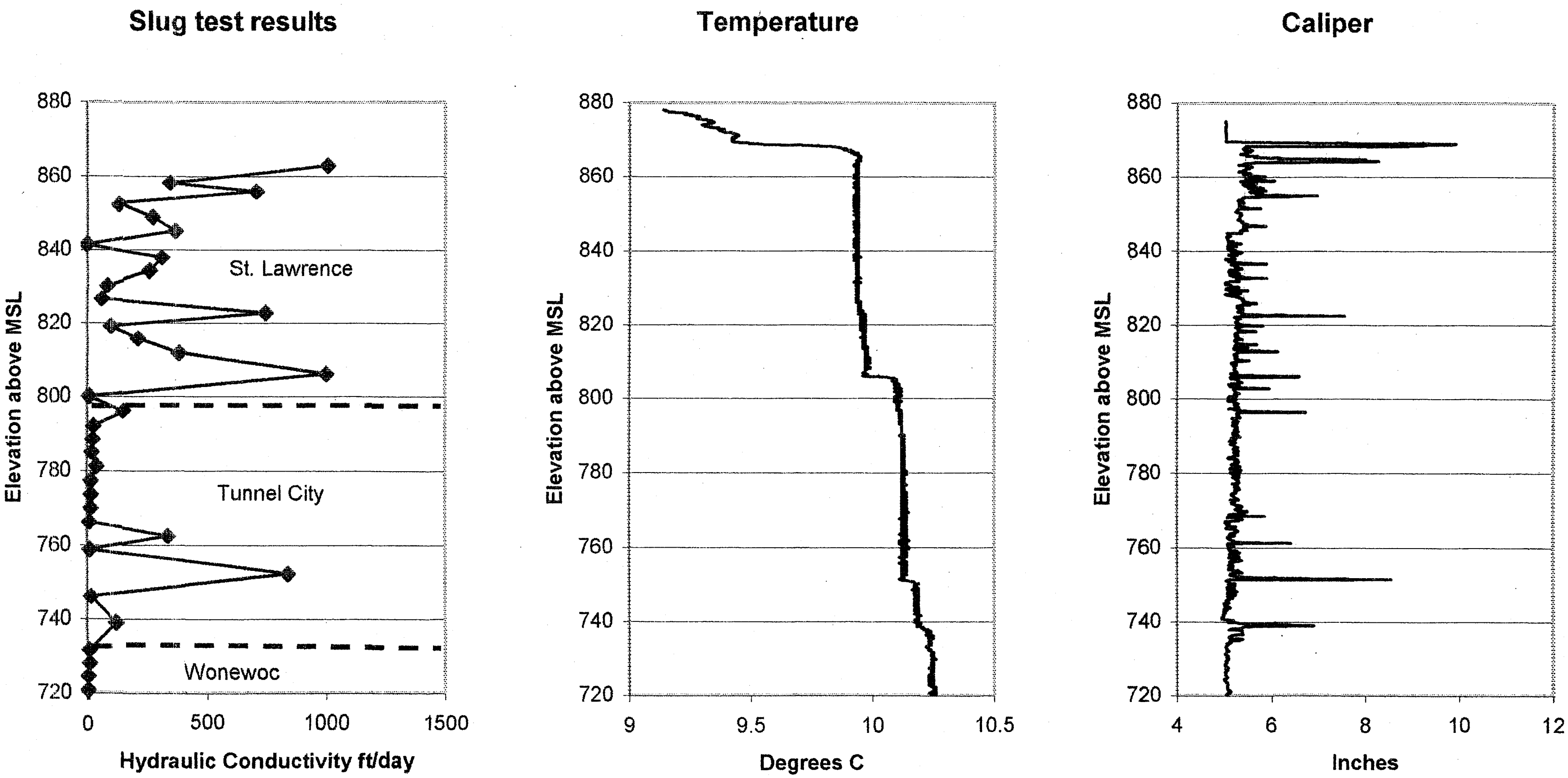


Figure 5: Slug test results compared to temperature and caliper logs

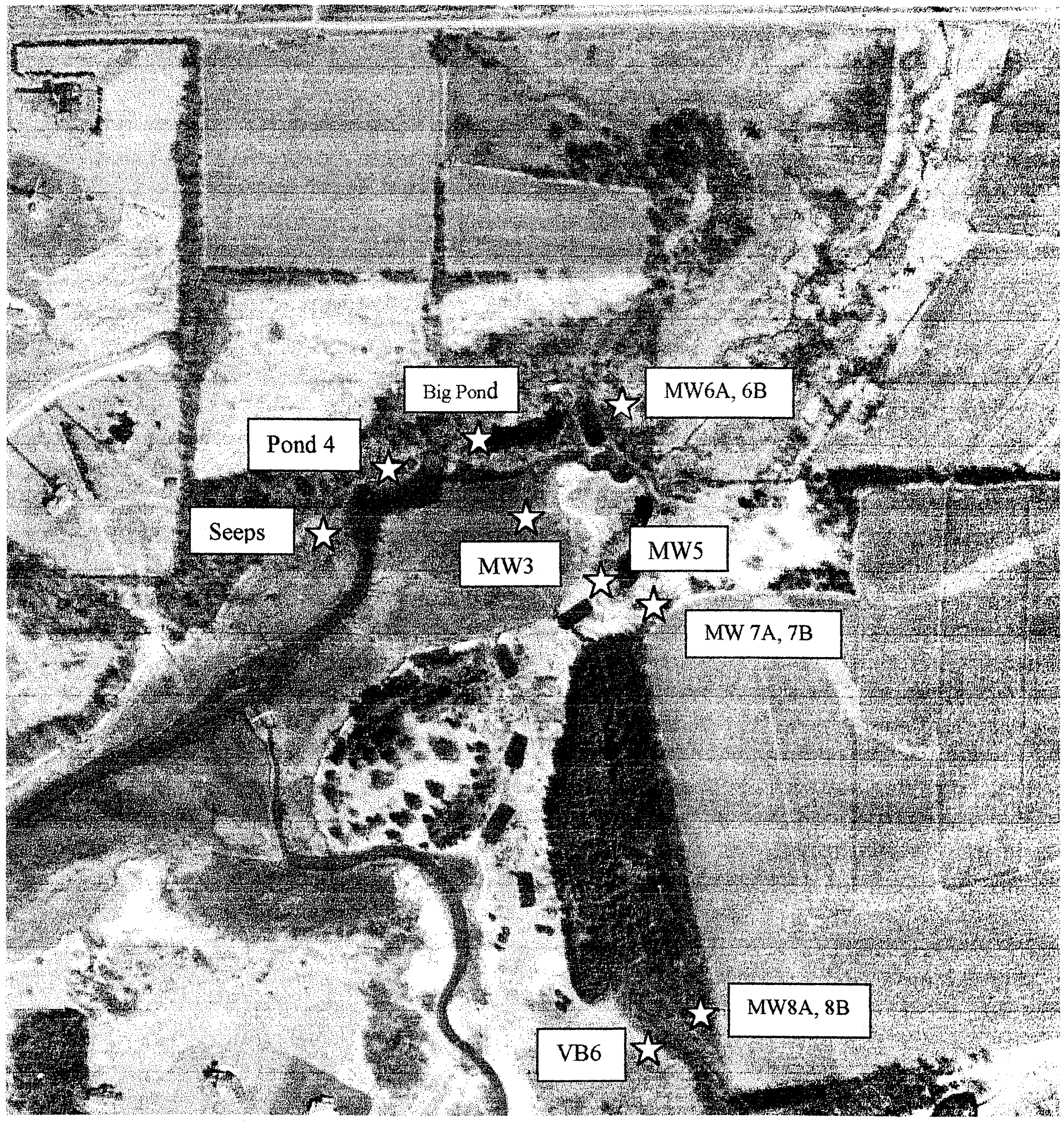


Figure 6: Shallow wells and surface water sampling locations

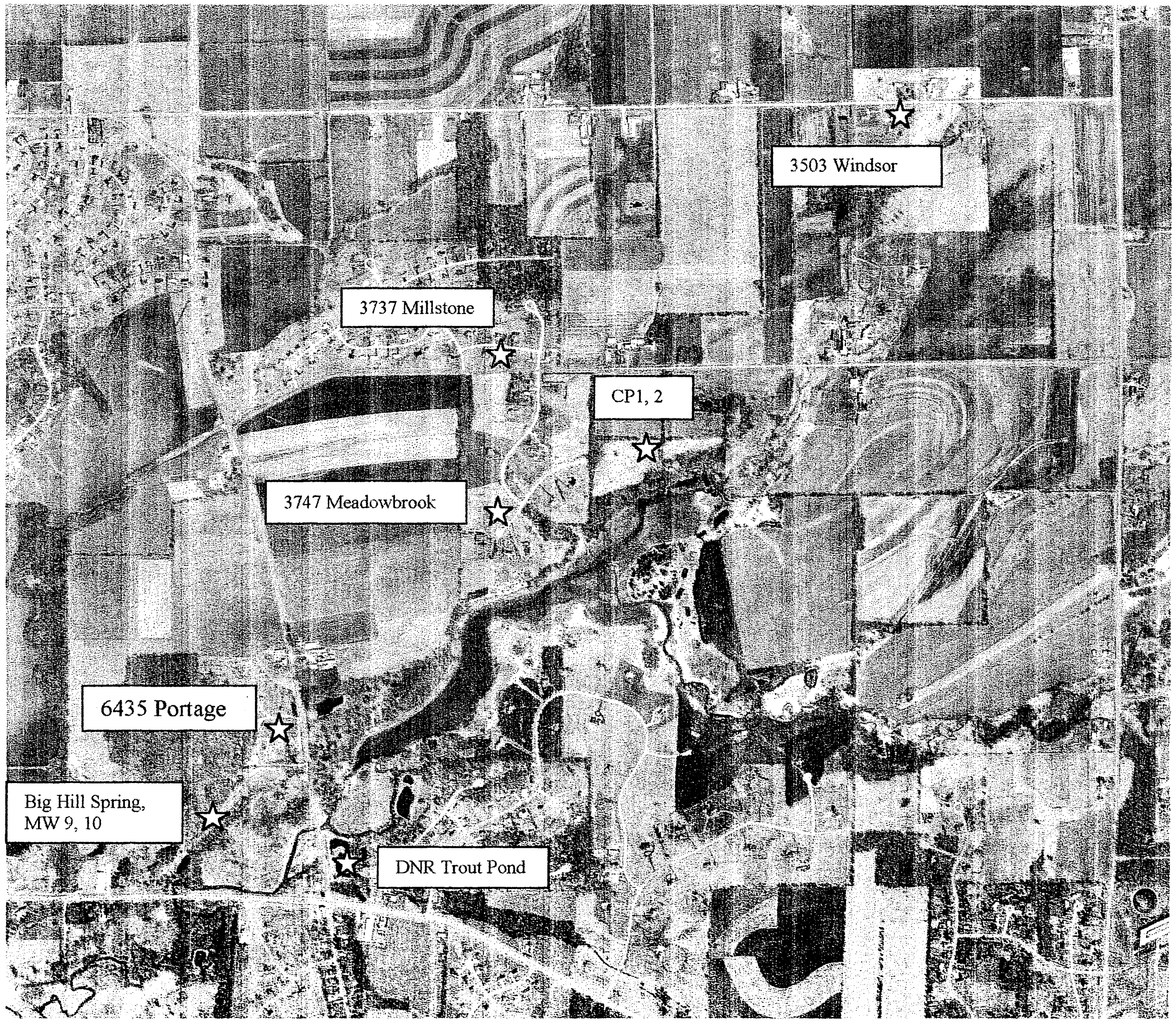


Figure 7. Big Hill, private wells and bedrock monitoring wells locations

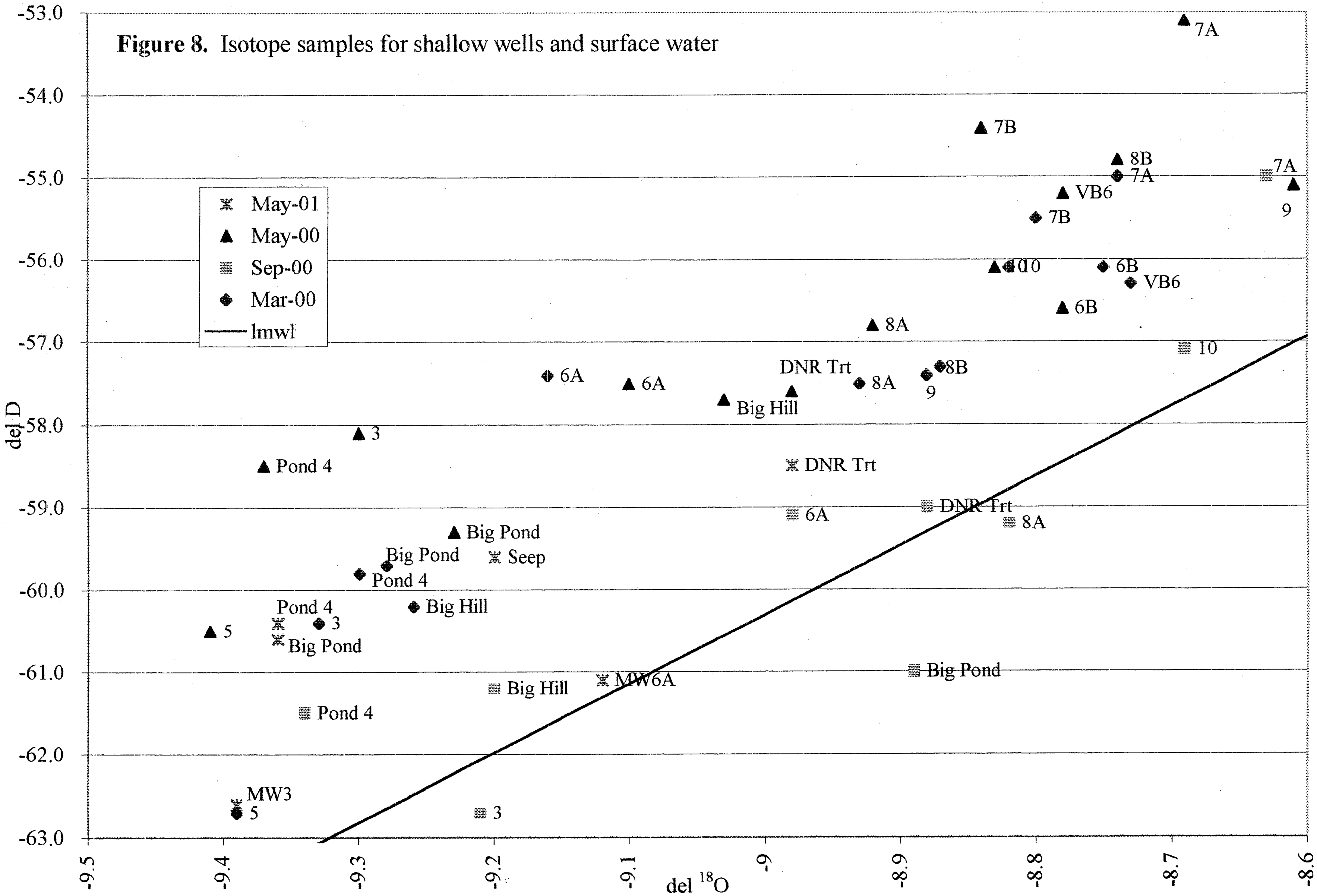


Figure 8. Isotope samples for shallow wells and surface water
May-01
May-00
Sep-00
Mar-00
lmwl
del D
del 18O
-53.0
-54.0
-55.0
-56.0
-57.0
-58.0
-59.0
-60.0
-61.0
-62.0
-63.0
-9.5
-9.4
-9.3
-9.2
-9.1
-9
-8.9
-8.8
-8.7
-8.6
