# AN EVALUATION OF THE POTENTIAL TO INCREASE THE PUMPING CAPACITY OF THE GROUND-WATER SUPPLY FOR THE CITY OF BOTTINEAU – PHASE II – RESULTS OF PUMPING TESTS, WATER CHEMISTRY SAMPLING AND RECOMMENDATIONS

**By Robert B. Shaver**
**North Dakota Water Commission**

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**NORTH DAKOTA GROUND-WATER STUDIES NUMBER 114**

**Bismarck, North Dakota**

**2004**

# AN EVALUATION OF THE POTENTIAL TO INCREASE THE PUMPING CAPACITY OF THE GROUND-WATER SUPPLY FOR THE CITY OF BOTTINEAU USING ADDITIONAL WELLS PHASE II– RESULTS OF PUMPING TESTS, WATER CHEMISTRY SAMPLING, AND RECOMMENDATIONS

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## INTRODUCTION

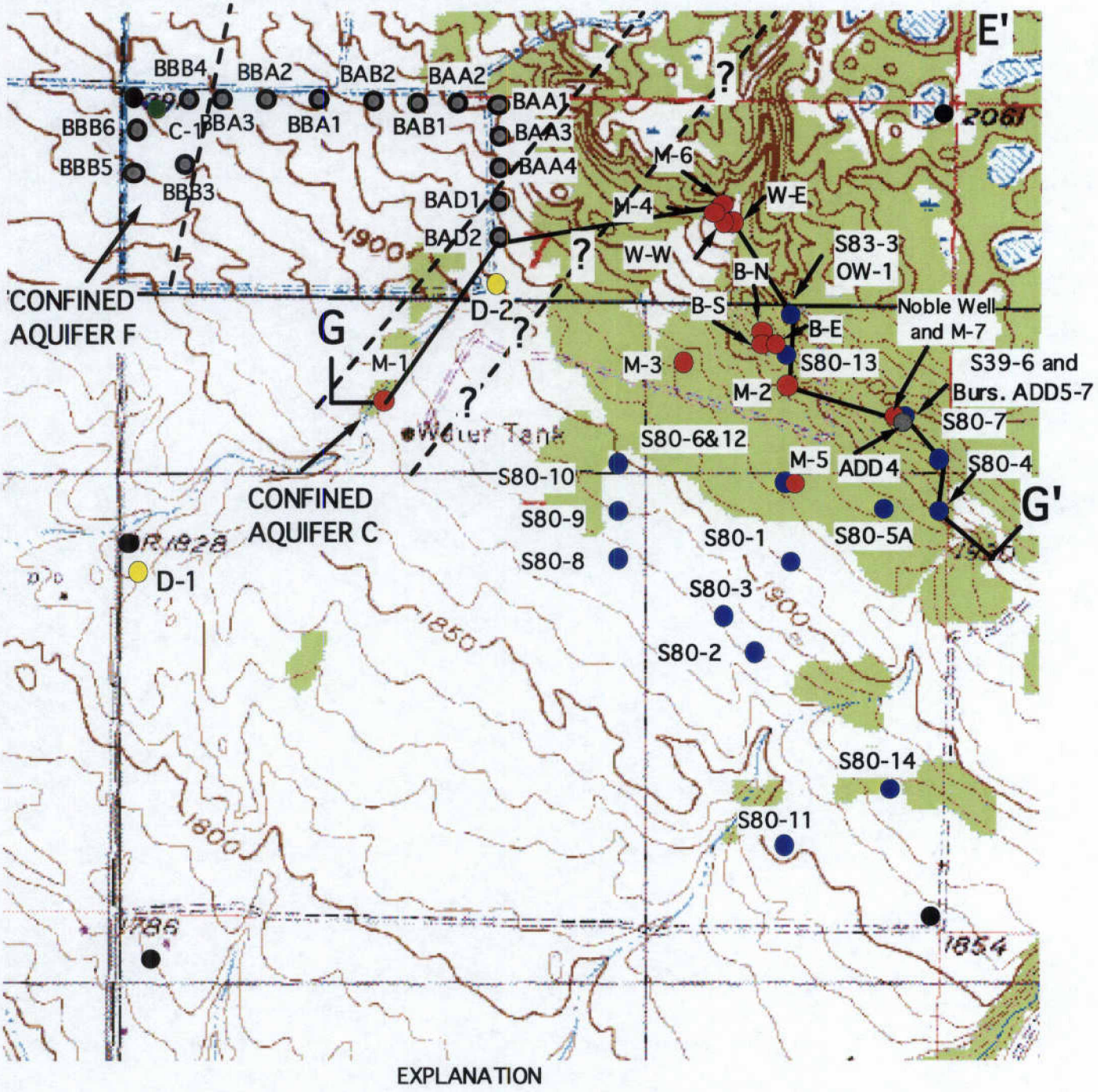
Due to elevated uranium concentrations in municipal wells 2 and 3 (well 3 exceeds USEPA primary contaminant level), the city of Bottineau is exploring options to augment its existing ground-water supply (fig. 1). The city has stopped pumping wells 2, 3, and 5, all of which are hydraulically connected and completed in the same discrete buried channel aquifer (confined aquifer B). Currently, ground water is being pumped from wells 1 and 6 and additional ground water is derived from the flowing "Bittner" and "Noble" wells. The city reports the pumping rate of well 6 at 185 gallons per minute (gpm) and the pumping rate of well 1 at about 70 gallons per minute. The total flowing rate of the three "Bittner" wells was measured at six gpm and the flowing rate of the Noble well was measured at 48 gpm (Keith Fulsebakke, Bottineau Municipal Works Supervisor – verbal communication). According to Mr. Fulsebakke, the current well-field discharge rate is meeting the city's needs but the city needs additional well-discharge capacity and back-up wells to ensure meeting peak demand.

In a report entitled "A Hydrogeologic Analysis to Determine the Sustained Yield of the Bottineau Municipal Well Field and All Seasons Rural Water Systems I and II Bottineau County, North Dakota" prepared by the North Dakota State Water Commission (North Dakota Ground Water Studies No. 109), the following recommendations were made to increase the pumping capacity of the Bottineau municipal ground-water supply:

1. Install a replacement well for the "Noble" well and install a pump to maximize the discharge rate instead of relying on natural flow.
2. Install a well(s) in the NW1/4 of Section 7.

On August 4, 2003, the city of Bottineau entered into a cooperative agreement with the North Dakota State Water Commission to evaluate the potential of increasing the pumping capacity of the ground-water supply for the city of Bottineau by using additional wells. This study was divided into two phases. Phase I consisted of test drilling, observation well (piezometer)

# TOWNSHIP 162 NORTH, RANGE 75 WEST, SECTION 7




EXPLANATION

- Bottineau Municipal Well: M-1 = Municipal Well #1, B = Bittner Wells, W = Walker Wells
- Simpson & Sons Drilling Test Hole: S39-6 = Simpson 1939 Test Hole #6, S80-9 = Simpson 1980 Test Hole #9, S83-3 = Simpson 1983 Test Hole/Observation Well #1
- N.D. State Water Commission Test Hole
- Domestic well D-1,D-2
- Commercial Test Well
- Test hole/piezometer completed for Phase I study, August, 2003


Location of geohydrologic section G-G' (See Fig. 3 )

Figure 1. -- Land-surface topography, location of wells, test holes, confined aquifers C and F, and geohydrologic section G-G' in the Bottineau well field area

construction, and sampling for water-chemistry analysis. Phase I was completed in September 2003. Results of the Phase I study are presented in a report entitled "An Evaluation of the Potential to Increase the Pumping Capacity of the Ground-Water Supply for the City of Bottineau Using Additional Wells, Phase I – Results of Test Drilling and Water Chemistry Sampling, prepared by the North Dakota State Water Commission (North Dakota Ground-Water Studies No. 109)."

The Phase I report identified three sites where additional ground-water development is feasible. These sites are:

1. 162-075-07ADD4 – about 30 feet south of the Noble well.
2. 162-075-07BAD2 – north of the Gordon Hall farmstead.
3. 162-075-07BBB4 – northwest corner of the NW1/4 of Section 7.

It was estimated that properly completed wells in each of the above three areas could provide long-term sustained yields of between 50 and 100 gallons per minute. In order to determine maximum sustained pumping rates, it was recommended that test wells be constructed at each of the three sites and long-term pumping tests should be conducted on each test well. It was further recommended that water samples for chemical analysis be collected periodically during each pumping test to determine changes, if any, in water chemistry (particularly uranium) over time.

A test well was installed at 162-075-07ADD6 (12 feet east of the old Noble well) in July 2004 and a pumping test was conducted on the test well in August 2004 (fig. 1). Over the duration of the pumping test, five water samples were collected for chemical analysis.

In the Phase I study, it was speculated that municipal well #1 and piezometer 162-075-07BAD2 (Gordon Hall farmstead site) are both completed in the same buried channel aquifer (confined aquifer C) (fig. 1). Except for the period from March 1 through March 17 when the pump was replaced, well #1 was continuously pumped from December 1, 2003 through May 25,

2004. Normally, this well is not used during the winter months. Because there are no other wells pumping in confined aquifer C, pumping municipal well #1 provided a unique opportunity to observe pumping effects (well interference) at proposed test well site 162-075-07BAD2 over an extended pumping period. Monitoring piezometer 162-075-07BAD2 during this time period eliminated the need to construct and pump a test well at site 162-075-07BAD2.

Based on the available water supply and projected water-use demand, it was decided that there was no immediate need to construct a test well at site 162-075-07BBB. If water use demand should increase significantly in the future, a production well could be constructed at this site and tested.

This Phase II report describes the results of pump testing, water-level monitoring, and water-quality sampling as related to pumping municipal well #1 and the test well located at 162-075-07ADD6. A maximum pumping rate of 100 gallons per minute is recommended at the production well located at 162-075-07ADD6.

Lithologic logs of wells and test holes are presented in Appendix I. Chemical analyses of five ground-water samples collected from test well 162-075-07ADD6 (Noble well site) are presented in Appendix II.

## Location-Numbering System

The location-numbering system used in this report is based on the public land classification system used by the U.S. Bureau of land Management. The system is illustrated in figure 2. The first number denotes the township north of a base line, the second number denotes the range west of the fifth principal meridian, and the third number denotes the section in which the well or test hole is located. The letters A, B, C, and D designate, respectively, the northeast, northwest, southwest, and southeast quarter section, quarter-quarter section, and quarter-quarter-quarter

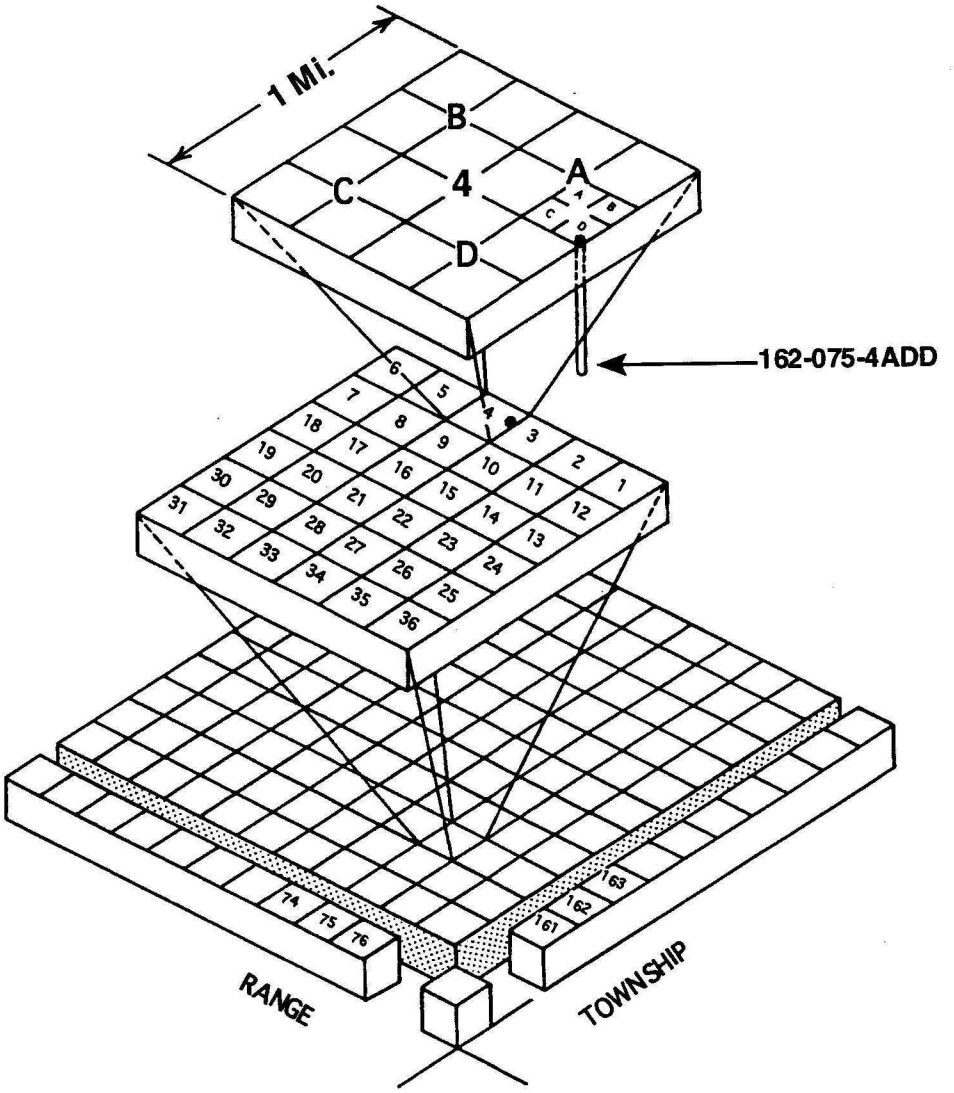



**Figure 2.-- Location-numbering system**

section (10-acre tract). For example, well 162-075-04ADD is located in the SE1/4SE1/4NE1/4 Section 4, Township 162 North, Range 75 West. Consecutive terminal numerals are added if more than one well or test hole is located within a 10-acre tract.

## Methods

Methods (drilling, piezometer/well construction, water sampling/analysis) and the description of the study area (physiography, climate, geology, hydrogeology) are described in Shaver (2002 and 2003). The location of all wells and piezometers are shown in figure 1.

## PROPOSED TEST SITE – 162-075-07BAD2 – CONFINED AQUIFER C

Production well test site 162-075-07BAD2 overlies confined aquifer C (figs. 1 and 3). At this site, the aquifer, which is comprised of sand and gravel, occurs from 83 to 98 feet below land surface. On September 3, 2003, the water level was measured at 49.40 feet below land surface. The width of the buried glaciofluvial channel referred to as confined aquifer C is unknown. It is probably less than about 800 feet. Prior to this Phase II study, it was uncertain as to whether municipal well #1 and piezometer 162-075-07BAD2 were both completed in confined aquifer C. To determine hydraulic continuity and if site 162-075-07BAD2 was suitable for a new municipal well, the construction and test pumping of a production well was recommended at this site.

## Evaluation of Pumping Effects of Municipal Well #1 in Piezometer 162-075-07BAD2

In a March 2004, telephone conversation with Mr. Keith Fulsebakke, Bottineau Municipal Works Supervisor, I was informed that municipal well #1 had been continuously pumping from December 1, 2003 through February 29, 2004. In the past, the city has not pumped municipal well #1 during the winter because the well/transmission line is not properly winterized. Due to elevated

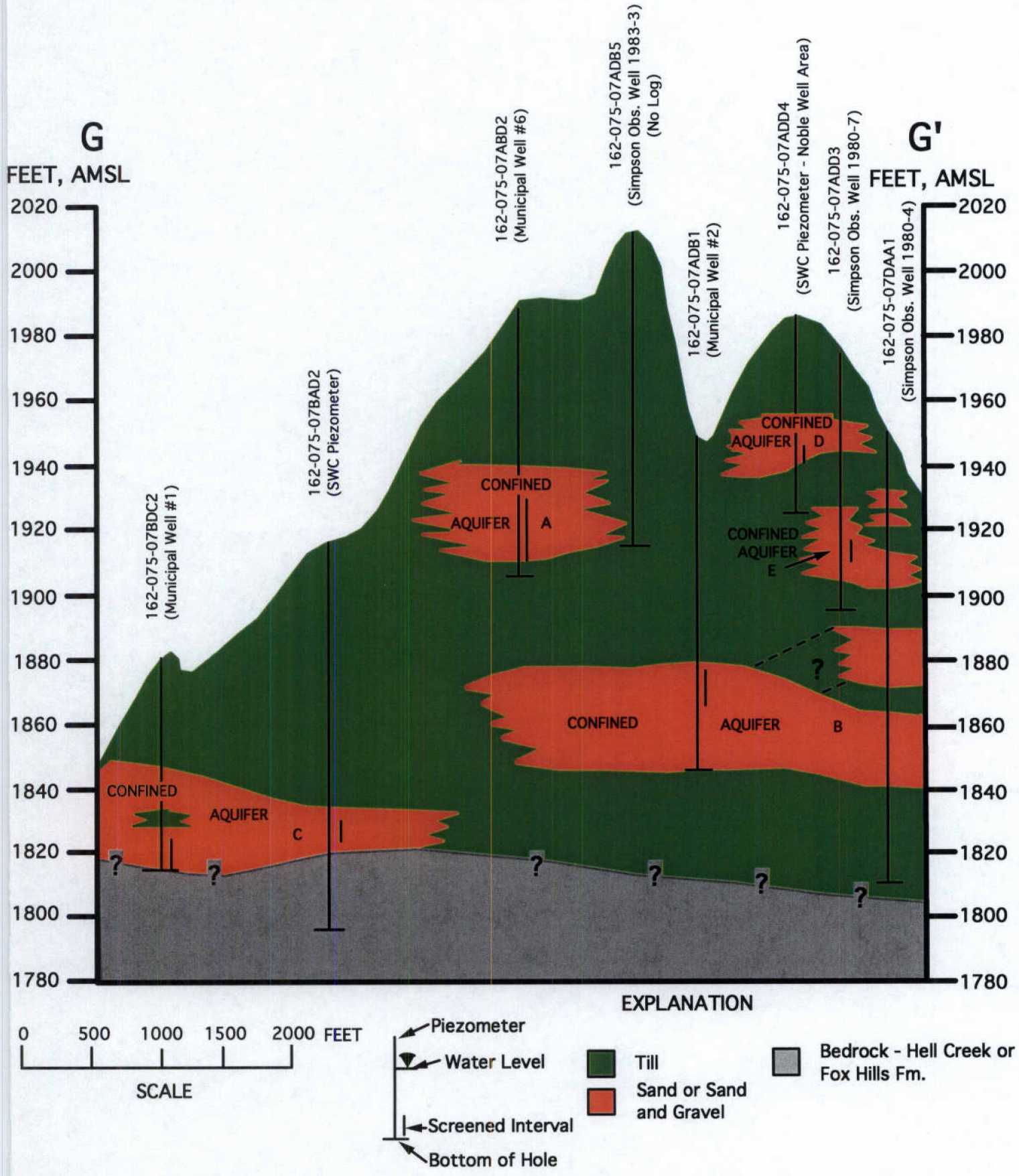



Figure 3. -- Geohydrologic section G-G' showing confined aquifers A,B,C,D, and E in the Bottineau aquifer

uranium concentrations in municipal wells 2, 3, and 5, all of which are completed in confined aquifer B (fig. 2), these wells were not used during the winter. To maintain an adequate water supply, well #1 was pumped continuously at a rate of 50 gallons per minute.

From 0800 hours on March 1, 2004 until 1420 hours on March 17, 2004, municipal well #1 was shut off and water levels were measured daily at 0830 hours in piezometer 162-075-07BAD2. On March 17, 2004, a new submersible pump was installed in municipal well #1. Beginning at 1420 hours on March 17, the well was pumped continuously at a rate of 72 gallons per minute until 0845 hours on May 25, 2004. Water levels were measured generally on a daily basis at 0830 hours in municipal well #1 and piezometer 162-075-07BAD2 from March 17, 2004 through May 28, 2004. Water-level fluctuations in municipal well #1 and piezometer 162-075-07BAD2 are shown in figure 4. Based on the pattern of water-level response shown in figure 4, it is clear that a good hydraulic connection exists between municipal well #1 and piezometer 162-075-07BAD2 and both the well and piezometer are completed in confined aquifer C.

As indicated in Shaver (2002), the total depth of municipal well #1 is 63.34 feet below the top of the 10-inch diameter steel casing inside the manhole. The screened interval is from 53.89 to 63.34 feet below the top of the steel casing. The "static" water level is estimated at about two feet below the top of the steel casing. This leaves 51.89 feet of available head above the top of the well screen.

## Evaluation of Installing an Additional Municipal Well at 162-075-07BAD2

Pumping municipal well #1 continuously from March 17 through May 25, 2004, provided a unique opportunity to evaluate the potential of installing an additional municipal well at 162-075-07BAD2 without constructing a test well and conducting a longer-term pumping test on the test

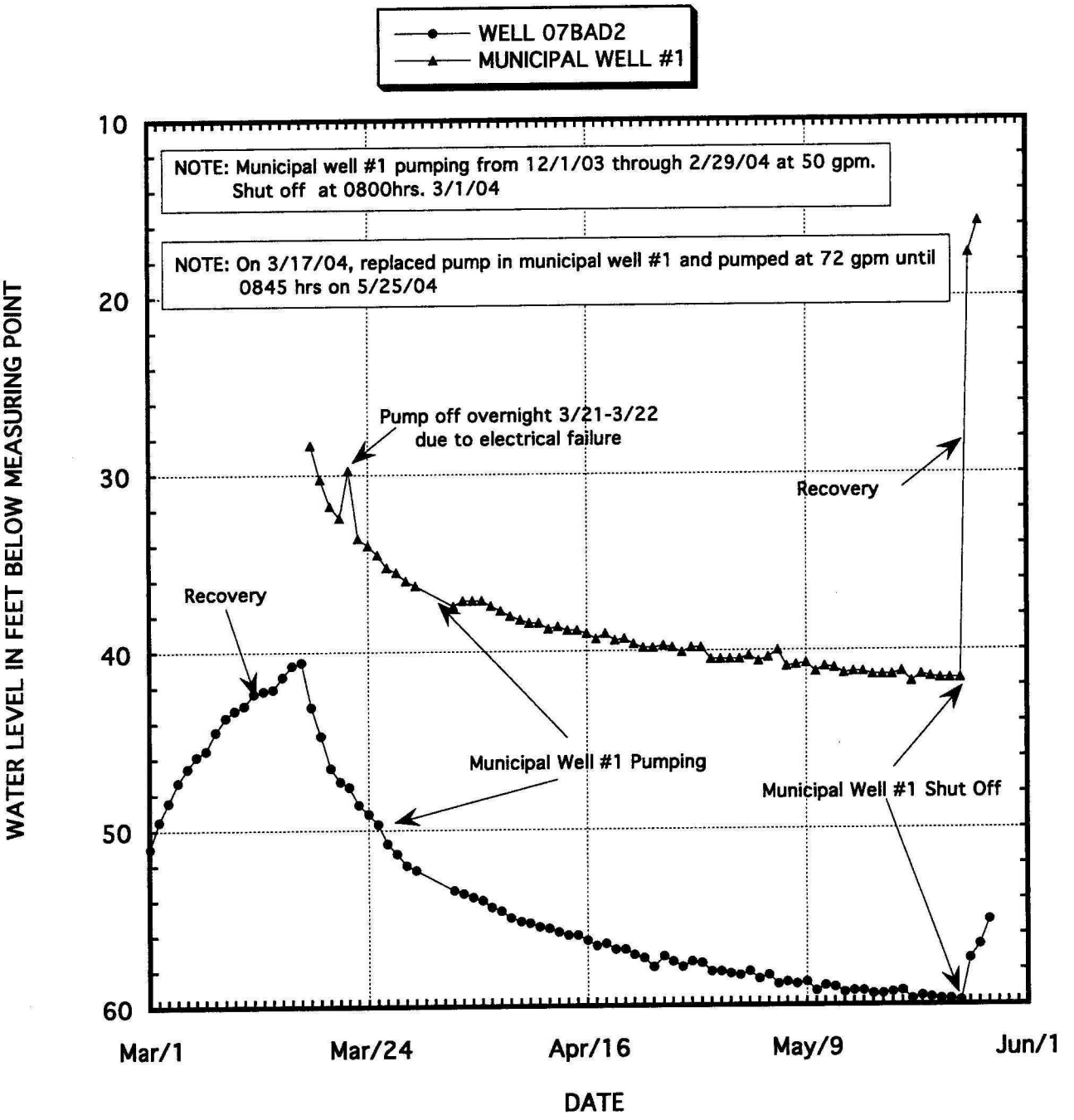



Figure 4. -- Water level fluctuations in municipal well #1 and SWC piezometer 162-075-07BAD2

well. Piezometer 162-075-07BAD2 is located about 1260 feet up gradient from municipal well #1 (fig. 1). Pumping municipal well #1 at a rate of 72 gallons per minute for about 69 days caused a drawdown of about 19.3 feet at piezometer 162-075-07BAD2 (fig. 4). Pumping a new municipal well at 162-075-07BAD2 at the same rate over the same length of time will cause at least about 19 feet of drawdown interference at municipal well #1. However, because 162-067-07BAD2 is located up gradient from municipal well #1, pumping at the same rate for the same length of time at 162-075-07BAD2 will likely cause more than 19 feet of drawdown interference at municipal well #1. At this time, the additional drawdown interference is indeterminate because the uniform flow field and aquifer width are not known.

At the end of the pumping period for municipal well #1 at 0830 hours on May 25, 2004, the pumping level in municipal well #1 was about 41.5 feet below the top of the 10-inch steel casing inside the manhole. The top of the well screen is about 53.9 feet below the top of the steel casing. Thus, after pumping continuously at a rate of 72 gallons per minute for 69 days, the pumping level was about 12.4 feet above the top of the well screen. As previously stated, pumping a new municipal well at 162-075-07BAD2 at a rate of 72 gallons per minute for 69 days would cause at least 19 feet of drawdown interference at municipal well #1. This would cause the pumping water level in municipal well #1 to drop below the top of the well screen thereby causing a significant reduction in pumping rate to occur. Based on the above, it is not practical to install a new municipal well at 162-075-07BAD2 or at any other location in confined aquifer C within Section 7 (fig. 3). Pumping a new well in confined aquifer C would essentially be a "robbing Peter to pay Paul" scenario yielding little total increase in pumping capacity.

## PROPOSED TEST SITE - - 162-075-07ADD4, NOBLE WELL AREA, CONFINED AQUIFER D

Shaver (2002) identified confined aquifer D based on test drilling completed by Simpson and Son Drilling in 1939 and 1980 (fig. 3). Prior to this Phase II study, it was inconclusive as to whether the aquifer interval in TH 39-6 and the upper aquifer interval in TH 80-7 formed a discrete buried confined aquifer (confined aquifer D) or were part of a southeast extension of confined aquifer A.

The drilling log for piezometer 162-075-07ADD4 completed in the Phase I study indicated an interval of stratified sand and gravel from 31 to 47 feet below land surface. This site is about 30 feet south of the older Noble well. Shortly after installing piezometer 162-075-07ADD4, Mr. Keith Fulsebakke shut-in the flowing Noble well and measured an almost instantaneous water-level use in piezometer 162-075-07ADD4. This indicates the old Noble well, for which no driller's log exists, is completed in the same aquifer (confined aquifer D) as piezometer 162-075-07ADD4.

On April 23, 2004, Bursinger Well Drilling completed a test hole at the Noble well site at 162-075-07ADD5. The driller's log is shown in table 1. The gravel interval from 30 to 41 feet below land surface is confined aquifer D (fig. 3).