7A
7B
8B
7A
VB6
7B
7A
9
10
6B
VB6
6B
8A
10
DNR Trt
8B
6A
6A
8A
9
Big Hill
3
DNR Trt
Pond 4
DNR Trt
6A
8A
Big Pond
Big Pond
Seep
Pond 4
Pond 4
Big Hill
5
3
Big Pond
Big Pond
Big Hill
MW6A
Pond 4
MW3
5
3

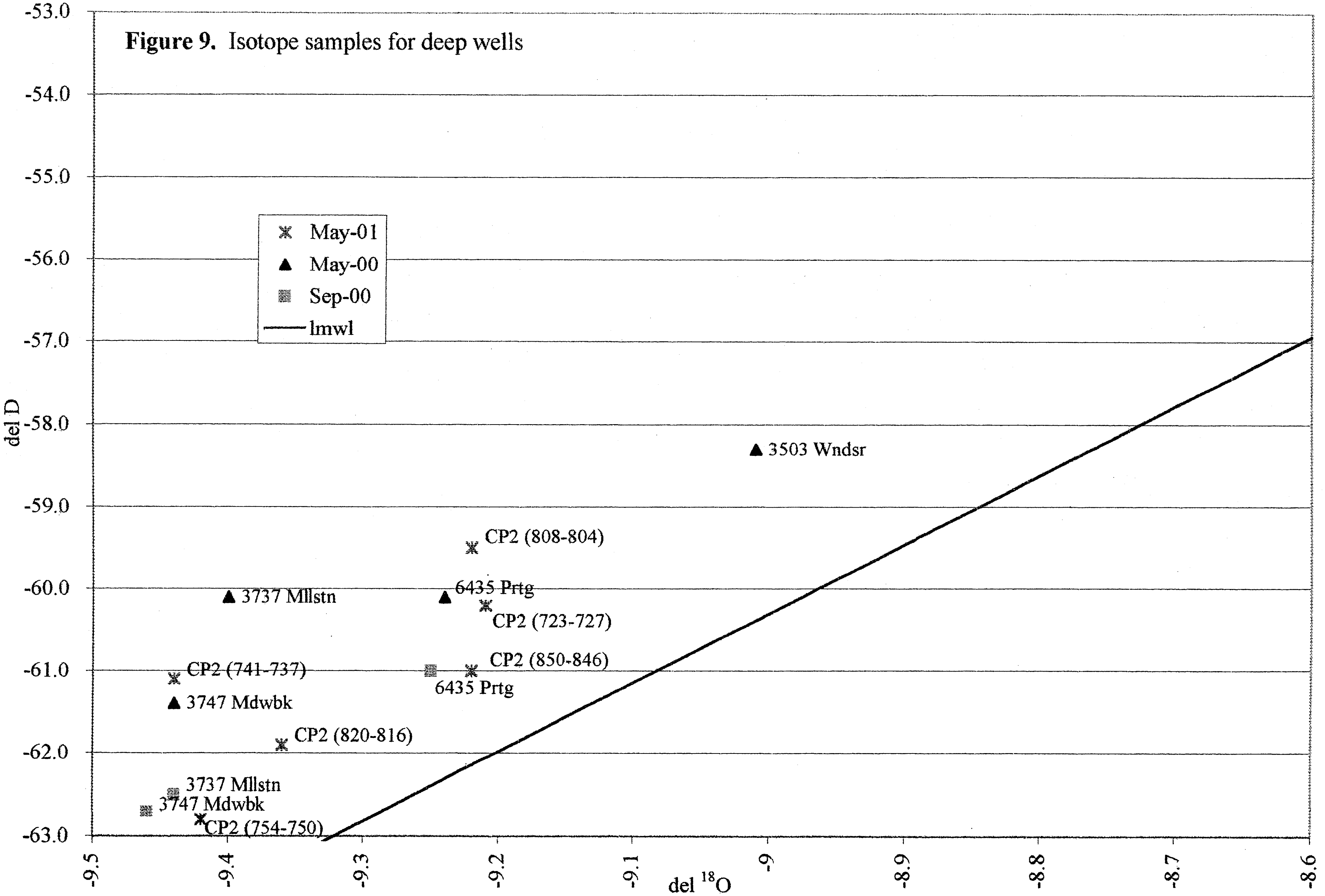


Figure 9. Isotope samples for deep wells
May-01
May-00
Sep-00
lmwl
3503 Wndsr
CP2 (808-804)
3737 Mllstn
6435 Prtg
CP2 (723-727)
CP2 (741-737)
CP2 (850-846)
6435 Prtg
3747 Mdwbk
CP2 (820-816)
3737 Mllstn
3747 Mdwbk
CP2 (754-750)
del D
del 18O
-53.0
-54.0
-55.0
-56.0
-57.0
-58.0
-59.0
-60.0
-61.0
-62.0
-63.0
-9.5
-9.4
-9.3
-9.2
-9.1
-9
-8.9
-8.8
-8.7
-8.6