Table 1. – Driller's log of test hole 162-075-07ADD5

| LITHOLOGIC DESCRIPTION | DEPTH From | DEPTH To |
|---|---|---|
| Topsoil | 0 | 1 |
| Yellow Clay | 1 | 18 |
| Blue Clay | 18 | 20 |
| Gravel | 20 | 21 |
| Blue Clay | 21 | 30 |
| Gravel | 30 | 41 |
| Blue Clay | 41 | 55 |
| Gravel | 55 | 61 |
| Clay | 61 | 62 |
| Gravel | 62 | 67 |
| Blue Clay | 67 | 70 |
| Fine dusty sand, drilled fast, smooth, poor recovery | 70 | 79 |
| Yellow Clay | 79 | 83 |
| Gravel | 83 | 93 |
| Blue Clay | 93 | 96 |
| Gray Clay, Bedrock | 96 | 112 |

Based on the above test hole, Bursinger Well Drilling installed a test production well 12 feet east of the old Noble well (fig. 1). The driller's log is shown in table 2.

Table 2. – Driller's log of municipal test well 162-075-07ADD6

| LITHOLOGIC DESCRIPTION | DEPTH From | DEPTH To |
|---|---|---|
| Yellow Clay | 0 | 12 |
| Blue Clay | 12 | 30.5 |
| Sand and Gravel, bottom 10 feet is coarse gravel, upper part was sandy | 30.5 | 49 |

The production well was completed with 10 feet of 8-inch diameter, pipe size, #60-slot, stainless-steel, high-Q Johnson screen set from 39 to 49 feet below land surface. The 8-inch diameter PVC well casing extended from 1.48 feet above land surface (water-level measuring point) to 39 feet below land surface.

After the test production well was installed, another piezometer was installed 45 feet southwest of the municipal test well in the gravel interval just below confined aquifer D. The driller's log of the piezometer is shown in table 3. The piezometer was completed with 60 feet of 2-inch diameter PVC casing and slotted screen. The screened interval is 58.1 to 63.1 feet below land surface. The screened interval was sand packed and the annular area above the screen was grouted with a bentonite slurry to land surface. The well would not pump and the water level was about 45 to 47 feet below land surface. This well did not respond to pumping the municipal test well at 162-075-07ADD6. It appears the well is either plugged or the sand and gravel in which the piezometer was completed is a small, isolated lense.

Table 3. – Driller's log of piezometer 162-075-07ADD7

| LITHOLOGIC DESCRIPTION | DEPTH | |
|---|---|---|
| | From | To |
| Topsoil | 0 | 1 |
| Yellow Clay | 1 | 17.5 |
| Blue Clay | 17.5 | 30 |
| Gravel | 30 | 39.5 |
| Blue Clay | 39.5 | 55 |
| Gravel | 55 | 66 |
| Yellow Clay | 66 | 72 |

## Development of Municipal Test Well 162-075-07ADD6

Development was initiated on the municipal test well (162-075-07ADD6) on July 20,2004. The well screen was jetted with water while pumping simultaneously using a suction-lift pump. In addition, the well was periodically "blown" with air and pumped with air using the drill rig air compressor.

During the development period, three, short-term pumping tests were conducted on the well to evaluate improvement in well efficiency. The pump tests ranged in length from 60 to 90 minutes. A suction lift pump was used to pump the well. Pumping rates were not kept constant during the

tests and discharge varied from about 120 to 86 gallons per minute. Higher pumping rates occurred during the beginning of each test when pumping water levels were high. Lower pumping rates occurred during later times as pumping water levels declined, thereby increasing pump lift. In addition, the old Noble well was shut-in but water flowed outside the top of the well "seal" causing the manhole to fill with water and overflow at land surface. The flow rate was estimated at less than five gallons per minute. Further, municipal well #6 was pumping from 1300 hours on July 19 to about 0830 hours on July 21. The "static" water level in the test well prior to initiating the first short-term pump test conducted at 0743 hours on July 21 was 5.33 feet below the measuring point. The "static" water level in the test well prior to initiating the second short-term pumping test on July 22 was 3.90 feet below the measuring point. The "static" water level in the test well prior to initiating the third short-term pumping test on July 23 was 3.54 feet below the measuring point. The lower "static" water level measured prior to the first short-term pumping test on July 21 was caused by pumping municipal well #6. Given the above, it was not possible to evaluate aquifer hydraulic properties (transmissivity and storativity) using water-level data measured during each of the three short-term pumping tests.

Log time versus arithemetic drawdown plots for each of the three pumping tests are shown in figure 5. Evaluation of the data indicates a small improvement in well efficiency after additional development on the well between pump tests 1 and 2. Development after pump test 2 did not significantly improve well efficiency. After 90 minutes of pumping at an average rate of about 103 gallons per minute, the specific capacity was calculated at 7.0 gallons per minute per foot of drawdown.

## Evaluation of Pumping Test Conducted on Municipal Test Well 162-075-07ADD6

On August 9, 2004, a preliminary pumping test was conducted on the test well to set the pumping rate for the long-term pumping test. The preliminary test was started at 1442 hours and

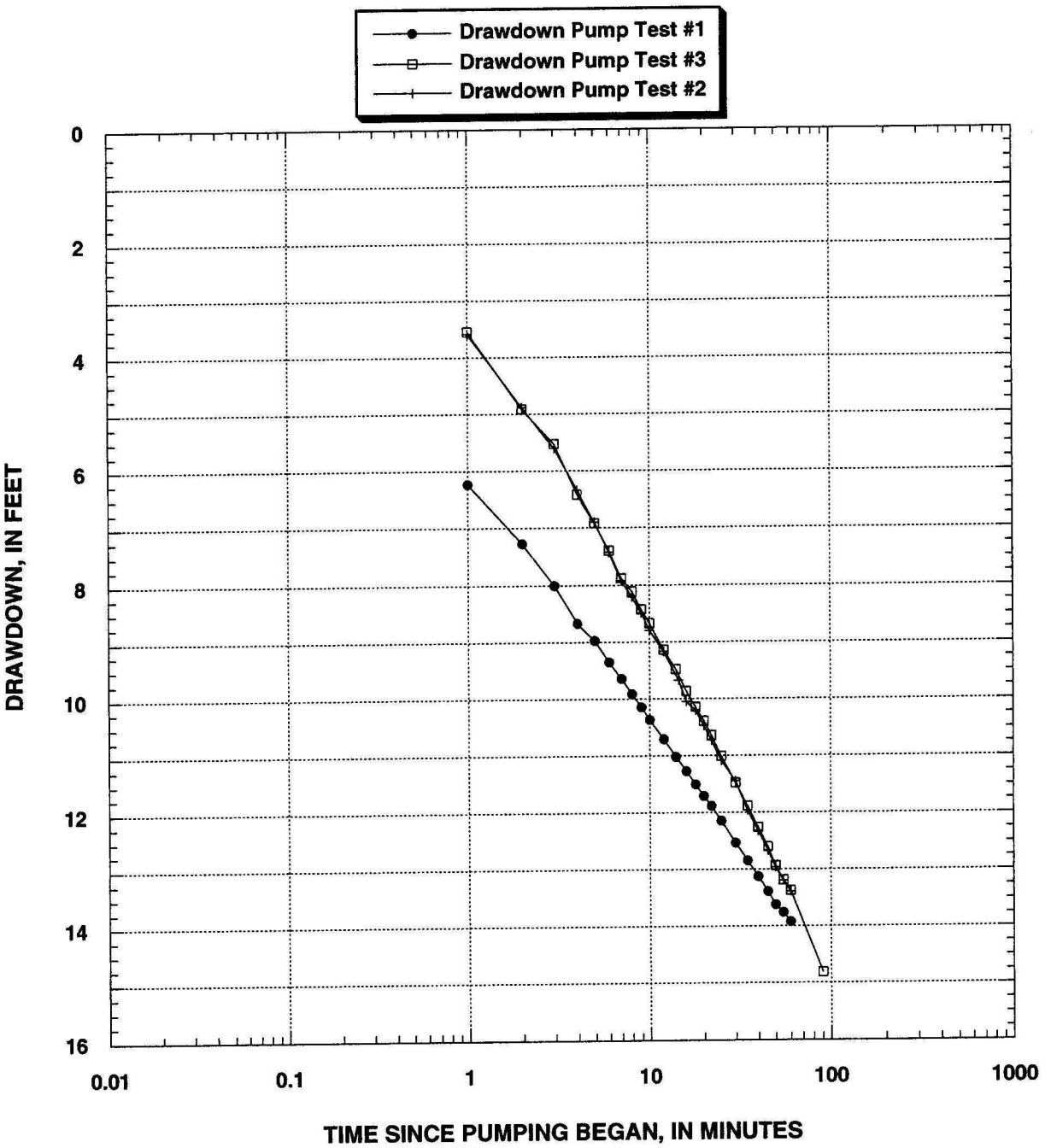



**Figure 5. -- Plot of log time versus arithmetic drawdown measured from three short-term pumping tests on municipal test well 162-075-07ADD6**

pumped continuously for 14 minutes to 1456 hours. After five minutes of pumping, the discharge rate was established at 100 gallons per minute using the Panametrics sonic flow meter. The in-line meter read 96 gallons per minute.

The pumping test was initiated at 0900 hours on August 10, 2004 and terminated at 1440 hours on August 24, 2004. The pumping rate varied from 93 to 99 gallons per minute throughout the pumping test. Adjustments were made to maintain a pumping rate of about 96 gallons per minute throughout the pumping test. The pumping test generally decreased slightly as drawdown and associated pumping lift increased.

The "static" water level in the production well prior to pumping was 2.73 feet below the measuring point (top of 8-inch diameter plastic casing) and the water level at the end of 20,500 minutes of pumping was 34.22 feet below the measuring point giving a total drawdown of 31.49 feet. Based on an average pumping rate of 96 gallons per minute the specific capacity after 20,500 minutes of pumping was calculated at 3.05 gallons per minute per foot of drawdown.

Water levels were measured continuously using Keck electric water-level sensing devices coupled with Stevens Type F recorders on piezometer 162-075-07ADD4, observation well 162-075-07ADB5 and municipal well #5 located at 162-075-07ADC. Water levels in the municipal test well located at 162-075-07ADD6 were measured manually for the first 152 minutes of pumping and then continuously thereafter, until the end of the test using the Keck/Stevens apparatus. Manual water-level measurements were also made by Bottineau municipal works employees twice daily on August 13 and 14, and then daily (generally around 0830 hours) until the end of the test on August 24, 2004 in the municipal test well (162-075-07ADD6), piezometer 162-075-07ADD4, and observation well 162-075-07ADB5.

The municipal test well is located about 12 feet east of the old Noble well at 162-075-07ADD2. Normally, the old Noble well flows at a rate of 48 gallons per minute out of a buried

transmission line that conveys water to the above ground storage tank to the west. In July, the discharge line to the Noble well was closed to prevent the well from discharging and causing interference during the pumping test. The top of the old well casing could not be practically sealed and water from the well overflowed the manhole and was discharging at land surface at a rate estimated at less than about five gallons per minute. As a result, the pumping test data include the effects of this additional "pumping." In addition, municipal well #6 located at 162-075-07ABD2 was pumped from 0842 hours on August 14 to 0842 hours on August 15. This pumping also caused additional drawdown interference during the pumping test.

A plot of log time versus arithmetic pumping level for the test production well (162-075-07ADD6) is shown in figure 6. Given the initial boundary conditions, it is not possible to apply analytical methods to determine aquifer hydraulic properties. It is hypothesized the aquifer is a relatively narrow buried channel with one flank of the aquifer located close to the production well. For about the first 200 minutes of pumping the slope of the data curve increases with time suggesting the cone of pressure relief intersects both flanks of the buried channel. This "roll-off" pattern is indicative of the effects of two barrier boundaries. After about 200 minutes of pumping, the slope of the data curve generally decreases up to about 0945 hours on August 14 when municipal well #6 was pumped. The decreased slope could be due to leakage, the intersection of other buried channels and/or conversion of the aquifer locally from confined to unconfined conditions. The top of the aquifer at the production well site is about 32 feet below the measuring point. The smallest slope of the data (except when municipal well #6 was pumping) curve occurred after about 3,000 minutes of pumping as the pumping level in the well approached the top of the aquifer (fig. 6). It is estimated that confined storativity is about $10^{-4}$ while unconfined storativity is about $10^{-1}$. Thus, in the area of the aquifer that converts from confined to unconfined conditions, the volume of water removed from storage per unit volume of aquifer increases by

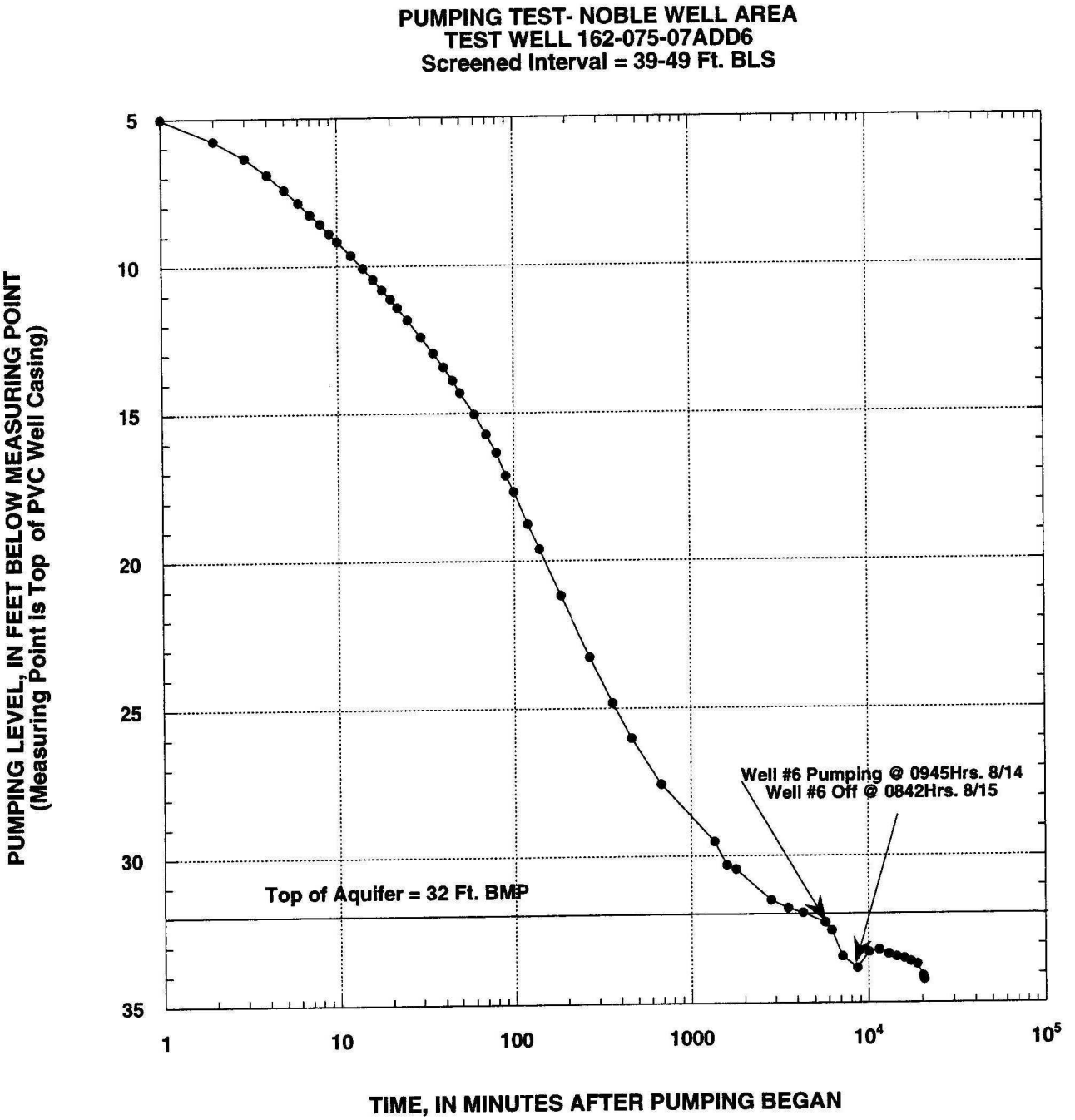



**Figure 6. -- Plot of log time versus arithmetic pumping level in municipal test well 162-075-07ADD6 (Noble Well Area)**

about three orders of magnitude. The result is to cause a decrease in the rate of change of drawdown over time (fig. 6). If the buried channel aquifer were quite narrow, the drawdown cone would be relatively broad and flat thereby creating a relatively large unconfined conversion area.

From 0945 hours on August 14 to 0842 hours on August 15, municipal well #6 was pumped continuously at a rate of about 185 gallons per minute. Pumping municipal well #6 caused about one foot of drawdown interference at the municipal test well located at 167-075-07ADD6. The city of Bottineau needed to pump municipal well #6 to maintain the city water supply while the old Noble well was shut in. In addition, municipal well #6 was also pumped to evaluate the drawdown interference, if any that may occur at the production well. This evaluation was necessary to help determine a maximum sustainable pumping rate for the municipal test well. Evaluation of the drawdown interference indicates that the aquifer in which municipal well #6 is completed in (confined aquifer A) is poorly connected hydraulically to the aquifer the municipal test well (167-075-07ADD6) is completed in (confined aquifer D). Pumping municipal well #6 will have a minor affect on the pumping level and associated maximum sustainable well yield of the new production well.

The last two water-level measurements indicate the slope of the data plot in figure 6 increases. This trend could be caused by image well affects due to barrier boundaries that begin to override the effects caused by conversion from confined to unconfined conditions or leakage. During this time period, the barometric pressure was generally decreasing, and as a result, would not contribute to a water-level decline.

North Dakota State Water Commission piezometer 162-075-07ADD4 is screened in confined aquifer D from 42 to 47 feet below land surface (fig. 3). It is located 30 feet south of the test well. The static water level was 2.18 feet below the measuring point (top lip of 2-inch diameter casing) and after 20,500 minutes of pumping the municipal test well, the water level was 33.35 feet below

the measuring point for total drawdown interference of 31.17 feet. The production well drawdown after 20,500 minutes of pumping was 31.49 feet. This amounts to a drawdown differential of only 0.32 feet between the two wells. The small hydraulic gradient between the two wells indicates a very flat drawdown cone which further supports the conceptual model that confined aquifer D is a relatively narrow buried channel and that the measured early-time drawdown data likely is affected by one of the flanking aquifer boundaries.

The drawdown pattern at piezometer 162-075-07ADD4 (fig. 7) mirrors that of the drawdown pattern in the production well (fig. 6). As with the production well it was not possible to apply an analytical method to calculate aquifer hydraulic properties given the initial boundary conditions.

Observation well 162-075-07ADB5 (old Simpson observation well) is located about 1000 feet northwest of production well 162-075-07ADD6. The "static" water level prior to pumping was 28.04 feet below the measuring point (top lip of 1.25-inch plastic casing) and the water level after 20,500 minutes of pumping the production well was 46.63 feet below the measuring point which amounts to a total drawdown of 18.59 feet. A plot of log time since pumping began versus arithmetic drawdown is shown in figure 8. The drawdown pattern mirrors the drawdown pattern in both the production well and piezometer 162-075-07ADD4. For the first 40 minutes of pumping, the slope of the drawdown curve is irregular and likely reflects the lack of precision using the 24-hour clock and the Stevens recording device. As with the production well and piezometer 162-075-07ADD4, it was not possible to apply an analytical method to calculate aquifer hydraulic properties given the initial boundary conditions.

A composite time divided by radius squared versus drawdown plot is useful in evaluating if certain Theis assumptions are valid. If all Theis assumptions are valid (which include aquifer confined, no additional sources or sinks, infinite areal extent) then the individual $t/r^2$ versus drawdown plots for each observation well should form a single curve that corresponds to a

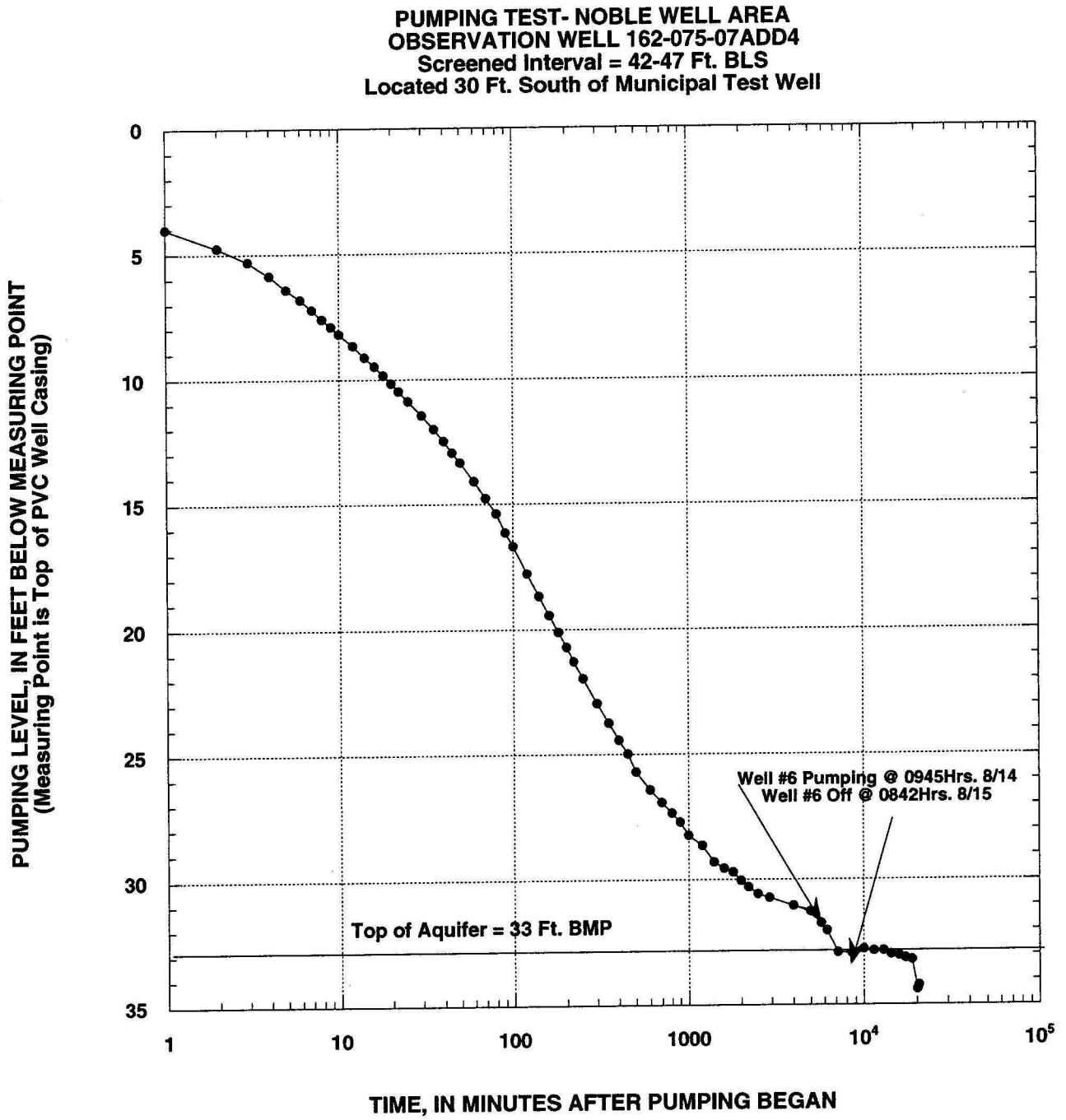



**Figure 7. -- Plot of log time versus arithmetic drawdown in piezometer 162-075-07ADD4 (Noble Well Area)**

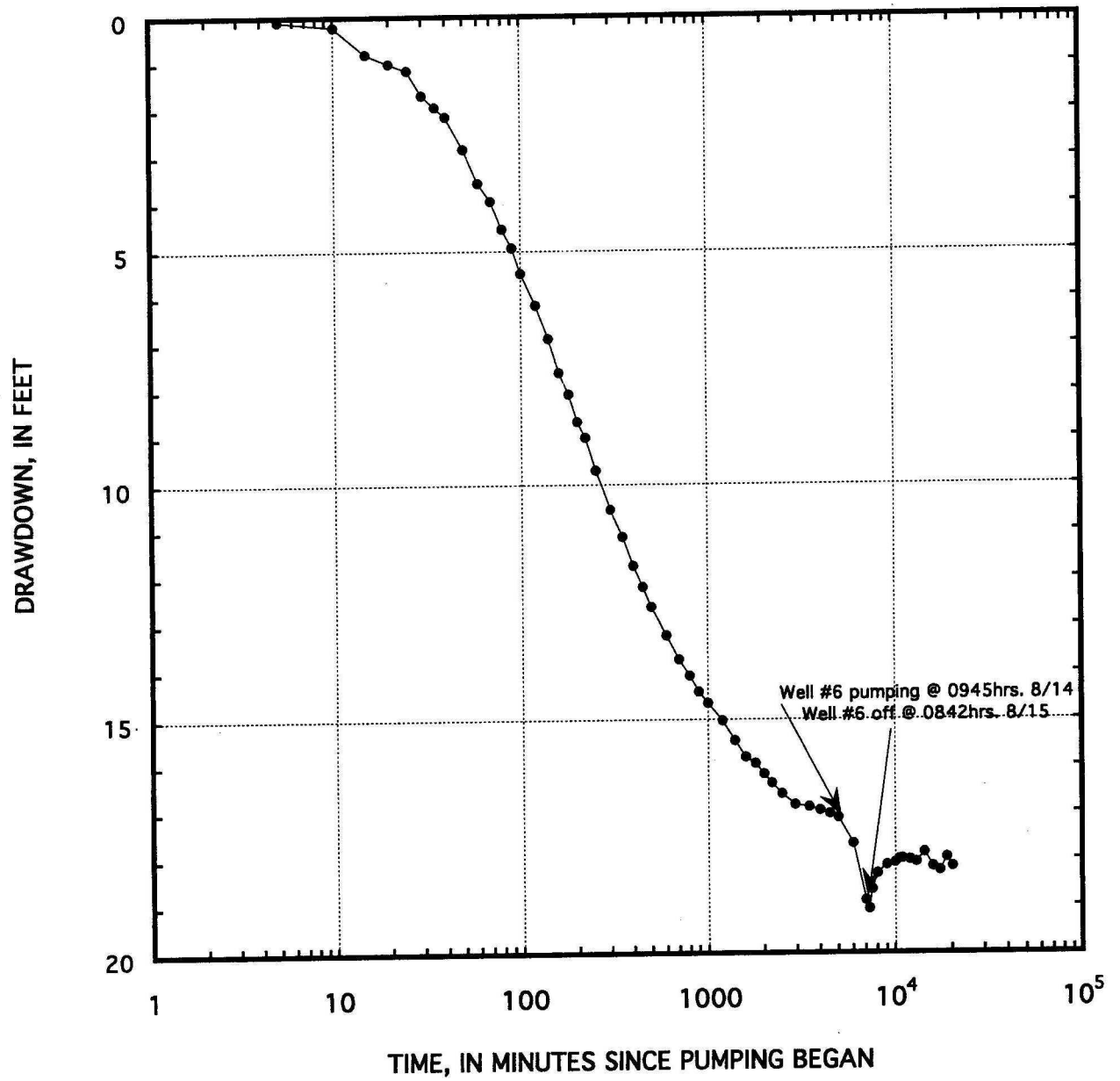



Figure 8. -- Plot of log time versus arithmetic drawdown in observation well 162-075-07ADB5

segment of the Theis type curve. Analysis of the composite data plot can be useful in identifying if barrier boundaries exist or if leakage is occurring.