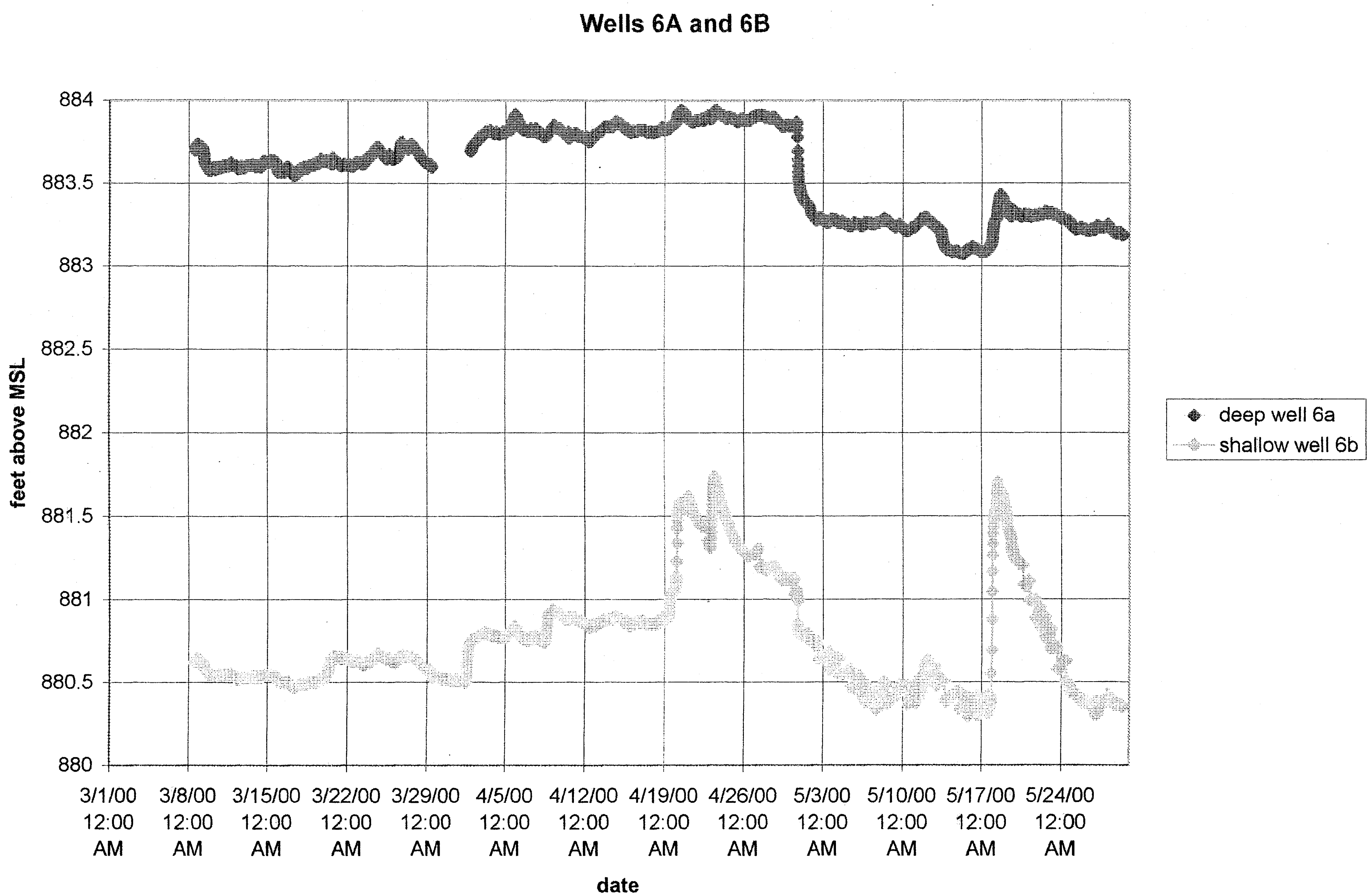


Figure 10: Nested wells 6A and 6B

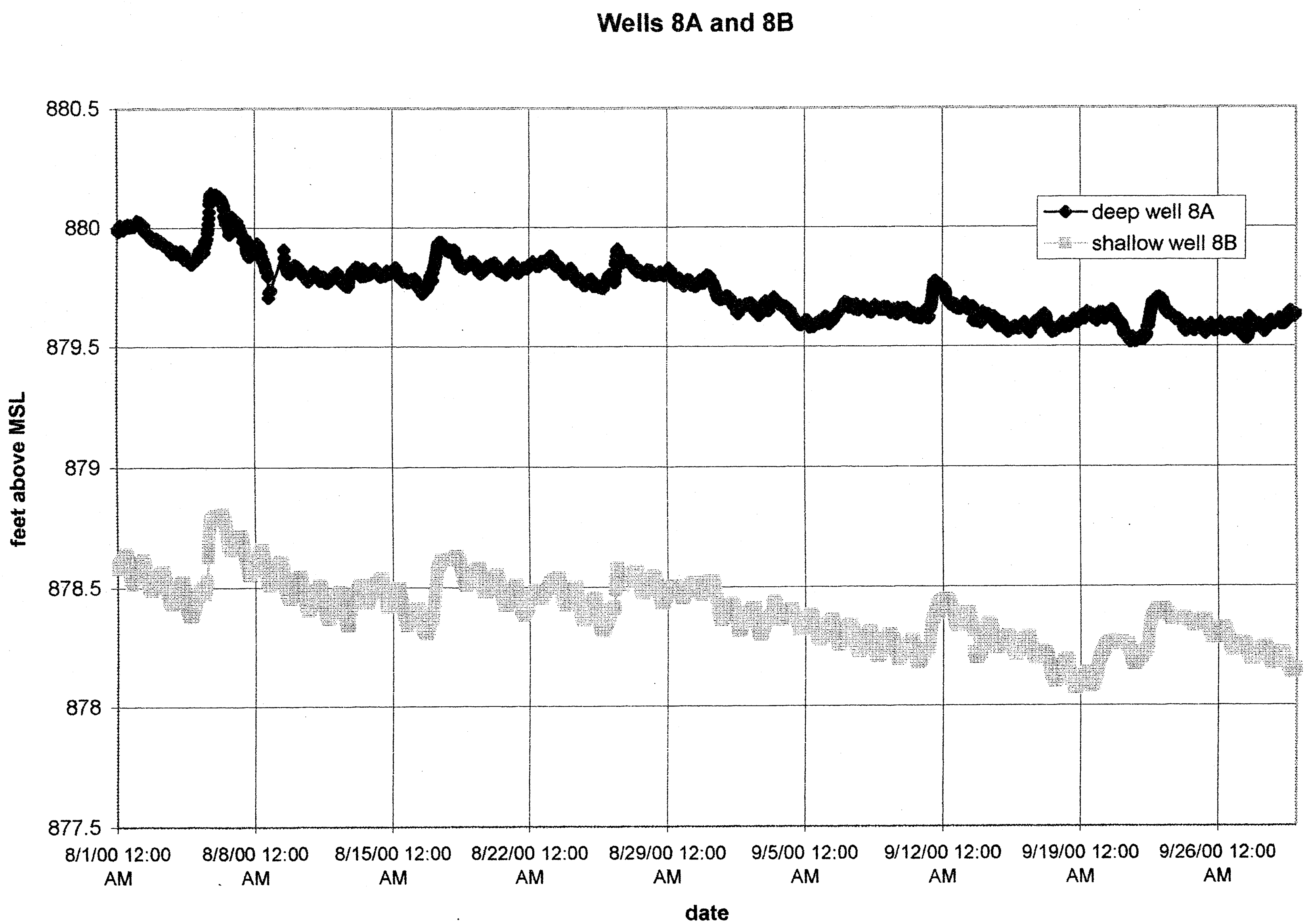


Figure 11: Nested wells 8A and 8B

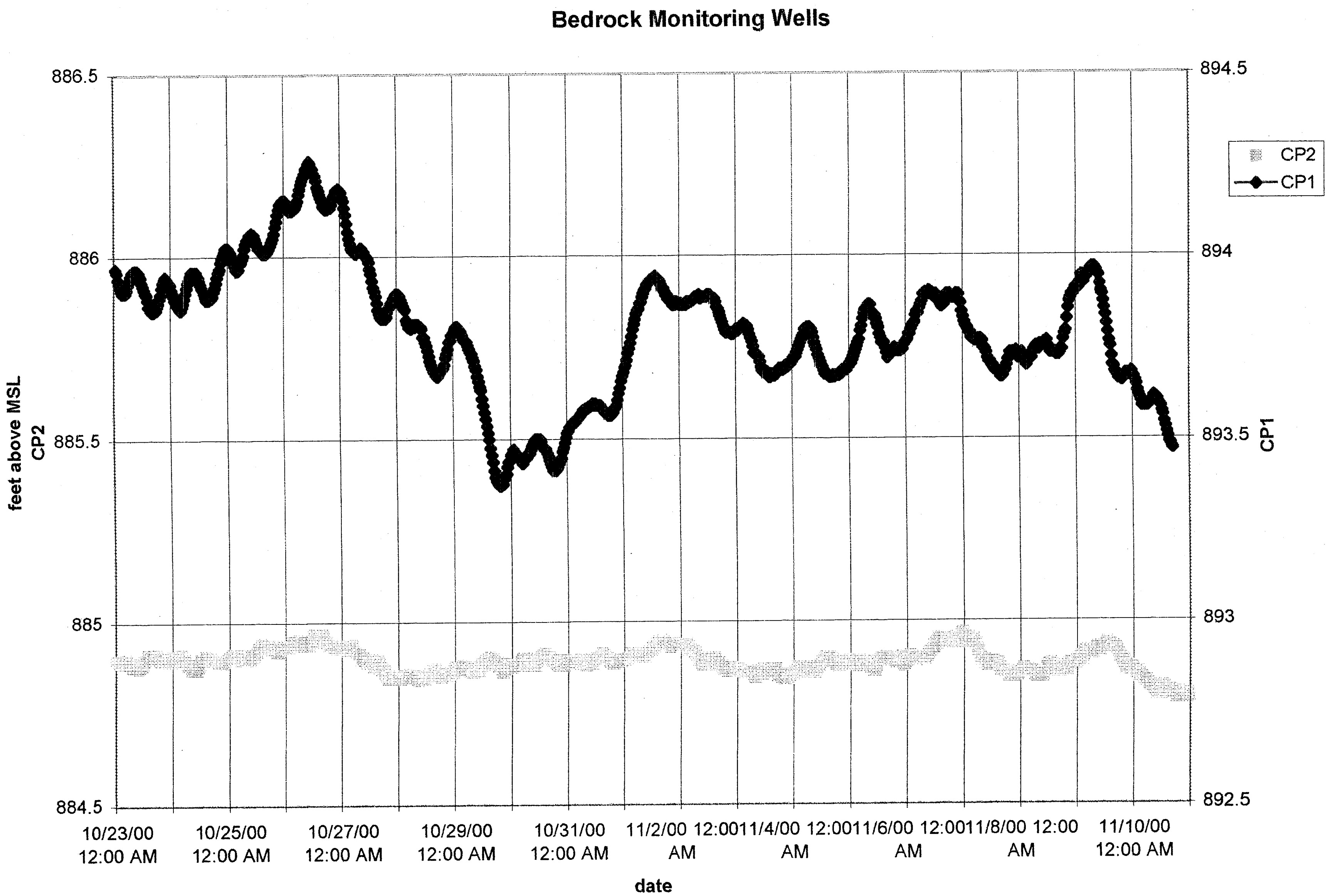


Figure 12: Bedrock monitoring wells CP1 and CP2

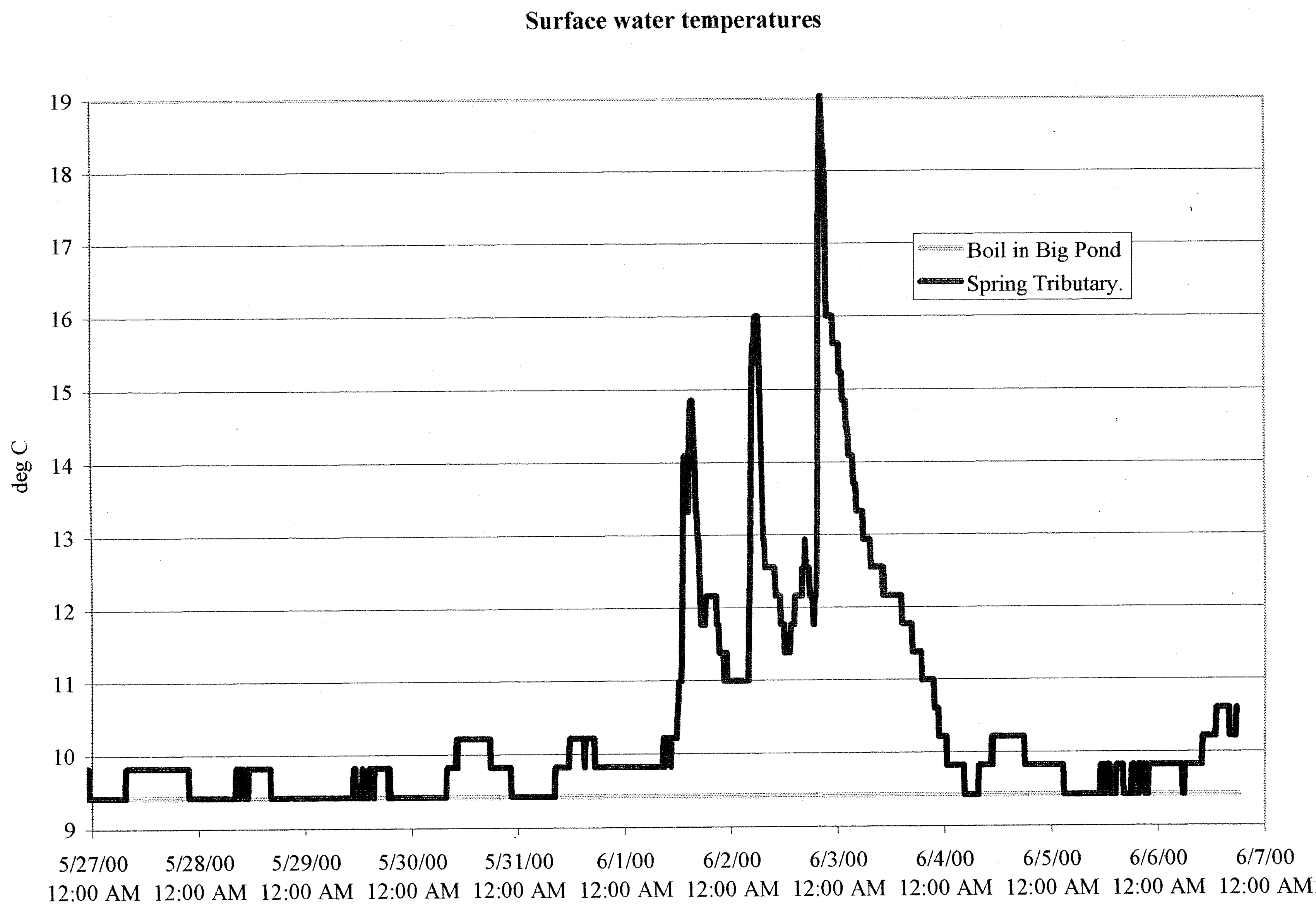


Figure 13: Surface water temperatures

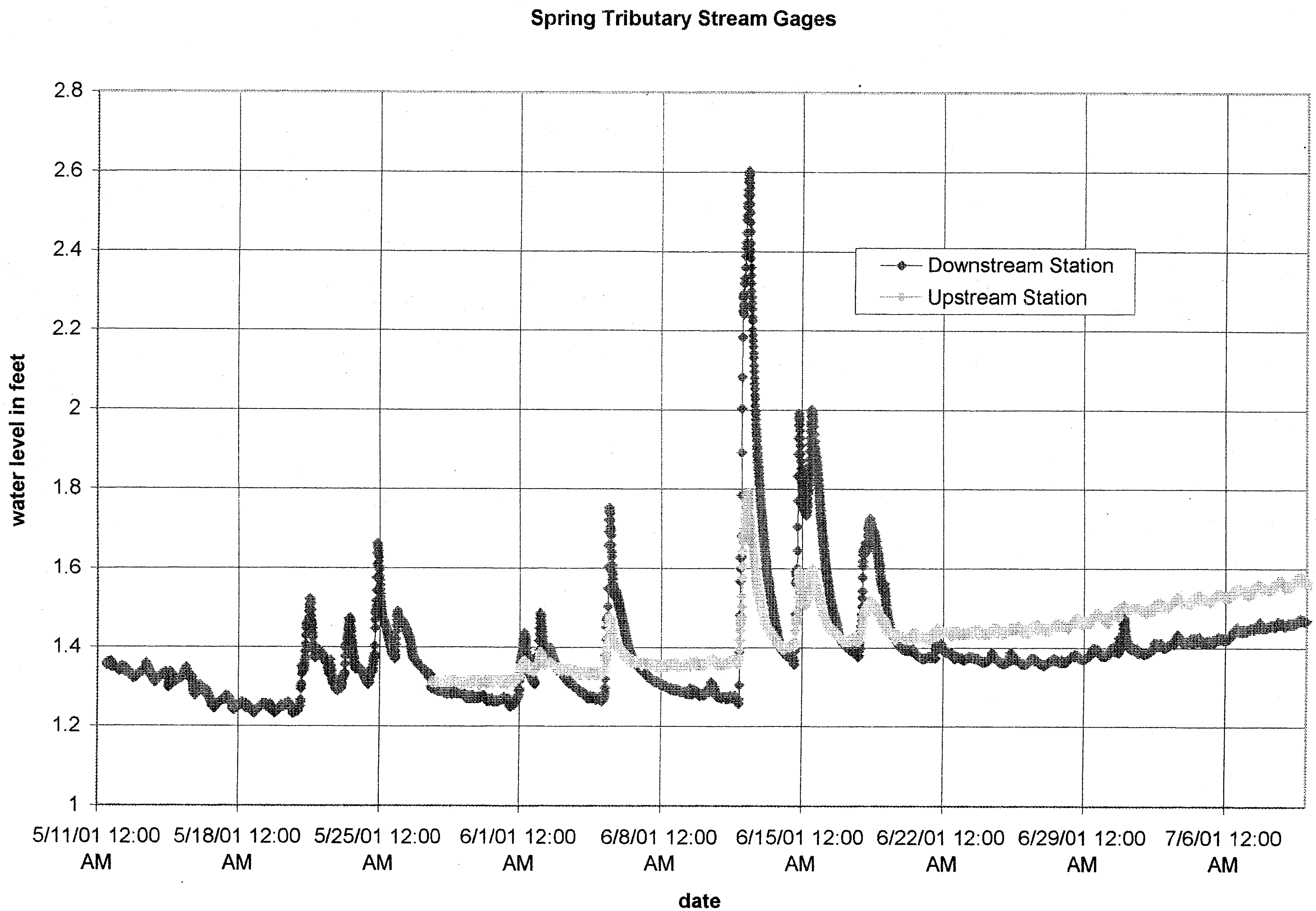


Figure 14. Stream gaging data from the Spring Tributary

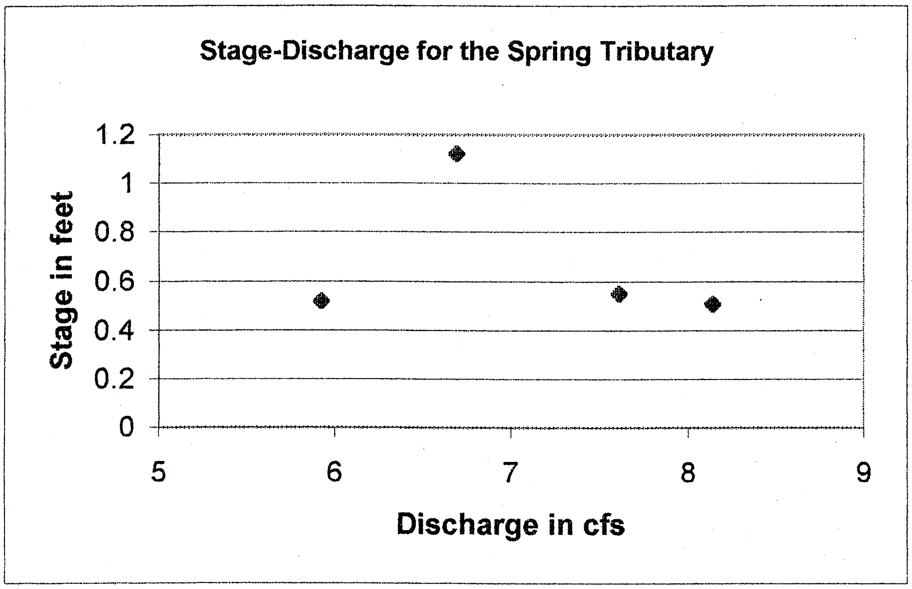


Figure 15. Attempted stage-discharge curve for the Spring Tributary

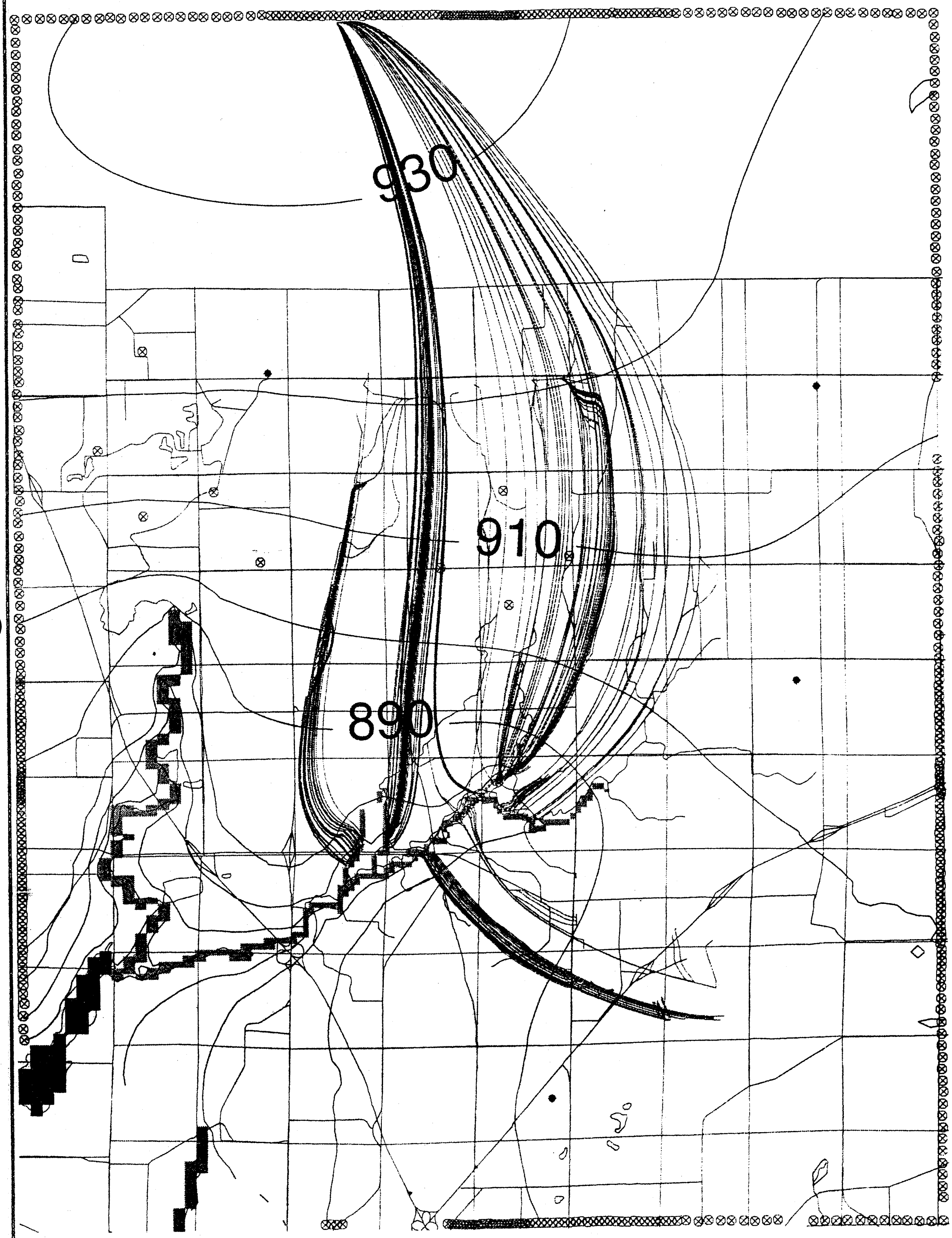


Figure 16. Groundwater basin for Upper Token Creek

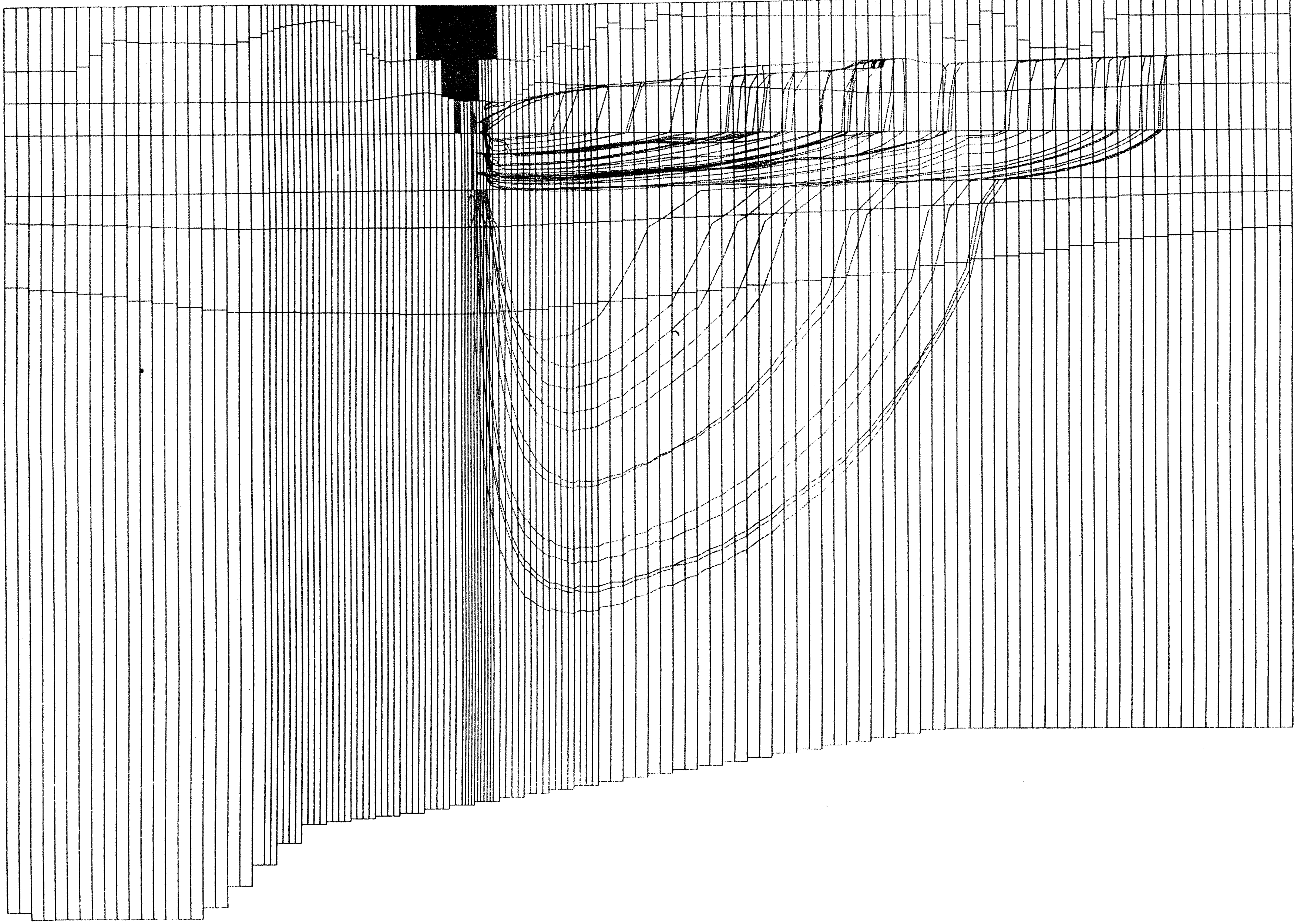


Figure 17. Cross section showing high-permeability layer

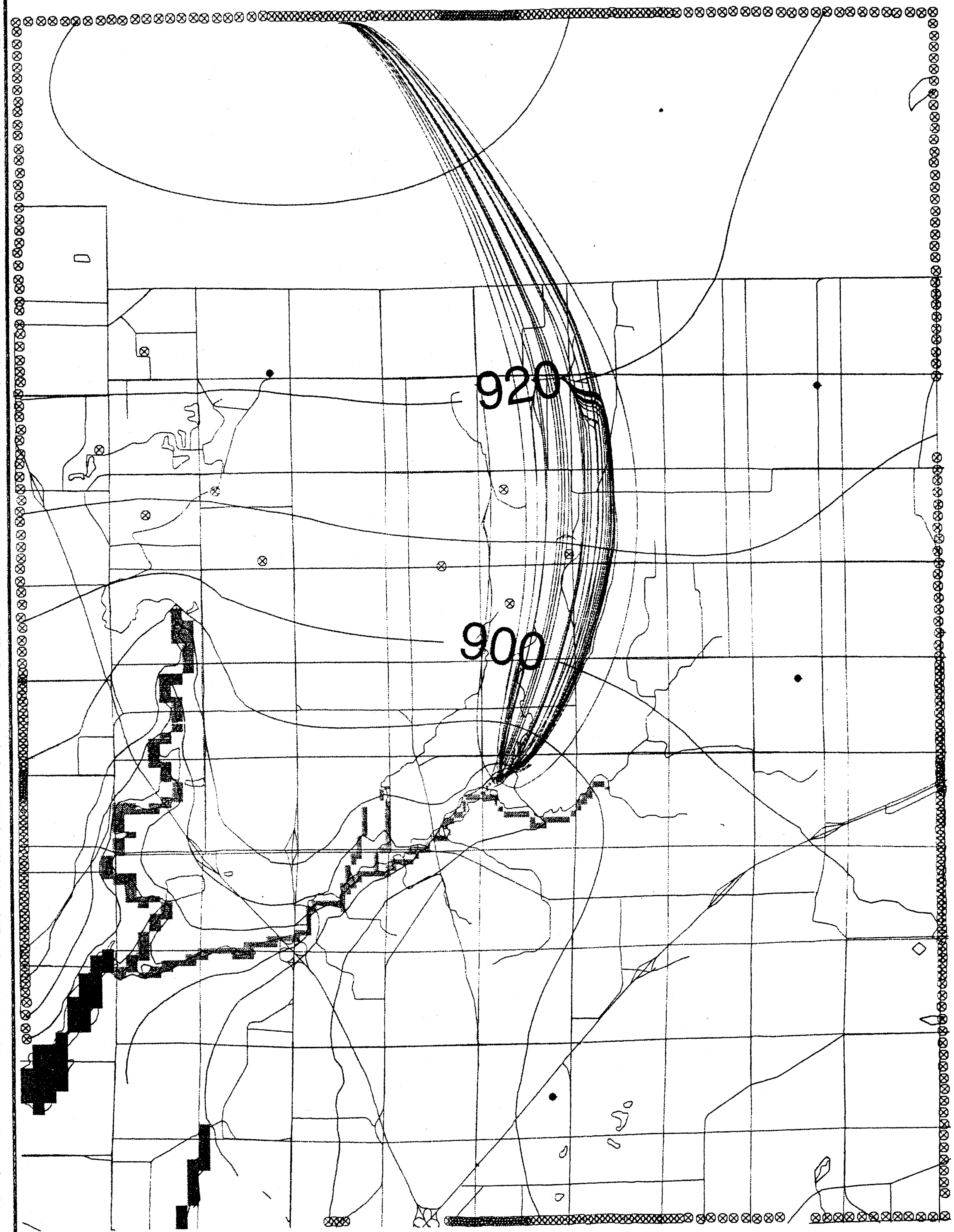


Figure 18. Groundwater basin for Culver Springs

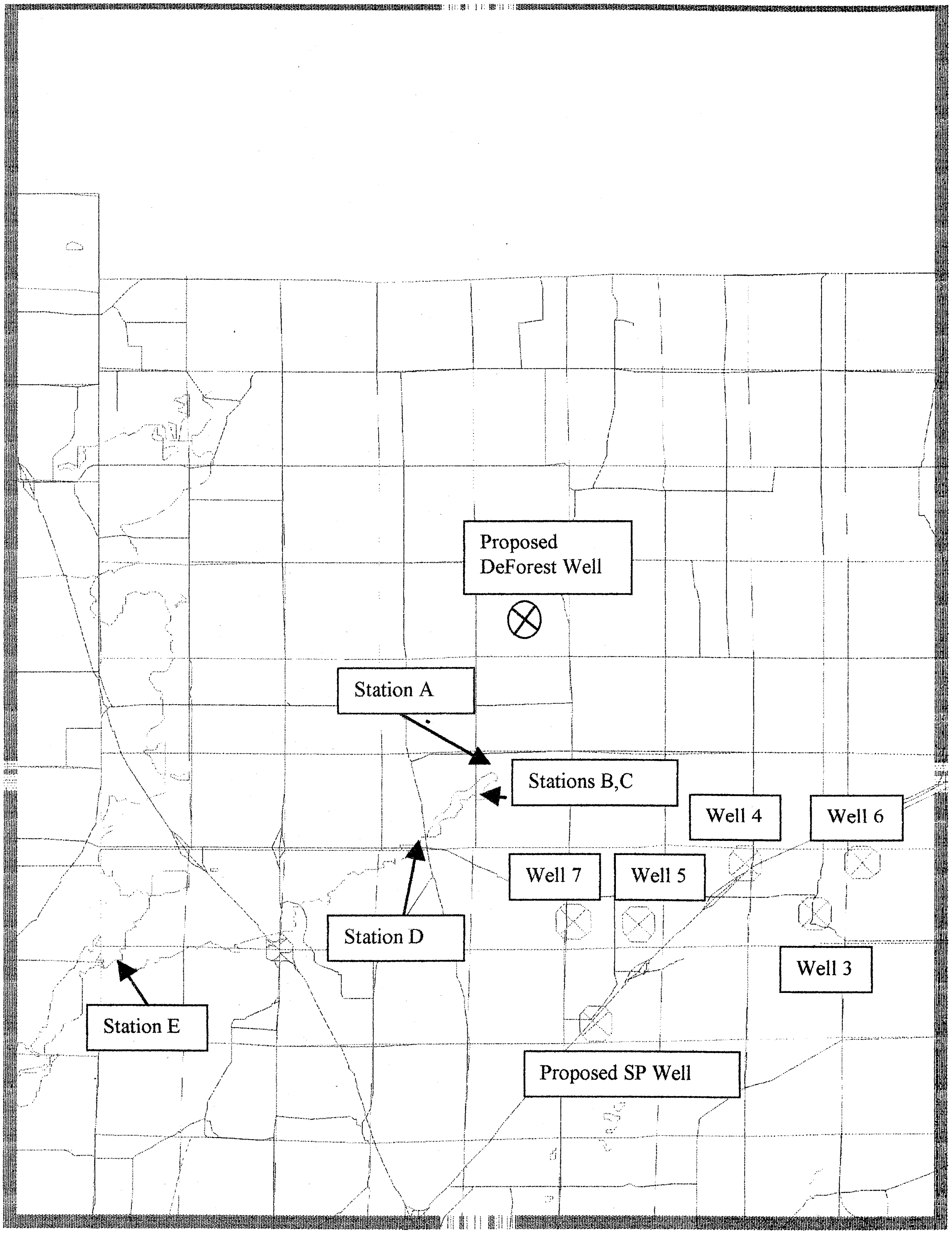


Figure 19. Locations of wells and reported stream flow stations.

TABLES

Table 1. Slug test results.				
Test	top of interval (msl)	bottom of interval (msl)	initial displacement (cubic ft.)	K (ft/day)
Wonewoc 1	715.56	719.26	1.64	4.18
Wonewoc 2	719.26	722.96	1.67	4.85
Wonewoc 3	722.96	726.66	1.62	3.71
Wonewoc 4	726.66	730.36	1.67	4.34
Wonewoc 5	730.36	734.06	1.64	11.11
Wonewoc 6	734.06	737.76	1.61	8.11
geometric mean				**5.56**
average				**6.05**
standard deviation				**2.94**
Tunnel City 1&2 (averaged)	741.28	170.7	1.70	122.90
Tunnel City 3	748.26	751.96	1.64	16.64
Tunnel City 4+5	754.26	157.72	1.70	837.90
Tunnel City 6	760.96	764.66	1.62	11.65
Tunnel City 7	764.66	147.32	1.79	337.18
Tunnel City 8	768.36	772.06	1.67	11.06
Tunnel City 9	772.26	775.96	1.67	16.56
Tunnel City 10	775.96	779.66	1.67	15.46
Tunnel City 11	779.66	783.36	1.68	16.57
Tunnel City 12	783.36	787.06	1.61	41.04
Tunnel City 13	787.06	790.76	1.70	21.08
Tunnel City 14	790.76	794.46	1.62	25.24
Tunnel City 16 out	794.46	798.16	1.78	27.16
Tunnel City 17+18	798.16	801.86	1.70	152.00
Tunnel City 19	802.26	805.96	1.62	11.00
geometric mean				**36.85**
average				**110.90**
standard deviation				**219.49**
Saint Lawrence 20 + 21	808.26	811.96	1.70	998.70
Saint Lawrence 22+23	813.96	817.66	1.70	383.70
Saint Lawrence 24	817.66	821.36	1.70	214.42
Saint Lawrence 25	821.36	825.06	1.70	99.00
Saint Lawrence 26&27	825.06	828.76	1.70	742.50
Saint Lawrence 28	828.76	832.46	1.70	60.61
Saint Lawrence 29	832.46	836.16	1.78	83.42
Saint Lawrence 30+31	836.16	839.86	1.70	260.00
Saint Lawrence 32	839.86	843.56	1.70	311.70
Saint Lawrence 33	843.56	847.26	1.40	0.23
Saint Lawrence 34+35	847.26	850.96	1.70	366.95
geometric mean				**132.06**
average				**320.11**
standard deviation				**305.71**
Saint Lawrence (Upper) 1&2	850.96	854.66	1.70	273.80
Saint Lawrence (Upper) 5	854.66	858.36	1.70	132.40
Saint Lawrence (Upper) 3&4	857.76	861.46	1.70	706.60