A composite log $t/r^2$ versus log drawdown plot for piezometer 162-075-07ADD4 and observation well 162-075-07ADB5 is shown in figure 9. The two data curves do not merge to form a segment of the Theis curve. The separation of the data curves suggests a complex aquifer geometry, which includes the existence of one or more barrier boundaries.

At 1440 hours on August 24 the pump was shut off in the production well and water levels were monitored in the production well and piezometer 162-075-07ADD4 and observation well 162-075-07ADB5. Recovery water-level data commonly is analyzed by plotting the log of time since pumping began divided by the time since pumping stopped ($t/t^1$) versus arithmetic residual drawdown ($s^1$). The residual drawdown is the remaining drawdown calculated at any time (t) in relation to the initial pre-pumping static water level.

The log $t/t^1$ versus arithmetic $s^1$ data plot for the production well is shown in figure 10. After 6,845 and 8, 270 minutes of recovery, the residual drawdown was 0.07 feet. After the 8,270-minute measurement, the discharge value was opened on the old Noble well located 12 feet west of the production well allowing the well to discharge into the distribution system to maintain the city water supply. Theoretically, the residual drawdown at $t/t^1 = 1$ (i.e. length of recovery period equals length of pumping period) should equal zero. The lack of any significant residual drawdown after only 8,270 minutes of recovery suggests that the aquifer receives significant recharge. It is possible that this buried channel is part of a "system" of interconnected buried channels that originate in the upland areas of the Turtle Mountains where significant recharge occurs.

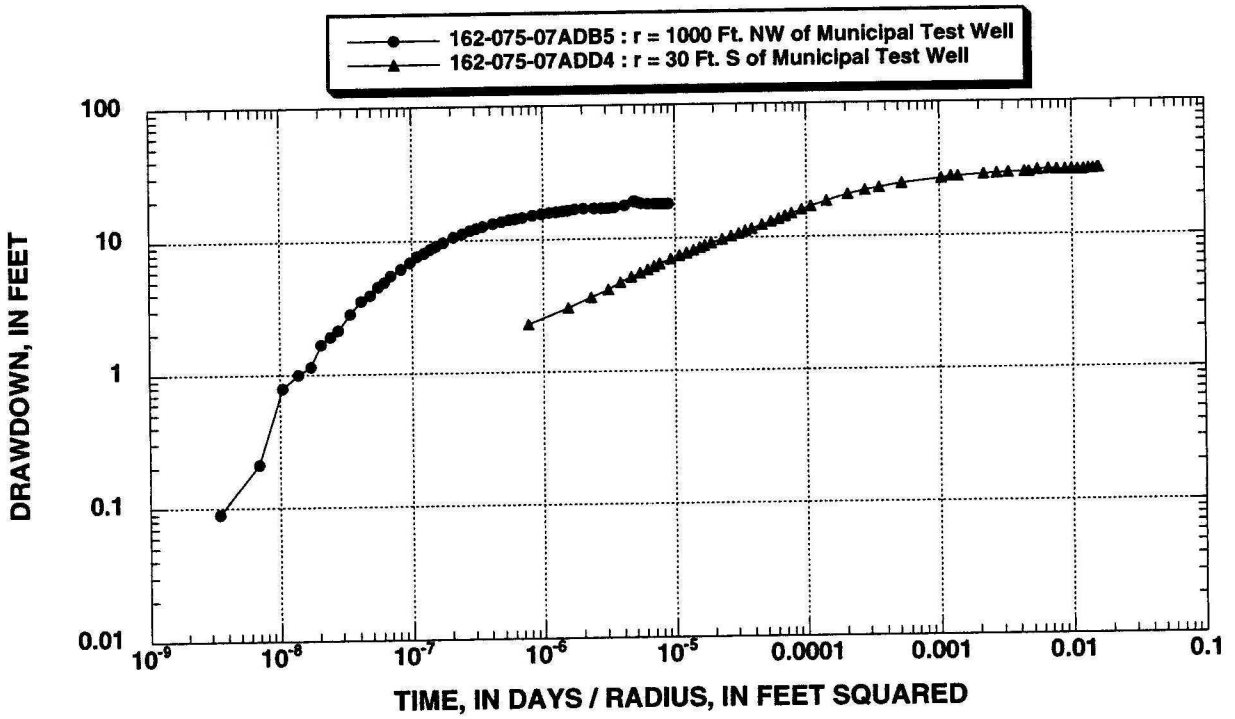



**Figure 9. -- Composite log time / radius squared versus log drawdown for piezometer 162-075-07ADD4 and observation well ADB5**

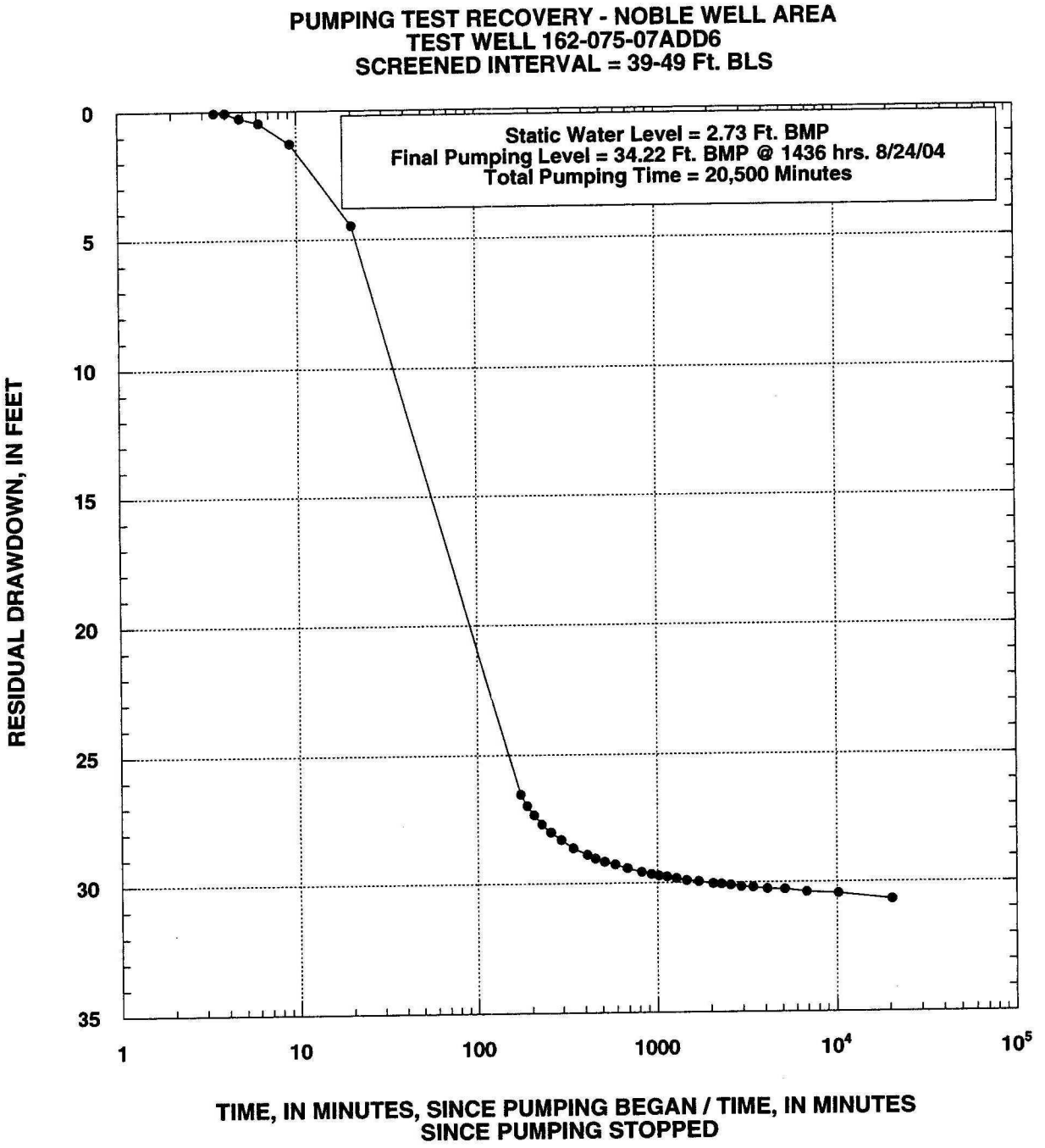



**Figure 10. -- Plot of log time since pumping began divided by time since pumping stopped versus arithmetic residual drawdown, in municipal test well 162-075-07ADD6**

## Determination of Maximum Sustained Well Yield in Municipal Test Well 162-075-07ADD6

As previously stated, the municipal test well is screened from 39 to 49 feet below land surface. The top of the aquifer is at 30.5 feet below land surface. With the old Noble well shut-in, the static water level is about two feet below land surface leaving 37 feet of available head above the well screen. In selecting a maximum pumping rate, a general rule of thumb is to reserve one-third of the total available head above the well screen to accommodate additional well interference and natural water level fluctuations caused by climate variation. Given the above, a target pumping level would be about 27 feet below land surface.

Keith Fulsebakke, Bottineau Municipal Works Supervisor indicates the new production well at the test site would be pumped continuously for a maximum period of four days. In addition, the well would be used generally during peak demand periods. Based on the results of the pumping test, the pumping level was about 31 feet below land surface after four days continuous pumping at a rate of 97 gallons per minute. Using a target pumping rate of 100 gallons per minute, and a specific capacity of three gallons per minute per foot of drawdown measured at the end of the pumping test, amounts to an additional foot of drawdown for a pumping level at about 32 feet below land surface. It is possible that municipal well #6 may be pumped concurrently with this new production well in the Noble well area. Based on the results of the pumping test, concurrent pumping of municipal well #6 may cause an additional two feet of drawdown interference over a four-day pumping period, giving a pumping level in the new municipal well at about 34 feet below land surface. This would leave five feet of available head above the top of the well screen. Given that no other major water users will be permitted to appropriate water from this aquifer (confined aquifer D) and that the aquifer recovery response indicates significant recharge capability, a maximum sustained yield of 100 gallons per minute from this well should be sustainable over continuous four-day pumping periods. Should this rate, at times, be not sustainable, the pumping rate can be temporarily reduced with a gate valve installed in the

discharge line. It is further recommended the pump intake be set at the top of the well screen. Finally, a measuring pipe should be installed through the pitless spool to accommodate measuring water levels,in particular, pumping levels within the well.

## Water Chemistry in Municipal Test Well 162-075-07ADD6

Water samples were collected for chemical analysis after one hour, 1, 2, 7 and 14 days of pumping. Chemical analysis included standard ions and selected trace elements including uranium. Uranium is an important analyte because municipal well #3 exceeds the USEPA primary maximum contaminant level of 30 ug/L.

Ground water from municipal test well 162-075-07ADD6 is a calcium-bicarbonate type (fig. 11). The range and mean values of selected ions, dissolved solids and hardness and USEPA secondary maximum contaminant levels (SMCL) are shown in table 4. SMCLs are non-enforceable recommended standards. Values exceeding SMCL are not considered a health hazard. Ground water from municipal test well 162-075-07ADD6 exceeds SMCL for sulfate, manganese and dissolved solids.

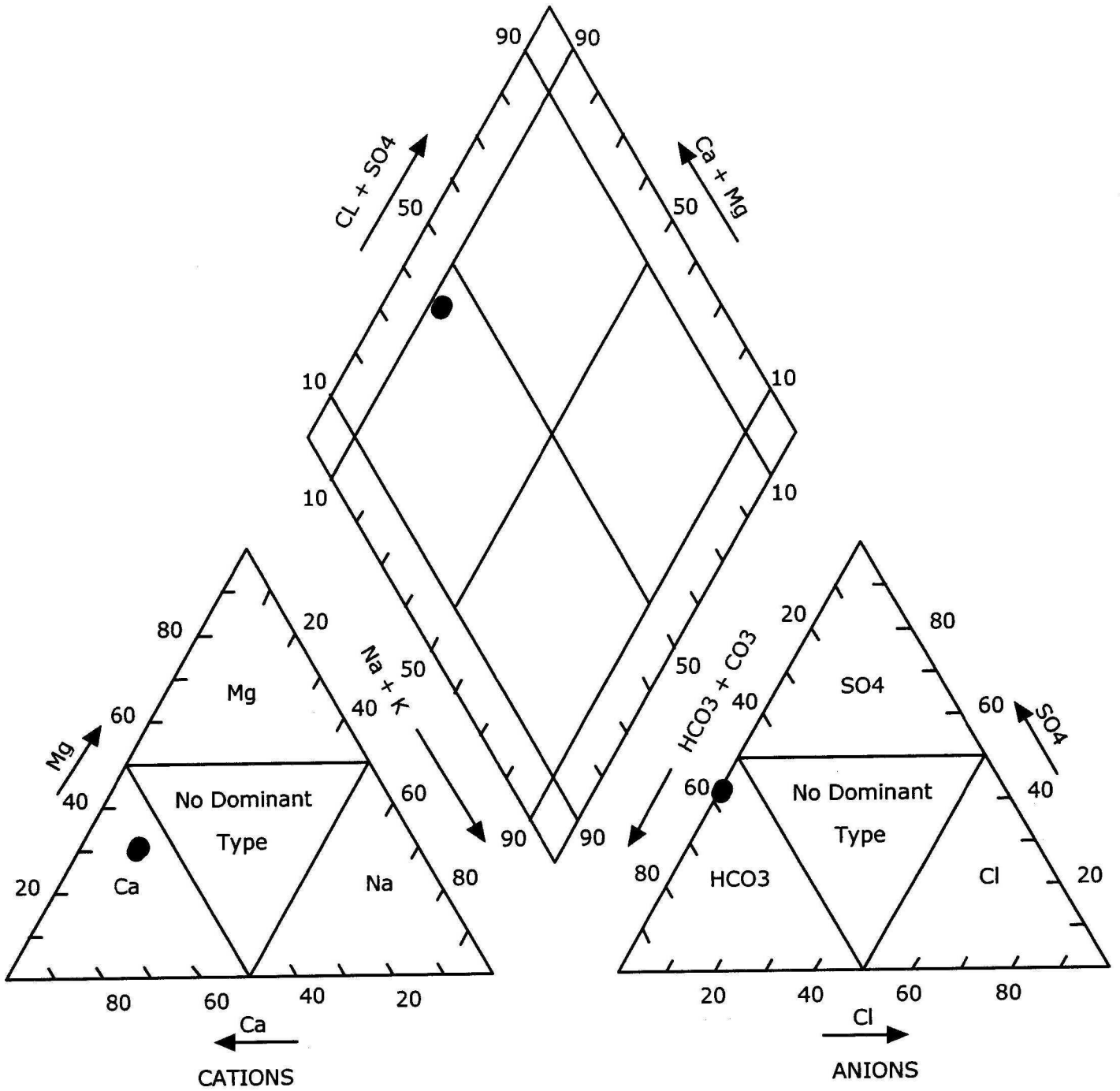



**Figure 11. -- Relative distribution of major ions in 5 ground water samples from municipal test well 162-075-07ADD6**

Table 4. -- Range and mean values of selected ions, dissolved solids, and hardness in five ground-water samples collected from municipal test well 162-075-07ADD6 and USEPA secondary maximum contaminant levels.