Saint Lawrence (Upper) 6&7	860.26	863.96	1.70	345.70
Saint Lawrence (Upper) 8&9	865.11	868.81	1.70	1004.48
geometric mean				**388.89**
average				**492.60**
standard deviation				**356.02**
All Saint Lawrence				
geometric mean				**185.08**
average				**374.01**
standard deviation				**320.82**

Table 2. Sample averages for major ion chemistry-shallow wells and surface waters																
Group	I	I	I	I	I	I	I	II	II	II	III	III	III	IV	IV	IV
Number of samples	3	4	4	1	2	4	3	2	3	2	3	4	2	3	2	2
	DNR Trt	Pond 1	Pond 4	Seeps	VB6	MW6A	MW7A	MW8b	MW8a	MW7B	BH Spring	Mw3	MW5	MW 9	MW 10	MW6B
Field Data																
Temperature (°C)	10.0	9.8	10.6	10.6	6.3	9.7	8.9	7.6	8.9	7.4	11.2	9.6	6.9	9.6	8.9	7.9
Conductivity* (μmho)	757	696	686	736	791	753	838	777	644	680	589	632	523	920	1107	966
Alkalinity (ppm)	270	255	273	275	325	306	350	465	283	350	232	279	245	483	600	525
pH	7.1	7.0	7.1	7.8	6.8	7.0	6.8	6.8	7.1	6.6	7.2	7.0	7.2	6.9	6.9	6.7
Dissolved oxygen (ppm)	5	7	6	6		5	4		2	3	4	3	4	4	3	1
Laboratory data																
Conductivity* (μmho)	719	686	667	712	766	727	831	704	678	692	579	611	508	870	1070	956
pH	7.5	7.7	7.7	7.7	7.6	7.5	7.7	7.7	7.8	7.6	8.0	7.7	7.9	7.6	7.6	7.4
Alkalinity (ppm)	292	272	263	309	325	306	356	327	321	302	285	283	283	493	629	485
Cations																
Calcium (ppm)	75	74	72	80	84	81	95	78	74	82	63	70	56	100	110	80
Magnesium (ppm)	42	42	40	44	46	45	52	47	46	45	39	40	38	65	86	62
Sodium (ppm)	15.0	8.3	7.8	10.0	5.9	7.5	6.3	5.3	5.1	5.5	3.3	4.0	3.0	3.4	4.3	43.5
Potassium (ppm)	1.1	1.3	1.2	0.0	1.1	1.6	0.7	1.3	1.3	nd	0.8	1.4	0.8	2.3	2.5	9.2
Anions																
Sulfate (ppm)	22.7	28.4	27.3	23.9	16.3	32.8	29.1	30.4	31.8	22.2	25.6	44.9	nd	23.7	26.0	38.0
Chloride (ppm)	37.7	22.8	21.5	26.8	19.0	23.2	22.8	17.1	15.3	16.8	6.0	11.9	1.4	2.6	2.0	18.6
Nitrate and Nitrate as N (ppm)	6.2	11.4	11.9	6.2	16.3	8.7	13.6	5.0	2.4	10.6	2.3	nd	0.2	nd	nd	2.2
*standardized to 25°C																

Table 3. Sample averages for major ion chemistry-deep wells

Number of samples	1	2	1	1	2	1	2	1	1	1	1
	CP2	3737 Millst	CP2	3503 Wndsr	6435 Prtg	CP2	3747 Mdwbk	CP2	CP2	CP2	MS well
Open interval, feet above MSL	850-846	834-797	820-816	818-803	815-768	808-804	795-777	754-750	741-737	723-719	608-588
Field Data											
Temperature (°C)	14.1	16.5	13.5	19.9	18.6	13.5	14.8	11.9	13.5	13.7	8.9
Conductivity* (μmho)	598	644	743	870	497	588	649	527	537	534	380
Alkalinity (ppm)	260	288	325	400	238	330	240	325	325	300	275
pH	7.3	7.4	7.3	6.8	7.4	7.3	7.4	7.4	7.4	7.4	7.4
Dissolved oxygen (ppm)	4	4	6	5	3	5	5	4	4	4	3
Laboratory data											
Conductivity* (μmho)	564	627	670	831	476	538	623	486	496	480	486
pH	7.8	7.7	7.7	7.5	7.8	7.8	7.8	7.9	7.9	8.0	7.7
Alkalinity (ppm)	271	284	271	320	260	263	260	255	264	254	256
Cations											
Calcium (ppm)	58	62	72	87	53	55	68	52	51	51	53
Magnesium (ppm)	40	45	42	47	33	40	39	34	36	34	32
Sodium (ppm)	3.7	6.1	6.0	15.0	2.6	3.5	7.1	2.7	2.6	3.1	2.7
Potassium (ppm)	1.0	1.8	0.7	2.0	1.0	0.7	1.4	0.9	0.7	0.6	1.1
Anions											
Sulfate (ppm)	10.9	21.9	27.4	31.4	6.2	8.7	21.8	6.2	4.9	7.4	0.0
Chloride (ppm)	6.9	16.0	18.3	39.9	0.8	5.8	18.6	1.0	0.9	0.8	0.9
Nitrate and Nitrate as N (ppm)	3.7	5.7	10.0	15.5	0.1	3.3	9.5	0.4	0.0	0.6	0.0
*standardized to 25°C											

Table 4: Sun Prairie well simulation results

All new wells pumping at same rate as Sun Prairie well 5 (54,816.6 cf/day)
Note: Sun Prairie wells open in layers 4-7 (St. Lawrence-Mt. Simon)

Station	cf/day	percent difference
S.P. Well 7 not pumping		
A	5.50E+05	
B	5.22E+05	
C	5.83E+05	
D	1.27E+06	
E	2.18E+06	
S.P. Well 7 pumping		
A	5.12E+05	-6.91
B	5.19E+05	-0.57
C	5.56E+05	-4.63
D	1.23E+06	-3.15
E	2.15E+06	-1.38
New Sun Prairie well pumping		
A	5.13E+05	-6.73
B	5.20E+05	-0.38
C	5.64E+05	-3.26
D	1.24E+06	-2.36
E	2.15E+06	-1.38
DeForest well pumping layers 3-7 (Jordan-Mt.Simon)		
A	5.09E+05	-7.45
B	5.16E+05	-1.15
C	5.74E+05	-1.54
D	1.25E+06	-1.57
E	2.16E+06	-0.92

APPENDICES

Appendix A
Well Construction Reports

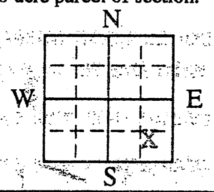
State of Wisconsin
Private Water Systems-DG/2
Department of Natural Resources
Box 7921
Madison, WI 53707 **(Please type or print using a black pen.)**

Well Construction Report For WISCONSIN UNIQUE WELL NUMBER OQ 269

Property Owner: U.W..Geology Dept.	Telephone Number: 608 294-1426
Mailing Address: 1215 Dayton Street, 411 Wecks Hall	
City: Madison	State: WI. Zip Code: 53706
County of Well Location:	Co. Well Permit No. W	Well Completion Date (mm-dd-yy): __-__-__

Well Constructor (Business Name): WATER WELLS INC.	License #: 3
Address: 6400 Lake Road	
City: Windsor State: WI Zip Code: 53598	

2. Mark well location with a dot in correct 40-acre parcel of section.



1. Well Location **Please use decimals instead of fractions.**

[X] Town [ ] City [ ] Village of Windsor/Token Creek — Fire # (If avail.):

Grid or Street Address or Road Name and Number: 3694 Mueller Road

Subdivision Name: Lot #: Block #:

Gov't Lot # ____ or SE 1/4 of SE 1/4 of Section 10, T 9 N; R 10 [X] E [ ] W

3. Well Type [X] New [ ] Replacement (see item 13 below) [ ] Reconstruction

of previous unique well # ____ constructed in 19____

Reason for replaced or reconstructed well? observation well

[X] Drilled [ ] Driven Point [ ] Jetted [ ] Other ____

4. Well serves – ____ # of homes and or ____ (Eg: barn, restaurant, church, school, industry, etc.)

High Capacity: Well? [ ] Yes [X] No — Property? [ ] Yes [X] No

5. Is the well located upslope or sideslope and not downslope from any contamination sources, including those on neighboring properties? [X] Yes [ ] No — If no, explain on back side.