| | Range (mg/L) | Mean mg/L) | SMCL[1.] (mg/L) |
|---|---|---|---|
| Calcium | 179-192 | 184 | N/A |
| Magnesium | 59.7-63.6 | 61.1 | N/A |
| Sodium | 41.9-44.0 | 43.1 | N/A |
| Potassium | 7.3-7.7 | 7.5 | N/A |
| Bicarbonate | 567-588 | 578 | N/A |
| Sulfate | 335-357 | 349 | 250 |
| Chloride | 3.14-3.32 | 3.35 | 250 |
| Iron | 0.02-0.28 | 0.18 | 0.3 |
| Manganese | 1.79-1.89 | 1.83 | 0.05 |
| Dissolved Solids | 922-955 | 934 | 500 |
| Hardness | 693-742 | 711 | NA |

1. USEPA secondary maximum contaminant level.

Trace element analysis included selenium, lead, mercury, arsenic, lithium, molybdenum, strontium and uranium. Concentrations of these trace elements and USEPA primary maximum contaminant levels (MCLs) are shown in table 5. None of the trace elements shown in table 5 exceed MCL.

Table 5. -- Concentrations of selected trace elements in five ground water samples collected from municipal test well 162-075-07ADD6, and USEPA primary maximum contaminant levels.

| Date of Collection | Selenium | Lead | Mercury | Arsenic | Lithium | Molybdenum | Strontium | Uranium |
|---|---|---|---|---|---|---|---|---|
| | micrograms per liter | | | | | | | |
| 8/10/04 | 2.66 | ND[4.] | ND[4.] | 1.83 | 128 | 3.86 | 855 | 17.8 |
| 8/11/04 | ND[4.] | ND[4.] | ND[4.] | 2.63 | 125 | 3.57 | 833 | 17.9 |
| 8/12/04 | 1.39 | ND[4.] | ND[4.] | ND[4.] | 129 | 3.73 | 862 | 20.9 |
| 8/17/04 | ND[4.] | ND[4.] | ND[4.] | 1.38 | 132 | 3.59 | 871 | 18.8 |
| 8/24/04 | 1.11 | 2.10 | ND[4.] | 1. 85 | 127 | 3.43 | 860 | 18.7 |
| USEPA PMCL[1.] | 50 | 15[2.] | 2 | 10 | N/A | N/A | N/A | 30[3.] |

1. U.S. Environmental Protection Agency Primary Maximum Contaminant Level.
2. Lead is regulated by a treatment technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water exceeds an action level of 15 ug/L water, systems must take additional steps.
3. Effective 12/8/03.
4. ND = No Detection

## RECOMMENDATIONS

Based on the results of this study, the following recommendations are made:

1. Install a pump with a maximum pumping capacity of not more than 100 gallons per minute in municipal test well 162-075-07ADD6.

2. Set the pump intake at the top of the well screen to maximize available pumping head in municipal test well 162-075-07ADD6.

3. Install a small diameter measuring pipe through the pitless spool in municipal test well 162-075-07ADD6 to accommodate measuring pumping levels within the well.

4. Do not install a municipal well at 162-075-07BAD2 or at any other site in confined aquifer C. Available data indicates confined aquifer C can only support the current level of ground-water withdrawals from municipal well #1.

5. At present, it appears the city of Bottineau has an adequate ground-water supply with the addition of the new municipal well in the Noble area at 162-075-07ADD6. The site described in the Phase I report in the NW1/4NW1/4 of Section 7 could be tested and developed in the future should municipal use increase.

## REFERENCES CITED

Shaver, R. B., 2002, A hydrogeologic analysis to determine the sustained yield of the Bottineau municipal well field and All Seasons Rural Water Systems I and II, Bottineau County, North Dakota, North Dakota Ground-Water Studies No. 109, 196 p.

Shaver, R. B., 2003, An evaluation of the potential to increase the pumping capacity of the ground-water supply for the city of Bottineau using additional wells Phase I – Results of test drilling and water chemistry sampling, North Dakota Ground-Water Studies No. 112, 61 p.

**APPENDIX I**

# Lithologic Logs of Wells and Test Holes

**162-075-07AAA**

NDSWC 8-738

Date Completed: 05/21/1962
L.S. Elevation (ft): 2061
Depth Drilled (ft): 94.5

Purpose: Test Hole

Data Source:

Completion Info:

Remarks: NDSWC-8 738

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-2 | TOPSOIL | black |
| 2-26 | TILL | clay, silty to gravelly, dark yellowish orange, oxidized, calcareous |
| 26-33 | TILL | clay, silty to gravelly, dark yellowish brown, oxidized, calcareous |
| 33-54 | TILL | clay, silty to gravelly, dark greenish gray, calcareous |
| 54-58 | TILL | as above with layers of fine to coarse sandy gravel |
| 58-63 | SILT | dark yellowish brown, partially oxidized, calcareous |
| 63-74 | SILT | sandy, olive gray, with layers of very fine to very coarse subrounded sand and fine to coarse subangular gravel |
| 74-82 | GRAVEL | fine to medium, clayey to sandy, subrounded |
| 82-91 | GRAVEL | fine to medium, clayey to sandy, subrounded |
| 91-94.5 | CLAY | very indurated, no samples |

**162-075-07AB**

City of Bottineau

Date Completed: 1938
L.S. Elevation (ft): N/A
Depth Drilled (ft): 145

Purpose: Test Hole

Data Source:

Completion Info:

Remarks: Probably completed in vicinity of Walker Wells (Walter Bog Area)

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-16 | PEAT | |
| 16-23 | GRAVEL | flowing water |
| 23-41 | CLAY | yellow |
| 41-59 | SAND | |
| 59-85 | CLAY | |
| 85-145 | SAND & GRAVEL | water came within 25 ft. of surfce |

**162-075-07ABD1**

City of Bottineau

| | | | |
|---|---|---|---|
| Date Completed: | 5/1956 | Purpose: | Municipal Well |
| L.S. Elevation (ft): | N/A | Well Type: | 10 in. - Steel |
| Depth Drilled (ft): | 80 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 68-76 | Data Source: | |

Completion Info:

Remarks: City of Bottineau Municipal Well #4
MP is top of 1-inch diameter pvc pipe extending 1.90 feet above well seal inside manhole.

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-10 | PEAT | soft |
| 10-16 | CLAY | sandy, light gray |
| 16-30 | CLAY | yellow, slightly sandy |
| 30-36 | GRAVEL | muddy, rocks |
| 36-58 | CLAY | sandy, gray, rocks |
| 58-64 | HARDPAN | |
| 64-67 | SAND & GRAVEL | coarse, little water |
| 67-68 | CLAY | gravelly |
| 68-76 | SAND & GRAVEL | flowing water |
| 76-80 | CLAY | gravelly |

**162-075-07ABD2**

City of Bottineau

| | | | |
|---|---|---|---|
| Date Completed: | 10/18/1983 | Purpose: | Municipal Well |
| L.S. Elevation (ft): | 1990 | Well Type: | 8 in. - Steel |
| Depth Drilled (ft): | 83 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 60-80 | Data Source: | |

Completion Info:

Remarks: Bottineau Municipal well #6

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-3 | PEAT | sandy |
| 3-5 | TOPSOIL | |
| 5-24 | CLAY | yellow |
| 24-51 | CLAY | blue |
| 51-79 | SAND | medium to coarse |
| 79-83 | CLAY | blue |

**162-075-07ABD3**

City of Bottineau

| | | | |
|---|---|---|---|
| Date Completed: | 1930 | Purpose: | Municipal Well |
| L.S. Elevation (ft): | 1991 | Well Type: | 4 in. - Steel |
| Depth Drilled (ft): | 51 | Aquifer: | Bottineau |
| Screen Int. (ft.): | | Data Source: | No log avaiable |

Completion Info:

Remarks: Walker West Well

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|

**162-075-07ABD4**

City of Bottineau

| | | | |
|---|---|---|---|
| Date Completed: | 1930 | Purpose: | Municipal Well |
| L.S. Elevation (ft): | 1990.84 | Well Type: | 4 in. - Steel |
| Depth Drilled (ft): | 51 | Aquifer: | Bottineau |
| Screen Int. (ft.): | | Data Source: | No log available |

Completion Info:

Remarks: Walker East Well - flows

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|

**162-075-07ACA**

City of Bottineau

| | | | |
|---|---|---|---|
| Date Completed: | 10/14/1987 | Purpose: | Municipal Well |
| L.S. Elevation (ft): | 1928 | Well Type: | 8 in. - Steel |
| Depth Drilled (ft): | 81 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 61-81 | Data Source: | |

Completion Info:

Remarks: Bottineau municipal well #3

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-1 | TOPSOIL | |
| 1-4 | CLAY | gray |
| 4-10 | CLAY | yellow |
| 10-13 | SAND | |
| 13-16 | CLAY | yellow |
| 16-46 | CLAY | blue |
| 46-81 | GRAVEL | |

**162-075-07ACC**

Bottineau

Date Completed: 11/01/1980
L.S. Elevation (ft): 1897
Depth Drilled (ft): 101

Purpose: Test Hole

Data Source:

Completion Info:

Remarks: Simpson 1980-10

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-1 | TOPSOIL | |
| 1-3 | CLAY | gray |
| 3-24 | GRAVEL | |
| 24-44 | CLAY | blue |
| 44-45 | GRAVEL | |
| 45-67 | CLAY | blue, some rocks |
| 67-68 | GRAVEL | rocks |
| 68-101 | CLAY | blue |

**162-075-07ADB1**

City of Bottineau

| | | | |
|---|---|---|---|
| Date Completed: | 01/09/1958 | Purpose: | Municipal Well |
| L.S. Elevation (ft): | 1943 | Well Type: | 12 in. - Steel |
| Depth Drilled (ft): | 100 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 68-80 | Data Source: | |

Completion Info:

Remarks: Bottineau Municipal well #2
MP is top of 1-inch diameter pvc pipe extending 2.26 feet above top of well seal inside manhole.

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-0.5 | TOPSOIL | |
| 0.5-4 | CLAY | gray |
| 4-11 | CLAY | yellow |
| 11-68 | CLAY | gray, rocks |
| 68-73 | SAND | and coarse gravel |
| 73-100 | SAND | very clayey, becoming finer |

**162-075-07ADB2**

City of Bottineau

| | | | |
|---|---|---|---|
| Date Completed: | 1936 | Purpose: | Municipal Well |
| L.S. Elevation (ft): | 1973 | Well Type: | 4 in. - Steel |
| Depth Drilled (ft): | 41 | Aquifer: | Bottineau |
| Screen Int. (ft.): | | Data Source: | No log available |

Completion Info:

Remarks: Bittner East Well - flows

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|

**162-075-07ADB3**

City of Bottineau

| | | | |
|---|---|---|---|
| Date Completed: | 1936 | Purpose: | Municipal Well |
| L.S. Elevation (ft): | 1972 | Well Type: | 4 in. - Steel |
| Depth Drilled (ft): | 41 | Aquifer: | Bottineau |
| Screen Int. (ft.): | | Data Source: | No log available |

Completion Info:

Remarks: Bittner West Well - flows

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|

**162-075-07ADB4**

City of Bottineau

| | | | |
|---|---|---|---|
| Date Completed: | 1936 | Purpose: | Municipal Well |
| L.S. Elevation (ft): | 1970 | Well Type: | 4 in. - Steel |
| Depth Drilled (ft): | 41 | Aquifer: | Bottineau |
| Screen Int. (ft.): | | Data Source: | No log available |

Completion Info:

Remarks: Bittner South Well - flows

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|

**162-075-07ADB5**

City of Bottineau

| | | | |
|---|---|---|---|
| Date Completed: | 1983 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 2014 | Well Type: | 1.25 in. - PVC |
| Depth Drilled (ft): | Unknown | Aquifer: | Bottineau |
| Screen Int. (ft.): | Unknown | Data Source: | |

Completion Info:

Remarks: Probably Simpson Test Hole Site 1983-3 for which no log is avaailable. Measured well depth is 99 feet.