Well located in floodplain? [ ] Yes [X] No

Distance in Feet From Well To Nearest: (include proposed)

____ 1. Landfill
____ 2. Building Overhang
____ 3. Septic or Holding Tank (circle one)
____ 4. Sewage Absorption Unit
____ 5. Nonconforming Pit
____ 6. Buried Home Heating Oil Tank
____ 7. Buried Petroleum Tank
____ 8. Shoreline/Swimming Pool (circle one)
____ 9. Downspout/Yard Hydrant
____ 10. Privy
____ 11. Foundation Drain to Clearwater
____ 12. Foundation Drain to Sewer
____ 13. Building Drain [ ] Cast Iron or Plastic [ ] Other
____ 14. Building Sewer [ ] Gravity [ ] Pressure [ ] Cast Iron or Plastic [ ] Other
____ 15. Collector Sewer: ___units ____in. diameter
____ 16. Clearwater Sump
____ 17. Wastewater Sump
____ 18. Paved Animal Barn Pen
____ 19. Animal Yard or Shelter
____ 20. Silo
____ 21. Barn Gutter
____ 22. Manure Pipe [ ] Gravity [ ] Pressure [ ] Cast Iron or Plastic [ ] Other
____ 23. Other Manure Storage ____
____ 24. Ditch
____ 25. Other NR 812 Waste Source

6. Drillhole Dimensions

Dia. (in.)	From (ft.)	To (ft.)
8.75	surface	37
5	37	370

Upper Enlarged Drillhole: Method of Construction

[X] 1. Rotary - Mud Circulation
[ ] 2. Rotary - Air
[ ] 3. Rotary - Foam
[ ] 4. Reverse Rotary
[ ] 5. Cable-tool Bit ____ in. dia.
[ ] 6. Temp. Outer Casing ____ in. dia. ____ depth — Removed? [ ] Yes [ ] No — If no, explain why not ____
[ ] 7. Other ____

9. Geology (DNR USE ONLY)

Type, Caving/Noncaving, Color, Hardness, Etc.	From (ft.)	To (ft.)
drift	surface	8
tan dolomite	8	120
red-brown sandstone	120	170
tan sandstone	170	270
light gray sandstone	270	355
pink sandstone	355	370

7. Casing, Liner, Screen

Dia. (in.)	Material, Weight, Specification, Manufacturer & Method of Assembly	From (ft.)	To (ft.)
5	std. steel PE	surface	37
	14.62 lbs		
	Saw-hill		

Dia. (in.)	screen type, material & slot size	From	To

10. Static Water Level

____ ft. above ground surface
100 ft. below ground surface

11. Pump Test

Pumping Level 140 ft. below surface
Pumping at 20 GPM for 25 hours

12. Well Is: 24 in. [X] Above [ ] Below Grade
Developed? [X] Yes [ ] No
Disinfected? [X] Yes [ ] No
Capped? [X] Yes [ ] No

8. ... or Other Sealing Material ... od: Tremie line-pumped

Kind of Sealing Material	From (ft.)	To (ft.)	# Sacks Cement
neat cement	surface	37	10

13. Did you notify the owner of the need to permanently abandon and fill all unused wells on this property? [ ] Yes [X] No — If no, explain: needs to be done

14. Signature of Point Driver or Licensed Supervisory Driller — Date Signed

Signature of Drill Rig Operator (Mandatory unless same as above) — Date Signed

Make additional comments on reverse side about geology, additional screens, water quality, etc.
Comments on reverse side ____ (CHECK √, IF YES)

WELL CONSTRUCTION REPORT
Form 3300-77A Rev. 8-98

Well Construction Report For WISCONSIN UNIQUE WELL NUMBER OQ 270

State of Wisconsin
Private Water Systems-DG/2
Department of Natural Resources
Box 7921
Madison, WI 53707

(Please type or print using a black pen.)

Property Owner: Laura Parent, U.W. Geology Dept.
Telephone Number: (608) 294-1426
Mailing Address: 1215 Dayton Street, 411 Wecks Hall
City: Madison | State: WI | Zip Code: 53706
County of Well Location: Dane | Co. Well Permit No. W_____ | Well Completion Date (mm-dd-yy): 6 - 21 - 00

Well Constructor (Business Name): WATER WELLS INC. | License #: 3
Address: 6400 Lake Road
City: Windsor, | State: WI | Zip Code: 53598

1. Well Location — **Please use decimals instead of fractions.**
[X] Town [ ] City [ ] Village of Token Creek/Windsor | Fire # (If avail.)
Grid or Street Address or Road Name and Number: 3667 Egre Road-Culver Preserve
Subdivision Name | Lot # | Block #
Gov't Lot # _____ or _____ 1/4 of _____ 1/4 of
Section _____, T _____ N; R _____ [ ] E [ ] W

2. Mark well location with a dot in correct 40-acre parcel of section. (N, E, S, W)

3. Well Type [X] New [ ] Replacement [ ] Reconstruction (see item 13 below)
of previous unique well # _____ constructed in 19___
Reason for replaced or reconstructed well? observation well
[X] Drilled [ ] Driven Point [ ] Jetted [ ] Other _____

4. Well serves ___ # of homes and or _____ (Eg: barn, restaurant, church, school, industry, etc.)
High Capacity: Well? [ ] Yes [X] No — Property? [ ] Yes [X] No

5. Is the well located upslope or sideslope and not downslope from any contamination sources, including those on neighboring properties? [ ] Yes [ ] No — If no, explain on back side.
Well located in floodplain? [ ] Yes [X] No
Distance in Feet From Well To Nearest: (include proposed)

___ 1. Landfill
___ 2. Building Overhang
___ 3. Septic or Holding Tank (circle one)
___ 4. Sewage Absorption Unit
___ 5. Nonconforming Pit
___ 6. Buried Home Heating Oil Tank
___ 7. Buried Petroleum Tank
___ 8. Shoreline/Swimming Pool (circle one)
___ 9. Downspout/Yard Hydrant
___ 10. Privy
___ 11. Foundation Drain to Clearwater
___ 12. Foundation Drain to Sewer
___ 13. Building Drain [ ] Cast Iron or Plastic [ ] Other
___ 14. Building Sewer [ ] Gravity [ ] Pressure [ ] Cast Iron or Plastic [ ] Other
___ 15. Collector Sewer: ___units ___in. diameter
___ 16. Clearwater Sump
___ 17. Wastewater Sump
___ 18. Paved Animal Barn Pen
___ 19. Animal Yard or Shelter
___ 20. Silo
___ 21. Barn Gutter
___ 22. Manure Pipe [ ] Gravity [ ] Pressure [ ] Cast Iron or Plastic [ ] Other
___ 23. Other Manure Storage _____
___ 24. Ditch
___ 25. Other NR 812 Waste Source

6. Drillhole Dimensions

Dia. (in.)	From (ft.)	To (ft.)
8.75	surface	35
6	35	285
4	285	310

Upper Enlarged Drillhole: Method of Construction
[ ] 1. Rotary - Mud Circulation
[X] 2. Rotary - Air
[ ] 3. Rotary - Foam
[ ] 4. Reverse Rotary
[ ] 5. Cable-tool Bit ___ in. dia.
[ ] 6. Temp. Outer Casing ___ in. dia. ___ depth — Removed? [ ] Yes [ ] No — If no, explain why not _____
[ ] 7. Other _____

9. Geology

Type, Caving/Noncaving, Color, Hardness, Etc.	From (ft.)	To (ft.)
drift	surface	13
red-brown sandstone	13	60
tan sandstone	60	160
light grey sandstone	160	230
orange sandstone	230	275
tan sandstone	275	310

7. Casing, Liner, Screen

Dia. (in.)	Material, Weight, Specification, Manufacturer & Method of Assembly	From (ft.)	To (ft.)
6	PE Std. steel	surface	35
	18.97 lbs		
4	PE Std. steel	0	285
	10.79 lbs.		

Dia. (in.)	screen type, material & slot size	From	To

8. Grout or Other Sealing Material: braiden bead-bentonite
Method: circulated before setting pipe

Kind of Sealing Material	From (ft.)	To (ft.)	Sacks Cement
neat cement	surface	35	20

10. Static Water Level: _____ ft. above ground surface; 16 ft. below ground surface

11. Pump Test: Pumping Level 285 ft. below surface; Pumping at 75 GPM for .25 hours

12. Well Is: 24 in. [X] Above [ ] Below Grade
Developed? [X] Yes [ ] No
Disinfected? [X] Yes [ ] No
Capped? [X] Yes [ ] No

13. Did you notify the owner of the need to permanently abandon and fill all unused wells on this property? [ ] Yes [X] No — If no, explain none

14. Signature of Point Driver or Licensed Supervisory Driller _____ Date Signed _____
Signature of Drill Rig Operator (Mandatory unless same as above) _____ Date Signed _____

Make additional comments on reverse side about geology, additional screens, water quality, etc.
Comments on reverse side _____ (CHECK √, IF YES)

WELL CONSTRUCTION REPORT
Form 3300-77A Rev. 8-98

Well Construction Report For
WISCONSIN UNIQUE WELL NUMBER OQ 271

State of Wisconsin
Private Water Systems-DG/2
Department of Natural Resources
Box 7921
Madison, WI 53707 **(Please type or print using a black pen.)**

Property Owner	Laura Parent / U.W. Geology Dept.
Telephone Number	(608) 294-1426
Mailing Address	1215 Dayton Street, 411 Weeks Hall
City	Madison
State	WI
Zip Code	53706
County of Well Location	Dane
Co. Well Permit No.	W
Well Completion Date (mm-dd-yy)	6 - 23 - 00
Well Constructor (Business Name)	WATER WELLS INC.
License #	3
Address	6400 Lake Road
City	Windsor
State	WI
Zip Code	53598

1. Well Location **Please use decimals instead of fractions.**

[X] Town [ ] City [ ] Village of Token Creek -Windsor   Fire # (If avail.)

Grid or Street Address or Road Name and Number: 3667 Egre Road

Subdivision Name ____ Lot # ____ Block # ____

Gov't Lot # ____ or ____ 1/4 of ____ 1/4 of

Section ____, T ____ N; R ____ [ ] E [ ] W

2. Mark well location with a dot in correct 40-acre parcel of section.

N / W / E / S

3. Well Type [X] New [ ] Replacement (see item 13 below) [ ] Reconstruction

of previous unique well # ____ constructed in 19____

Reason for replaced or reconstructed well? observation well

[X] Drilled [ ] Driven Point [ ] Jetted [ ] Other ____

4. Well serves __ # of homes and or ____ (Eg: barn, restaurant, church, school, industry, etc.)

High Capacity: Well? [ ] Yes [X] No   Property? [ ] Yes [X] No

5. Is the well located upslope or sideslope and not downslope from any contamination sources, including those on neighboring properties? [ ] Yes [ ] No   If no, explain on back side.

Well located in floodplain? [ ] Yes [X] No

Distance in Feet From Well To Nearest: (include proposed)

____ 1. Landfill	____ 9. Downspout/Yard Hydrant	____ 17. Wastewater Sump
____ 2. Building Overhang	____ 10. Privy	____ 18. Paved Animal Barn Pen
____ 3. Septic or Holding Tank (circle one)	____ 11. Foundation Drain to Clearwater	____ 19. Animal Yard or Shelter
____ 4. Sewage Absorption Unit	____ 12. Foundation Drain to Sewer	____ 20. Silo
____ 5. Nonconforming Pit	____ 13. Building Drain [ ] Cast Iron or Plastic [ ] Other	____ 21. Barn Gutter
____ 6. Buried Home Heating Oil Tank	____ 14. Building Sewer [ ] Gravity [ ] Pressure [ ] Cast Iron or Plastic [ ] Other	____ 22. Manure Pipe [ ] Gravity [ ] Pressure [ ] Cast Iron or Plastic [ ] Other
____ 7. Buried Petroleum Tank	____ 15. Collector Sewer: ___units ___in. diameter	____ 23. Other Manure Storage ____
____ 8. Shoreline/Swimming Pool (circle one)	____ 16. Clearwater Sump	____ 24. Ditch
		____ 25. Other NR 812 Waste Source

6. Drillhole Dimensions

Dia. (in.)	From (ft.)	To (ft.)
8.75	surface	37
5	37	200

Upper Enlarged Drillhole: Method of Construction

- [ ] 1. Rotary - Mud Circulation
- [X] 2. Rotary - Air
- [ ] 3. Rotary - Foam
- [ ] 4. Reverse Rotary
- [ ] 5. Cable-tool Bit ____ in. dia.
- [ ] 6. Temp. Outer Casing ____ in. dia. ____ depth; Removed? [ ] Yes [ ] No; If no, explain why not ____
- [ ] 7. Other ____

9. Geology (DNR USE ONLY)

Type, Caving/Noncaving, Color, Hardness, Etc.	From (ft.)	To (ft.)
drift	surface	13
red-brown sandstone	13	60
tan sandstone	60	160
light grey sandstone	160	200

7. Casing, Liner, Screen

Dia. (in.)	Material, Weight, Specification Manufacturer & Method of Assembly	From (ft.)	To (ft.)
5	std. steel PE	surface	37
	14.62 lbs		

Dia. (in.)	screen type, material & slot size	From	To

8. Grout or Other Sealing Material — Method: tremie line-pumped

Kind of Sealing Material	From (ft.)	To (ft.)	# Sacks Cement
neat cement	surface	37	30

10. Static Water Level
____ ft. above ground surface
23 ft. below ground surface

11. Pump Test
Pumping Level 225 ft. below surface
Pumping at 75 GPM for 25 hours

12. Well Is: 36 in. [X] Above [ ] Below Grade
Developed? [X] Yes [ ] No
Disinfected? [X] Yes [ ] No
Capped? [X] Yes [ ] No

13. Did you notify the owner of the need to permanently abandon and fill all unused wells on this property? [ ] Yes [X] No   If no, explain none

14. Signature of Point Driver or Licensed Supervisory Driller ____ Date Signed ____

Signature of Drill Rig Operator (Mandatory unless same as above) ____ Date Signed ____

Make additional comments on reverse side about geology, additional screens, water quality, etc.

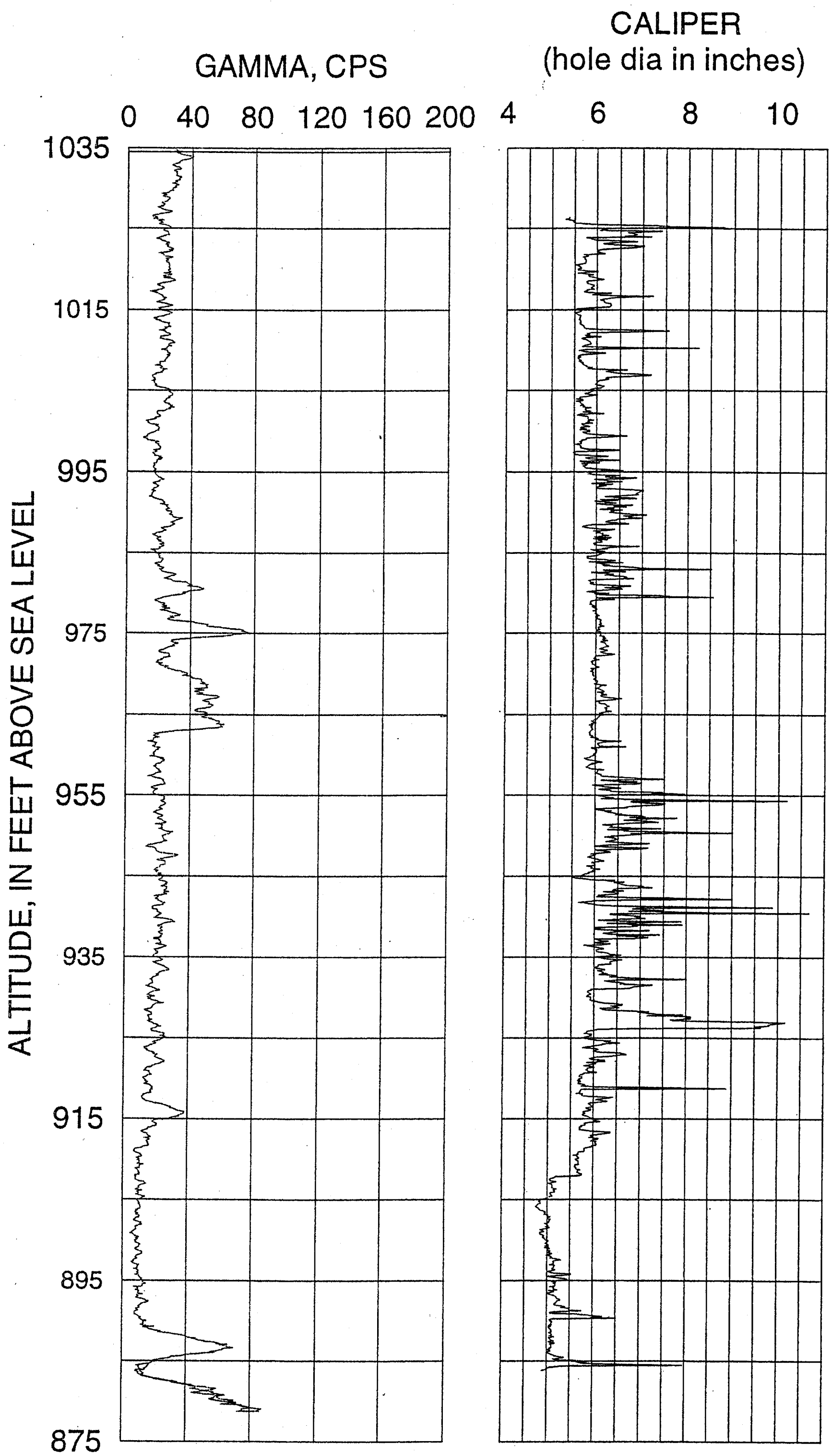
Comments on reverse side ____ **(CHECK √, IF YES)**

WELL CONSTRUCTION REPORT
Form 3300-77A Rev. 8-98

Appendix B
Geophysical Logs

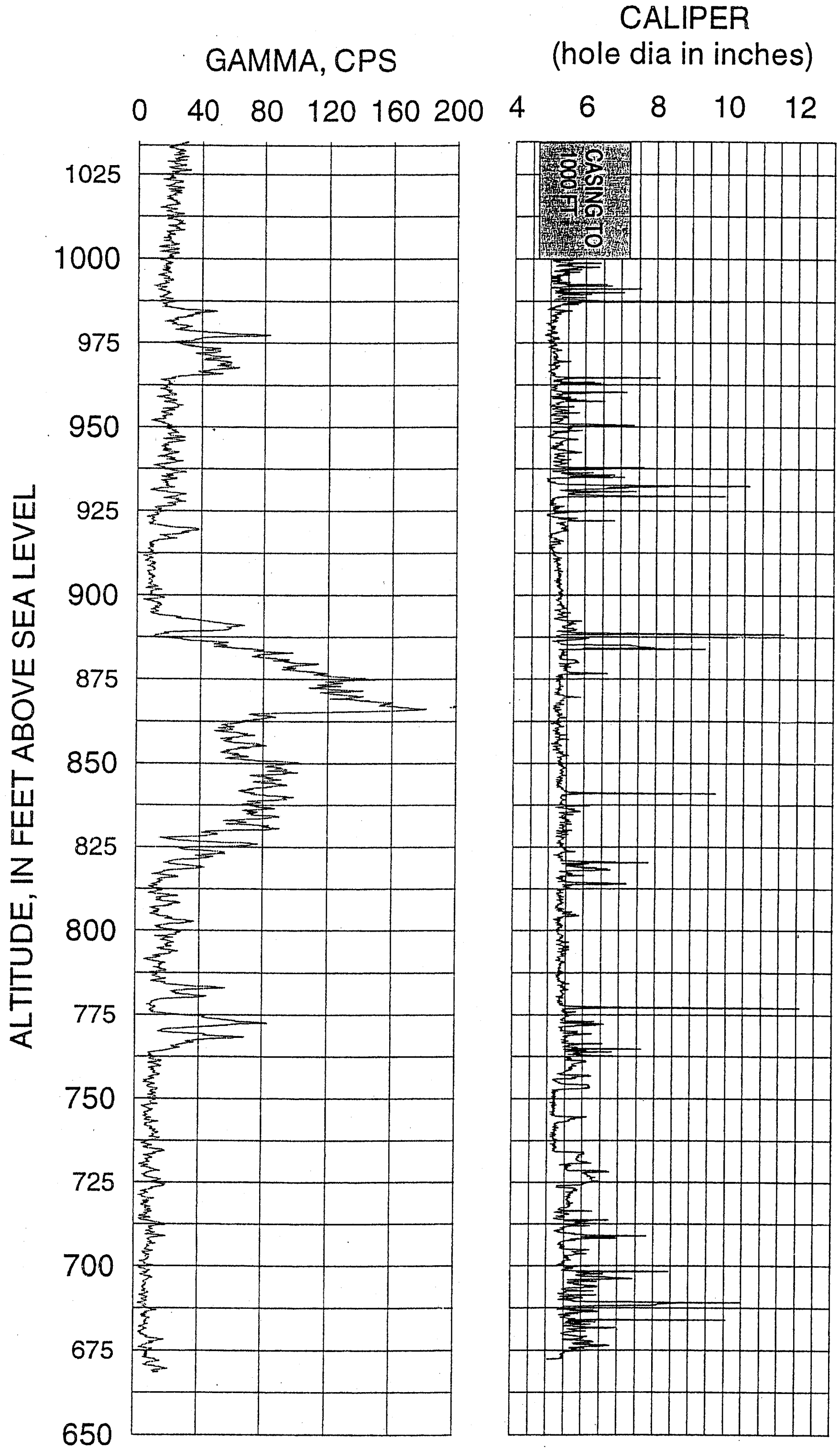
MUELLER ROAD PRIVATE WELL

Land surface altitude is 1035 ft above sea level
Log-depth values in ft above sea level
Casing depth 5 ft



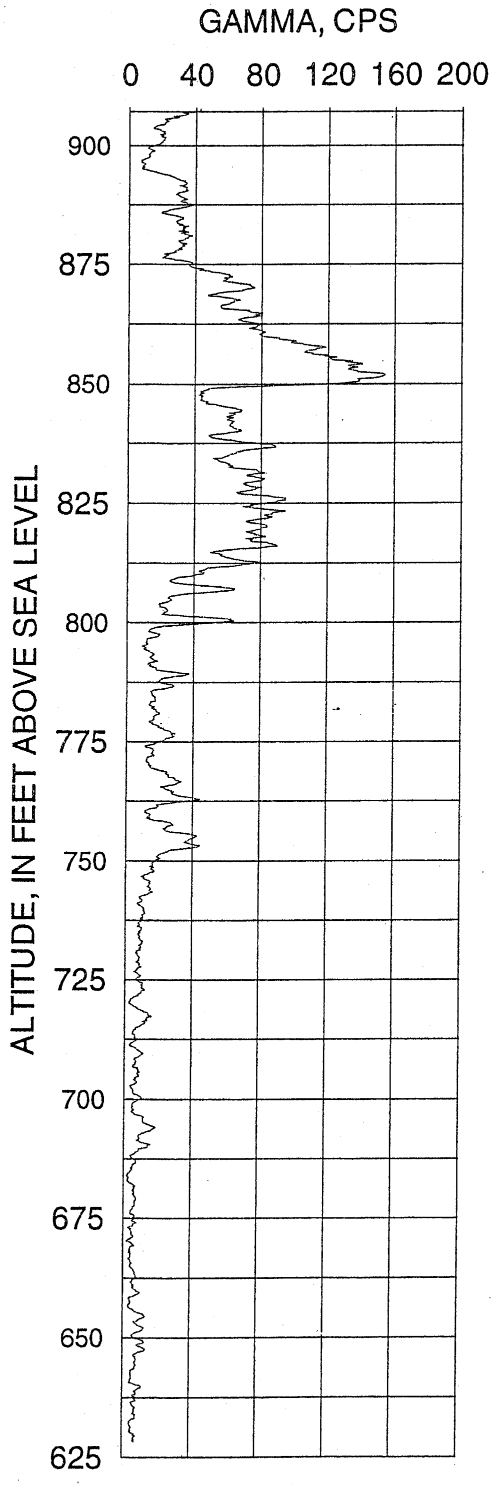
MUELLER ROAD DEEP WELL

Land surface altitude is 1035 ft above sea level
Log-depth values in ft above sea level
Casing depth 35 ft



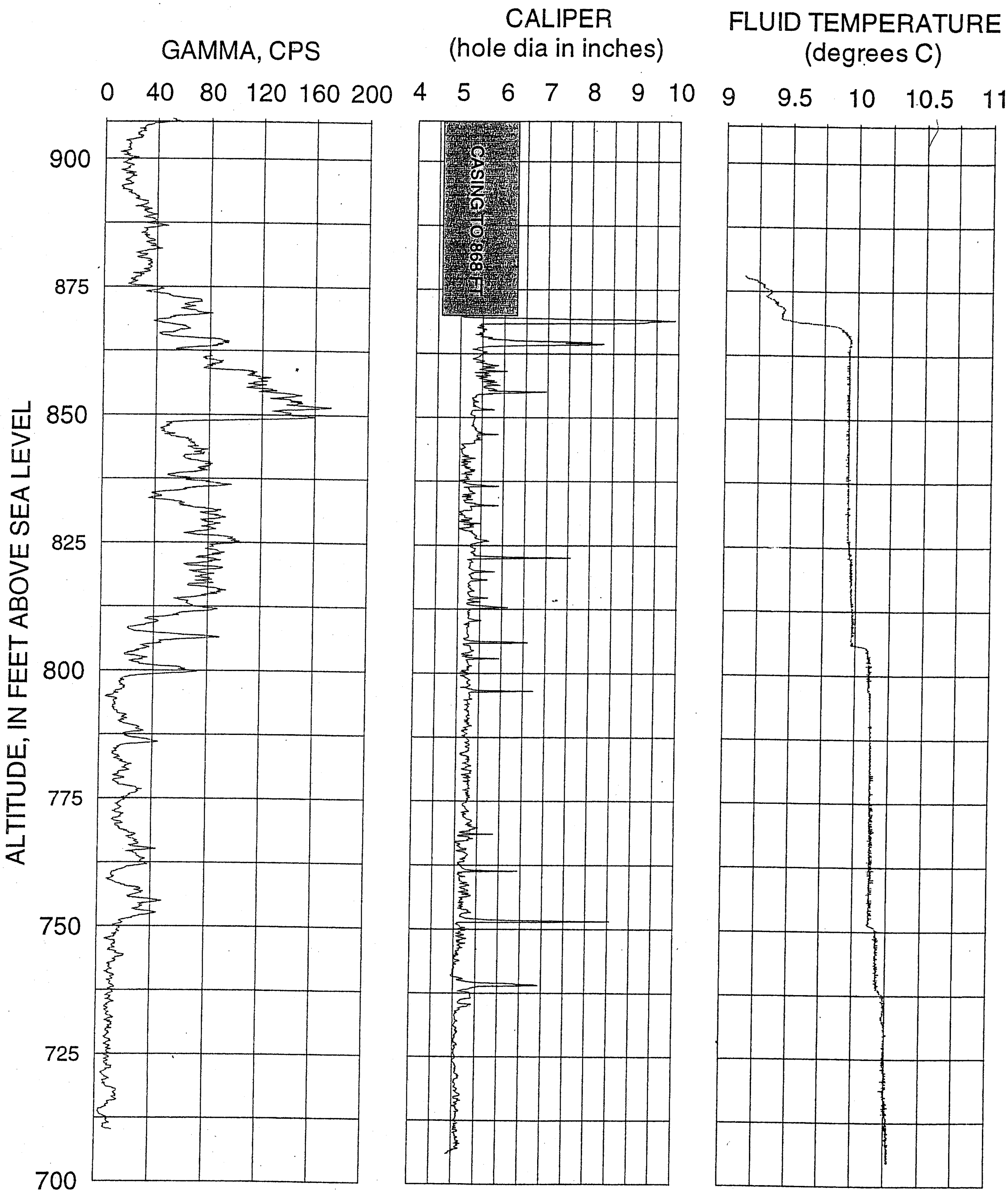
CULVER SPRINGS WELL 1

Land surface altitude is 908 ft above sea level
Log-depth values in ft above sea level
Casing depth 40 ft