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|

**162-075-07ADB6**

City of Bottineau

| | | | |
|---|---|---|---|
| Date Completed: | 1980 | Purpose: | Observation Well - Destroyed |
| L.S. Elevation (ft): | 1950 | Well Type: | 1.25 in. - PVC |
| Depth Drilled (ft): | 41 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 24.5-26.5 | Data Source: | |

Completion Info:

Remarks: Simpson 1980-13

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-1 | TOPSOIL | black |
| 1-8 | GRAVEL | mostly shale |
| 8-14 | CLAY | yellow |
| 14-17 | CLAY | blue |
| 17-30 | GRAVEL | |
| 30-41 | CLAY | blue |

**162-075-07ADC1**

City of Bottineau

| | | | |
|---|---|---|---|
| Date Completed: | 1980 | Purpose: | Observation Well - Destroyed |
| L.S. Elevation (ft): | 1923 | Well Type: | 1.25 in. - PVC |
| Depth Drilled (ft): | 85 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 74-79 | Data Source: | |

Completion Info:

Remarks: Simpson 1980-6

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-1 | TOPSOIL | black |
| 1-2 | CLAY | gray |
| 2-14 | CLAY | yellow |
| 14-52 | CLAY | with a few gravel and rocks |
| 52-63 | SAND | fine to medium, yellow, some rocks |
| 63-67 | SAND & GRAVEL | some coarse |
| 67-68 | CLAY | |
| 68-80 | SAND & GRAVEL | coarse with pebbles |
| 80-85 | CLAY | gray |

**162-075-07ADC2**

City of Bottineau

Date Completed: 1980
L.S. Elevation (ft): 1923
Depth Drilled (ft): 85.5

Purpose: Test Hole

Data Source:

Completion Info:

Remarks: Simpson 1980-12 Site of Municipal Well #5 162-075-07ADC3

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-2 | TOPSOIL | |
| 2-3 | CLAY | gray |
| 3-12 | CLAY | yellow |
| 12-24 | CLAY | yellow, stones |
| 24-53 | CLAY | blue, stones |
| 53-66 | SAND | yellow, medium, some stones |
| 66-72 | CLAY | blue, gravel layers |
| 72-85 | GRAVEL | medium to coarse |
| 85-85.5 | CLAY | blue |

**162-075-07ADC3**

City of Bottineau

| | | | |
|---|---|---|---|
| Date Completed: | 1/1980 | Purpose: | Municipal Well |
| L.S. Elevation (ft): | 1927 | Well Type: | 8 in. - Steel |
| Depth Drilled (ft): | 85 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 74-85 | Data Source: | |

Completion Info:

Remarks: Bottineau Municipal well #5

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-2 | TOPSOIL | |
| 2-3 | CLAY | gray |
| 3-12 | CLAY | yellow |
| 12-24 | CLAY | yellow, with stones |
| 24-53 | CLAY | blue, with stones |
| 53-66 | SAND | yellow, medium, with stones |
| 66-72 | CLAY | clay, blue, gravel layers |
| 72-85 | CLAY | blue |

**162-075-07ADD1**

City of Bottineau

| | | | |
|---|---|---|---|
| Date Completed: | 1939 | Purpose: | Municipal Well |
| L.S. Elevation (ft): | 1984 | Well Type: | 10 in. - Steel |
| Depth Drilled (ft): | 50 | Aquifer: | Bottineau |
| Screen Int. (ft.): | | Data Source: | No log available |

Completion Info:

Remarks: Noble Well
MP is 1-inch diameter pvc pipe extending 0.97 feet above the well seal inside manhole. Well has 8-inch diameter steel liner.

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|

**162-075-07ADD2**

City of Bottineau

| | | | |
|---|---|---|---|
| Date Completed: | 1939 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 1985 | Well Type: | 10 in. - Steel |
| Depth Drilled (ft): | 54.5 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 48-54 | Data Source: | Simpson & Sons, Bisbee, ND |

Completion Info:

Remarks: Test well installed 10 feet east of Noble house, both of which have been removed. This test well probably is within 25 to 50 feet of existing Noble well and therefore the log of this well is representative of the Noble well site where no log is available.

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-2 | TOPSOIL | |
| 2-16 | CLAY | yellow |
| 16-35 | CLAY | gravelly, blue |
| 35-54 | SAND & GRAVEL | |
| 54-54.5 | CLAY | blue |

**162-075-07ADD3**

City of Bottineau

| | | | |
|---|---|---|---|
| Date Completed: | 01/01/1980 | Purpose: | Observation Well - Destroyed |
| L.S. Elevation (ft): | 1975 | Well Type: | 1.25 in. - PVC |
| Depth Drilled (ft): | 80 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 60-65 | Data Source: | |

Completion Info:

Remarks: Simpson 1980-7

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-1 | TOPSOIL | |
| 1-8 | CLAY | yellow, sandy |
| 8-21 | CLAY | blue, a few gravel particles |
| 21-22 | ROCK | |
| 22-23 | CLAY | blue |
| 23-30 | SAND & GRAVEL | pebbles, mostly shale |
| 30-50 | CLAY | blue |
| 50-66 | SAND | fine to coarse to small gravel, mostly shale |
| 66-68 | CLAY | |
| 68-71 | SAND & GRAVEL | |
| 71-80 | CLAY | yellow |

**162-075-07ADD4**

NDSWC 15047

| | | | |
|---|---|---|---|
| Date Completed: | 08/28/2003 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 1985.5 | Well Type: | 2 in. - PVC |
| Depth Drilled (ft): | 60 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 42-47 | Data Source: | |

Completion Info:

Remarks: Located 30 feet south of test well (Municipal Well #7)

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-16 | TILL | clay, silty, sandy, pebbly, soft to mod. hard, plastic, pale yellow-gray-brown, oxidized. |
| 16-31 | TILL | as above, olive gray, unoxidized. |
| 31-47 | SAND & GRAVEL | sand (20-30%), cse. to v.cse, and gravel (70-80%), up to 1-inch diam., mostly 1/4-1/8 -inch diam., no fines in back of mud tub, clean section, drills as stratified, comprised of silicates, carbonates, shale, quartz, angular to well rounded, mostly well rounded, takes water, mixed 4 bags mud at 40 ft., caving badly. |
| 47-58 | TILL | clay, as above, olive gray. |
| 58-60 | SAND & GRAVEL | poor recovery, mud thick, bit slipped fast. * Did not want to drill into deeper aquifer that may have elevated uranium concentrations. This is a test hole for a possible replacement well for the "Noble Well" used by the city of Bottineau. |

**162-075-07ADD5**

City of Bottineau

Date Completed: 04/23/2004
L.S. Elevation (ft): N/A
Depth Drilled (ft): 112

Purpose: Test Hole

Data Source: Bursinger Drilling

Completion Info:

Remarks:

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-1 | TOPSOIL | black |
| 1-18 | CLAY | yellow |
| 18-20 | CLAY | blue |
| 20-21 | GRAVEL | |
| 21-30 | CLAY | blue |
| 30-41 | GRAVEL | |
| 41-55 | CLAY | blue |
| 55-61 | GRAVEL | |
| 61-62 | CLAY | blue |
| 62-67 | GRAVEL | |
| 67-70 | CLAY | blue |
| 70-79 | SAND | fine, dirty, yellow |
| 79-83 | CLAY | yellow |
| 83-93 | GRAVEL | |
| 93-96 | CLAY | blue |
| 96-112 | BEDROCK | gray, blue |

**162-075-07ADD6**

City of Bottineau

| | | | |
|---|---|---|---|
| Date Completed: | 04/29/2004 | Purpose: | Municipal Well |
| L.S. Elevation (ft): | N/A | Well Type: | 8 in. - PVC |
| Depth Drilled (ft): | 50 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 39-49 | Data Source: | Bursinger Drilling |

Completion Info:

Remarks: Municipal Well #7 -- Well completed with 8-inch stainless steel #60 slot screen. Located 12 feet east of old Noble well and 30 feet north of SWC ADD4.

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-12 | CLAY | yellow |
| 12-30.5 | CLAY | blue |
| 30.5-49 | GRAVEL | |
| 49-50 | CLAY | blue |

**162-075-07ADD7**

City of Bottineau

| | | | |
|---|---|---|---|
| Date Completed: | 04/29/2004 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 1985 | Well Type: | 2 in. - PVC |
| Depth Drilled (ft): | 72 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 58-63 | Data Source: | Bursinger Drilling |

Completion Info:

Remarks: Located 45 feet southwest of new municipal well ADD6. Well would not pump for a water sample.

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-1 | TOPSOIL | |
| 1-17.5 | CLAY | yellow |
| 17.5-30 | CLAY | blue |
| 30-39.5 | GRAVEL | |
| 39.5-55 | CLAY | blue |
| 55-66 | GRAVEL | |
| 66-72 | CLAY | yellow |

**162-075-07BAA1**

NDSWC 15041

Date Completed: 08/26/2003
L.S. Elevation (ft): 1950
Depth Drilled (ft): 80

Purpose: Test Hole

Data Source:

Completion Info:

Remarks:

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-2 | TILL | clay, silty, sandy, pebbly, pale yellow-gray-brown, oxidized, soft, cohesive. |
| 2-4 | GRAVEL | and cobbles, 1/4 to 2 inches diam., comprised of silicates, carbonates, and shale |
| 4-26 | TILL | clay, as above. |
| 26-31 | TILL | clay, as above, olive gray, unoxidized. |
| 31-80 | SAND | sequence of silty, clayey, sands, v.fn., silty, sandy, clays and some gray-brown silty, sandy, clays to silty clays, soft to mod. hard, lignite layers from 41 to 42 ft. and 74 to 75 ft., from 60 to 80 ft., mostly greenish-gray sand, v.fn., silty, clayey, soft, cohesive, ( Bedrock -- Hell Creek - Fox Hills?). |

**162-075-07BAA2**

NDSWC 15031

| | | | |
|---|---|---|---|
| Date Completed: | 08/25/2003 | Purpose: | Test Hole |
| L.S. Elevation (ft): | 1950 | | |
| Depth Drilled (ft): | 140 | | |
| | | Data Source: | |

Completion Info:

Remarks:

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-42 | TILL | clay, silty, sandy, pebbly, up to 1-inch diam. pebbles, granite, diorite, carbonates, yellow gray-brown with red-yellow stringers, oxidized, cohesive, mod. plastic to sl. brittle, rocks at 26 and 36 ft. |
| 42-61 | SAND | v.fn. to fn., silty,clayey,cohesive, pale greenish-gray with some interbedded brown sticky clay (shale), no chatter, no pebbles, good recovery (Bedrock - Hell Creek - Fox Hills?) |
| 61-68 | CLAY | greenish-gray to brownish gray, sticky, hard, some ribbon-like cuttings, drills smooth (Bedrock- Hell Creek - Fox Hills?) |
| 68-71 | CLAY | dark brown, fissle, softer than above, ( Bedrock -- Hell Creek - Fox Hills?) |
| 71-77 | SAND | as interval from 61 to 68 ft. (Bedrock -- Hell Creek - Fox Hills?) |
| 77-78 | CLAY | as interval from 68 to 71ft. ( Bedrock -- Hell Creek - Fox Hills?) |
| 78-81 | CLAY | sticky, hard, as interval from 61 to 68 ft. ( Bedrock -- Hell Creek - Fox Hills?) |
| 81-82 | SAND | v. fn. to fn., silty, clayey, green to grayish green, cohesive, slightly brittle, drills smooth, good recovery, very low k, does not take water. (Bedrock -- Hell Creek - Fox Hills?) |
| 82-83 | CLAY | silty, olive gray, sticky, (Bedrock -- Hell Creek - Fox Hills?) |
| 83-103 | SAND | as interval from 83 to 103 ft., (Bedrock -- Hell Creek - Fox Hills?) |
| 103-104 | LIGNITE | good bit chatter, recovered lignite chips, (Bedrock -- Hell Creek - Fox Hills?) |
| 104-123 | CLAY | sequence of olive gray and dark brown sticy hard clays, drills smooth, (Bedrock -- Hell Creek - Fox Hills?) |
| 123-124 | LIGNITE | (Bedrock -- Hell Creek - Fox Hills?) |
| 124-128 | CLAY | sequence of olive gray and dark brown clays, as from 104 to 123 ft. (Bedrock -- Hell Creek - Fox Hills?) |
| 128-140 | CLAY | as interval from 104 to 123 ft., with interbedded v.fn. to fn. clayey, silty, sand, (Bedrock -- Hell Creek - Fox Hills?) |

**162-075-07BAA3**

NDSWC 8/26/03

Date Completed: 08/26/2003
L.S. Elevation (ft): 1950
Depth Drilled (ft): 60

Purpose: Test Hole

Data Source:

Completion Info:

Remarks:

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-36 | TILL | clay, silty, sandy, pebbly, pale yellow-gray-brown, oxidized, soft to mod. hard with depth, cohesive. |
| 36-38 | CLAY | silty, dark brown, soft, cohesive (Bedrock -- Hell Creek - Fox Hills?), |
| 38-60 | CLAY | silty, to sl. silty, greenish-gray, hard, sticky, some ribbon-like cuttings, good recovery, (Bedrock -- Hell Creek - Fox Hills?). |

**162-075-07BAA4**

NDSWC 15043

Date Completed: 08/26/2003
L.S. Elevation (ft): 1940
Depth Drilled (ft): 100

Purpose: Test Hole

Data Source:

Completion Info:

Remarks:

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-45 | TILL | clay, silty, sandy, pebbly, pale yellow-gray-brown, oxidized, soft to mod. hard with depth. |
| 45-68 | TILL | clay, as above, olive gray, unoxidized. |
| 68-76 | SAND & GRAVEL | sand is fn. to v. cse., predom. cse. to v.cse., (40 -50%) and gravel, up to 1 -inch diam., mostly 1/4-inch diam., (50-60%). comprised of silicates, carbonates, shale, quartz, angular to well rounded, good clean section, no fines in mud tub, mod. bit chatter, drills as stratified, caving, takes water. |
| 76-98 | CLAY | silty, to v. sl. silty, greenish-gray, hard, some ribbon-like cuttings, mixed 1 bag mud at 80 ft., upper S&G caving, (Bedrock -- Hell Creek - Fox Hills?). |
| 98-100 | SAND | v.fn. to fn., silty, clayey, greenish-gray, soft (Bedrock -- Hell Creek - Fox Hills?). |