CULVER SPRINGS WELL 2

Land surface altitude is 908 ft above sea level
Log-depth values in ft above sea level
Casing depth 40 ft



Appendix C: Major Ion and Stable Isotope Geochemistry

Sample Location	BH Spring	BH Spring	BH Spring	MW9	MW9	MW9	MW10	MW10	DNR Trt	DNR Trt	DNR Trt	MW1 Spr
Date Collected	3/26/2000	6/2/2000	9/25/2000	3/26/2000	6/2/2000	9/28/2000	3/26/2000	6/2/2000	6/2/2000	9/25/2000	5/13/2001	3/26/2000
Notes												
Field Data												
Temperature (°C)	11.9	11	10.8	8.9	9	10.9	9	8.7	10	10	10	9.3
Conductivity* (μmho)	556	636	576	797	835	1128	1104	1110	737	727	808	633
Alkalinity (ppm)	170	275	250	400	450	600	600	600	250	260	300	250
pH	6.9	7.26	7.4	6.8	7.02		6.93	6.79	6.87	7.2	7.14	6.88
Dissolved oxygen (ppm)	2	5	6	4	4	3	4	2	5	5	4	6
State Lab												
Conductivity* (μmho)	554	611	572	798	731	1080	1080	1060	709	717	731	630
pH	8	8.22	7.75	7.65	7.83	7.31	7.56	7.61	7.53	7.47	7.57	7.7
Alkalinity (ppm)	271	306	278	440	437	601	631	627	298	290	288	277
Cations												
Calcium (ppm)	59	68	63	80	100	120	110	110	73	75	76	66
Magnesium (ppm)	37	42	39	54	52	88	87	85	41	43	43	40
Sodium (ppm)	3.3	3.5	3.2	3	2.3	4.8	4.5	4.1	14	15	16	5.7
Potassium (ppm)	0.9	0.5	0.9	2.3	1.4	3.2	2.3	2.6	1.2	1	1.2	1
Anions												
Sulfate (ppm)	19.2	34.7	22.9	28.2	21.2	21.6	26.3	25.6	23.8	21.5	22.9	20.7
Chloride (ppm)	5.9	5.8	6.4	2	1.5	4.2	2	2	35	37.1	41	14.9
Nitrate and Nitrate as N(ppm)	2.31	lost	2.28	nd	lost	nd	nd	nd	5.89	6.55	6.24	7.47
*standardized to 25°C												
Stable Isotopes												
del^{18}O	-9.26	-9.03	-9.2	-8.82	-8.83	-8.69	-8.87	-8.61	-8.98	-8.88	-8.98	-9.26
delD	-60.2	-57.7	-61.2	-56.1	-56.1	-57.1	-57.3	-55.1	-57.6	-59	-58.5	-59.6

Sample Location	Mw3	Mw3	Mw3	Mw3	Pond 1	Pond 1	Pond 1	Pond 1	Pond 4	Pond 4	Pond 4	Pond 4
Date Collected	3/26/2000	6/5/2000	9/28/2000	5/13/2001	3/26/2000	6/2/2000	9/25/2000	5/2/2001	3/26/2000	6/1/2000	9/25/2000	5/2/2001
Notes					Boil at NW edge	Boil at NW edge	Boil at NW edge	Boil at NW edge	Boil in Center of	Boil in Center of	Boil in Center of	Boil in Center of
Field Data												
Temperature (°C)	8.6	8.5	11.7	9.7	9.8	9.7	9.8	9.8	9.7	13	9.8	9.8
Conductivity* (μmho)	615	620	615	678	711	704	626	744	676	684	677	706
Alkalinity (ppm)	250	290	275	300	275	240	230	275	275	250	225	340
pH	6.95	6.85	7.11	7.23	6.54	7	7.09	7.24	6.84	6.91	7.25	7.36
Dissolved oxygen (ppm)	<1	<1	2	3	6	8	7	6	5	5	7	6
State Lab												
Conductivity* (μmho)	612	605	613	612	701	685	678	681	671	647	673	678
pH	7.73	7.7	7.58	7.63	7.76	7.69	7.55	7.8	7.76	7.67	7.65	7.64
Alkalinity (ppm)	284	292	275	280	272	271	275	270	265	262	264	260
Cations												
Calcium (ppm)	68	68	73	71	75	74	73	74	72	69	73	74
Magnesium (ppm)	39	40	41	40	41	40	43	42	40	38	41	41
Sodium (ppm)	3.9	3.8	4.1	4	8.7	8.2	8.4	8	8.3	7.1	7.8	7.9
Potassium (ppm)	1.4	1.3	1.6	1.3	1.4	1.1	1.4	1.1	1.2	1.2	1.4	1
Anions												
Sulfate (ppm)	43.3	46.5	47.9	41.7	29.9	29.9	26.6	27	27.9	27.3	26.4	27.4
Chloride (ppm)	10.9	11	14.2	11.5	24.2	23	21.9	22	21.5	20	22.4	22.2
Nitrate and Nitrate as N(ppm)	nd	nd	nd	nd	12.5	12.2	9.94	10.9	12.1	11.6	11.4	12.3
*standardized to 25°C												
Stable Isotopes												
del^{18}O	-9.33	-9.3	-9.21	-9.39	-9.28	-9.23	-8.89	-9.36	-9.3	-9.37	-9.34	-9.36
delD	-60.4	-58.1	-62.7	-62.6	-59.7	-59.3	-61	-60.6	-59.8	-58.5	-61.5	-60.4

Sample Location	Seeps	VB6	VB6	MW8b	MW8b	MW8a	MW8a	MW8a	MW5	MW5	MW6A	MW6A
Date Collected	5/10/2001	3/27/2000	5/29/2000	3/27/2000	5/29/2000	3/27/2000	5/29/2000	9/27/2000	3/29/2000	6/5/2000	3/29/2000	5/29/2000
Notes												
Field Data												
Temperature (°C)	10.6	5	7.5	6.8	8.3	7.8	9.3	9.5	5.6	8.1	9.5	9.6
Conductivity* (μmho)	736	781	800	773	780	647	640	644	517	529	701	736
Alkalinity (ppm)	275	350	300	430	500	300	300	250	255	235	300	300
pH	7.76	6.89	6.8	6.94	6.73	7.02	6.87	7.35	7.08	7.39	6.9	6.87
Dissolved oxygen (ppm)	6							1.5	4	4	4	
State Lab												
Conductivity* (μmho)	712	762	769	645	762	770	629	635	509	506	712	709
pH	7.74	7.64	7.46	7.79	7.52	7.75	7.74	7.79	7.81	8.06	7.63	7.52
Alkalinity (ppm)	309	322	327	293	361	384	292	286	283	283	304	303
Cations												
Calcium (ppm)	80	82	86	68	87	81	70	71	60	52	78	81
Magnesium (ppm)	44	44	47	41	53	53	42	43	38	38	44	44
Sodium (ppm)	10	5.5	6.2	4.9	5.6	4.9	5.1	5.2	3.2	2.7	7.2	7.3
Potassium (ppm)	0	0.9	1.2	1.4	1.1	0.9	1.5	1.5	0.9	0.7	1.5	1.5
Anions												
Sulfate (ppm)	23.9	15.9	16.6	37.7	23	22.9	36.3	36.1	nd	nd	32.4	32.1
Chloride (ppm)	26.8	18.4	19.5	16.7	17.5	13.8	15.4	16.7	1.3	1.4	21.9	22.5
Nitrate and Nitrate as N(ppm)	6.18	15.9	16.7	1.47	8.46	3.83	1.55	1.92	0.17	0.2	8.66	8.46
*standardized to 25°C												
Stable Isotopes												
del^{18}O	-9.20	-8.73	-8.78	-8.88	-8.74	-8.93	-8.92	-8.82	-9.39	-9.41	-9.16	-9.1
delD	-59.6	-56.3	-55.2	-57.4	-54.8	-57.5	-56.8	-59.2	-62.7	-60.5	-57.4	-57.5

Sample Location	MW6A	MW6A	MW7A	MW7A	MW7A	MW6B	MW6B	MW7B	MW7B	6435 Prtg	6435 Prtg	3503 Wndsr
Date Collected	9/27/2000	5/13/2001	3/29/2000	5/29/2000	9/27/2000	3/29/2000	5/29/2000	3/29/2000	5/29/2000	6/1/2000	9/28/2000	6/1/2000
Notes												
Field Data												
Temperature (°C)	10	9.6	6.9	8.5	11.4	7.6	8.1	5.6	9.1	19	18.1	19.9
Conductivity* (µmho)	744	830	827	836	852	944	988	760	599	496	497	870
Alkalinity (ppm)	275	350	450	250	350	550	500	400	300	250	225	400
pH	7.14	7.28	6.75	6.61	7.01	6.81	6.57	6.64	6.56	7.28	7.5	6.84
Dissolved oxygen (ppm)		6	3		5	1		3		3		5
State Lab												
Conductivity* (µmho)	744	741	834	822	837	955	957	764	620	475	476	831
pH	7.53	7.47	7.77	7.43	8.03	7.4	7.31	7.84	7.37	7.73	7.85	7.46
Alkalinity (ppm)	311		359	359	350	479	490	319	284	263	256	320
Cations												
Calcium (ppm)	82	84	94	97	95	77	83	87	77	51	55	87
Magnesium (ppm)	45	46	51	53	51	60	63	47	42	32	33	47
Sodium (ppm)	7.7	7.9	6	6.4	6.4	44	43	5.3	5.7	2.6	2.6	15
Potassium (ppm)	1.6	1.7	0.7	0.6	0.9	8.4	10	nd	nd	0.9	1	2
Anions												
Sulfate (ppm)	33	33.6	29.6	28.6	29.1	38.9	37	25.9	18.5	5.9	6.5	31.4
Chloride (ppm)	24.1	24.3	21.3	21.9	25.3	18.9	18.2	20.3	13.2	0.8	0.7	39.9
Nitrate and Nitrate as N(ppm)	8.91	8.93	13.2	13.1	14.6	2.27	2.22	13.4	7.83	nd	0.12	15.5
*standardized to 25°C												
Stable Isotopes												
del^{18}O	-8.98	-9.12	-8.74	-8.69	-8.63	-8.75	-8.78	-8.8	-8.84	-9.24	-9.25	-9.01
delD	-59.1	-61.1	-55	-53.1	-55	-56.1	-56.6	-55.5	-54.4	-60.1	-61	-58.3

Sample Location	3737 Millst	3737 Millst	3747 Mdwbk	3747 Mdwbk
Date Collected	6/1/2000	9/28/2000	6/1/2000	9/28/2000
Notes				
Field Data				
Temperature (°C)	21.2	11.7	15.4	14.2
Conductivity* (µmho)	633	654	632	665
Alkalinity (ppm)	300	275	250	230
pH	7.35	7.43	7.21	7.5
Dissolved oxygen (ppm)	4		5	
State Lab				
Conductivity* (µmho)	610	644	597	648
pH	7.68	7.74	7.63	7.87
Alkalinity (ppm)	282	286	259	260
Cations				
Calcium (ppm)	58	66	63	73
Magnesium (ppm)	43	47	37	41
Sodium (ppm)	5.8	6.3	6.2	8
Potassium (ppm)	1.9	1.7	1.4	1.4
Anions				
Sulfate (ppm)	22	21.7	20.4	23.1
Chloride (ppm)	14.8	17.1	15.8	21.4
Nitrate and Nitrate as N(ppm)	5.47	5.84	8.6	10.4
*standardized to 25°C				
Stable Isotopes				
del^{18}O	-9.4	-9.44	-9.44	-9.46
delD	-60.1	-62.5	-61.4	-62.7