**162-075-07BAB1**

NDSWC 15032

| | | | |
|---|---|---|---|
| Date Completed: | 08/25/2003 | Purpose: | Test Hole |
| L.S. Elevation (ft): | 1938 | | |
| Depth Drilled (ft): | 80 | | |
| | | Data Source: | |

Completion Info:

Remarks:

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-42 | TILL | clay, silty, sandy, pebbly, pebbles up to 1-inch diam.,pale yellow-gray-brown, oxidized, yellow stringers, cohesive, mod. plastic, at 27 and 35ft., rocks, from 7 to 8ft., v.fn. to v. cse. sand, predom. cse., sl. gravelly, up to 1/4 -inch diam., yellow stained, oxidized. |
| 42-43 | CLAY | dark brown, soft to mod. sticky, cohesive, (Bedrock -- Hell Creek - Fox Hills?) |
| 43-55 | SAND | v.fn.to fn., silty, clayey, cohesive, pale yellow green to brownish green, soft, oxidized, low k, (Bedrock -- Hell Creek - Fox Hills?) |
| 55-56 | CLAY | dark brown, soft, cohesive, mod. sticky, (Bedrock -- Hell Creek -- Fox Hills?) |
| 56-66 | CLAY | sequence of oxidized silty clay and v.fn., clayey, silty, sands, yellow green to yellow brown, (Bedrock -- Hell Creek - Fox Hills?) |
| 66-68 | CLAY | as interval 55 to 56 ft. (Bedrock -- Hell Creek -- Fox Hills?) |
| 68-69 | CLAY | silty, greenish gray, sticky, (Bedrock -- Hell Creek - Fox Hills?) |
| 69-70 | SANDSTONE | hard, indurated, yellow stained, oxidized, good bit chatter, (Bedrock -- Hell Creek - Fox Hills?) |
| 70-74 | CLAY | as interval from 68 to 69 ft., (Bedrock -- Hell Creek - Fox Hills?) |
| 74-80 | SAND | v.fn. to fn., silty, clayey, soft, cohesive, olive gray, low k, (Bedrock -- Hell Creek - Fox Hills?) |

**162-075-07BAB2**

NDSWC 15033

Date Completed: 08/25/2003
L.S. Elevation (ft): 1925
Depth Drilled (ft): 60

Purpose: Test Hole

Data Source:

Completion Info:

Remarks:

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-18 | TILL | clay, silty, sandy, pebbly, pebbles up to 1-inch diam., pale yellow-gray-brown,, yellow stringers, oxidized, cohesive, mod. plastic. |
| 18-36 | TILL | as above, olive gray, unoxidized. |
| 36-38 | SAND | v.fn.to fn., silty, clayey, green, soft, cohesive, low k, (Bedrock -- Hell Creek - Fox Hills?) |
| 38-60 | CLAY | sequence of brown to red-brown clays and olive gray to greenish-gray sandy, silty, clays, (Bedrock -- Hell Creek - Fox Hills?) |

**162-075-07BAD1**

NDSWC 15044

| | | | |
|---|---|---|---|
| Date Completed: | 08/27/2003 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 1924.7 | Well Type: | 2 in. - PVC |
| Depth Drilled (ft): | 120 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 61-66 | Data Source: | |

Completion Info:

Remarks: North of well BAD2

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-27 | TILL | Clay, silty, sandy, pebbly, pale yellow-gray-brown, oxidized, soft, cohesive, mod. plastic, @19Ft. rock |
| 27-43 | TILL | Clay, as above, olive gray, unoxidized |
| 43-66 | SAND | very fine to very cse.,predom. cse., becomes gravelly at aboout 43 to 45 Ft., comprised of shale, carbonates, silicates, quartz, subangular to well rounded, very clean section, no fines in back of mud tub, no bit chatter drilled smooth and fast, takes water, mixed 1 bag mud at 45 Ft. |
| 66-67 | CLAY | or till?, bit slowed , no recovery |
| 67-80 | GRAVEL | (70-80%), up to 3/4 inch diam., mostly 1/8 to 1/4 inch, sand cse. to v.cse, good bit chatter, composition as above, subangular to well rounded, no fines in back o fmud tub, takes water, caving badly, nice clean section, stratified, mixed 1 bag mud at 70 Ft., and 2 bags mud at 80 Ft. |
| 80-101 | TILL | clay, as bbove, olive gray, rock at 86 -87Ft., upper sand and gravel caving badly, mixed 2 bags mud at 100Ft. |
| 101-103 | CLAY | or till?, poor recovery, bit slowed |
| 103-109 | SAND & GRAVEL | good bit chatter, large washed cavity above, very poor sample recovery, drilling mud very thick, much into suspension, based on bit chatter this is a coarse, clean section, drills as stratified |
| 109-120 | CLAY | very slightly silty, gray brown, hard, sticky, plastic, drills very slow with pull-down, fair sample recovery, (Bedrock -- Hell Creek - FoxHills?) |

**162-075-07BAD2**

NDSWC 15045

| | | | |
|---|---|---|---|
| Date Completed: | 08/27/2003 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 1916.6 | Well Type: | 2 in. - PVC |
| Depth Drilled (ft): | 120 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 88-93 | Data Source: | |

Completion Info:

Remarks: South of well BAD1

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-25 | TILL | clay, silty, sandy, pebbly , pale yellow-gray-brown, oxidized, soft, cohesive |
| 25-83 | TILL | clay, as above, unoxidized, sand lens from 27 to 28 Ft. |
| 83-98 | SAND & GRAVEL | sand (50%), med. to very coarse, predom. cse to v.cse, gravel(50%) up to 1-inch diam., mostly 1/8 to 1/4 inch, comprised of silicates, carbonates, shale, qtz., angular to well rnded, good bit chatter,clean section, takes water, drills as stratified, @ 93-94 Ft. bit slowed, clay layer? |
| 98-120 | CLAY | Clay, gray brown to greenish gray, hard, greasy, drills slow, some dark brown softer clay at base (Bedrock -- Hell Creek - Fox Hills?). |

**162-075-07BAD3**

NDSWC 15046

Date Completed: 08/27/2003
L.S. Elevation (ft): 1925
Depth Drilled (ft): 82

Purpose: Test Hole

Data Source:

Completion Info:

Remarks: Core hole set up about 10 feet north of 07BAD1(#15044). Used 10-foot core barrel which would not hold unconsolidated sands and gravels. Samples dropped out of barrel during retreival from hole. See log for 07BAD1.

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|

**162-075-07BAD4**

Gordon Hall

| | | | |
|---|---|---|---|
| Date Completed: | 06/18/2004 | Purpose: | Domestic Well |
| L.S. Elevation (ft): | N/A | Well Type: | 5 in. - PVC |
| Depth Drilled (ft): | 92 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 74-84 | Data Source: | Bursinger Drilling |

Completion Info:

Remarks: Owner – Gordon Hall

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-1 | TOPSOIL | black |
| 1-32 | CLAY | yellow |
| 32-39 | GRAVEL | |
| 39-72 | CLAY | blue |
| 72-84 | GRAVEL | |
| 84-88 | CLAY | gravelly, blue |
| 84-92 | BEDROCK | |

**162-075-07BBA1**

NDSWC 15034

| | | | |
|---|---|---|---|
| Date Completed: | 08/25/2003 | Purpose: | Test Hole |
| L.S. Elevation (ft): | 1925 | | |
| Depth Drilled (ft): | 60 | Data Source: | |

Completion Info:

Remarks:

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-30 | TILL | clay, silty, sandy, pebbly, pale yellow-gray-brown, oxidized, cohesive, mod. plastic, at 2 to 4 ft., sand, v.fn. to v. cse., pred. cse., gravelly, 10-15%, up to 11/2-inch diam., yellow stained, oxidized. |
| 30-39 | CLAY | sl. silty to silty, olive gray, hard to sl. brittle, to sticky, ribbon-like cuttings, (Bedrock -- Hell Creek - Fox Hills?) |
| 39-41 | LIGNITE | moderate bit chatter, good recovery, (Bedrock -- Hell Creek - Fox Hills?) |
| 41-43 | CLAY | silty, sl. sticky, hard, olive gray, (Bedrock -- Hell Creek - Fox Hills?) |
| 43-49 | CLAY | dark brown, hard, sl. mod. sticky, (Bedrock -- Hell Creek - Fox Hills?) |
| 49-51 | CLAY | as interval from 41 to 43 ft., (Bedrock -- Hell Creek - Fox Hills?) |
| 51-60 | SAND | v.fn.to fn., silty, clayey, soft, cohesive, low k, does not take water, (Bedrock -- Hell Creek - Fox Hills?) |

**162-075-07BBA2**

NDSWC 15035

Date Completed: 08/25/2003
L.S. Elevation (ft): 1908
Depth Drilled (ft): 60

Purpose: Test Hole

Data Source:

Completion Info:

Remarks:

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-24 | TILL | clay, silty, sandy, pebbly, pale yellow-gray-brown, oxidized, cohesive, moderately plastic, at 2 to 4 ft., sand, v.fn. to v.cse.,pred. cse, gravelly, up to 1 -inch diam., yellow stained, oxidized, angular to well rounded |
| 24-36 | TILL | clay, as above, olive gray, unoxidized. |
| 36-50 | CLAY | sequence of olive gray to greenish gray silty clays and clayey, silty, sands, clays are sticky, sands are soft, and cohesive, (Bedrock -- Hell Creek - Fox Hills?) |
| 50-51 | SANDSTONE | well indurated, very hard drilling, strong chatter, greenish gray chips with green specks, (Bedrock -- Hell Creek - Fox Hills?) |
| 51-60 | CLAY | silty, sandy,, sand, v.fn. to fn., olive gray to greenish gray, soft, sl. sticky, (Bedrock -- Hell Creek - Fox Hills?) |

**162-075-07BBA3**

NDSWC 15036

| | | | |
|---|---|---|---|
| Date Completed: | 08/25/2003 | Purpose: | Test Hole |
| L.S. Elevation (ft): | 1900 | | |
| Depth Drilled (ft): | 80 | Data Source: | |

Completion Info:

Remarks:

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-9 | SAND | v.fn., v. cse., gravelly, up to 1-inch diam., 10-15% gravel, yellow stained, oxidized, comprised of carbonates, shield silicates, shale, lignite, quartz, sub-angular to well rounded. |
| 9-11 | TILL | clay, silty, sandy, pebbly, pale yellow-gray-brown, oxidized, soft, cohesive. |
| 11-47 | TILL | clay, as above, olive gray, unoxidized. |
| 47-56 | CLAY | silty, dark brown, soft, (Bedrock -- Hell Creek - Fox Hills?) |
| 56-80 | CLAY | sequence of interbedded dark brown clays and vfn to fn., silty, clayey greenish-gray sands, (Bedrock -- Hell Creek - Fox Hills?) |

**162-075-07BBB1**

NDSWC 26-738

| | | | |
|---|---|---|---|
| Date Completed: | 06/19/1962 | Purpose: | Test Hole |
| L.S. Elevation (ft): | 1890 | | |
| Depth Drilled (ft): | 126 | | |
| | | Data Source: | |

Completion Info:

Remarks: Test Hole 26-738

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-3 | TOPSOIL | silty, black, organic |
| 3-4 | SILT | sandy, olive gray, noncohesive |
| 4-8 | GRAVEL | fine to coarse, sandy yellowish brown, subangular to rounded |
| 8-10 | TILL | clay, silty, yellowish brown, oxidized, slightly calcareous |
| 10-15 | TILL | clay, silty to pebbly, moderate olive brown, oxidized, sligtly calcareous |
| 15-18 | SAND | fine to coarse with fine gravel, well rounded |
| 18-32 | TILL | clay, silty, grayish olive, cohesive and plastic, slightly calcareous |
| 32-48 | SILT | clayey, dark greenish gray, smooth |
| 48-52 | GRAVEL | fine to coarse, subangular to subrounded, clean |
| 52-62 | SAND | fine to coarse, silty and clayey, angular to subrounded |
| 62-74 | SANDSTONE | fine, grayish olive, subangular to rounded, highly indurated, calcareous cement |
| 74-93 | CLAY | moderate olive brown, smooth, soapy |
| 93-104 | SAND | fine, grayish olive, rounded, well sorted, slightly indurated |
| 104-126 | SHALE | silty, dark brown, oily, high organic content, slightly indurated |

**162-075-07BBB2**

| | | | |
|---|---|---|---|
| Date Completed: | 04/01/1996 | Purpose: | Domestic Well |
| L.S. Elevation (ft): | 1892 | Well Type: | 5 in. - PVC |
| Depth Drilled (ft): | 74 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 54-74 | Data Source: | |

Completion Info:

Remarks:
Open casing, drilled for retirement home that is not yet built.

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-1 | TOPSOIL | |
| 1-3 | CLAY | and stones |
| 3-14 | SAND & GRAVEL | |
| 14-33 | CLAY | yellow |
| 33-55 | CLAY | blue |
| 55-57 | LIGNITE | and stones |
| 57-71 | SAND | coarse, and fines |
| 71-74 | CLAY | dark |

**162-075-07BBB3**

NDSWC 15038

Date Completed: 08/26/2003
L.S. Elevation (ft): 1880
Depth Drilled (ft): 80

Purpose: Test Hole

Data Source:

Completion Info:

Remarks:

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-6 | TILL | clay, silty, sandy, pebbly, pale yellow-gray-brown, oxidized, soft, cohesive. |
| 6-29 | CLAY | as above, olive gray, unoxidized. |
| 29-36 | SAND | v.fm., to fn., silty,good recovery, drills fairly slow, smooth, appears yellow brown, oxidized. |
| 36-37 | SAND | as above, but med. to cse. |
| 37-42 | CLAY | As above, olive gray (till) |
| 42-71 | CLAY | sequence of brown silty clays, greenish gray, clayey, sandy, v.fn., silty, and harder greenish-gray silty clays, (Bedrock -- Hell Creek - Fox Hills?) |
| 71-77 | LIGNITE | small black chips, good recovery |
| 77-80 | CLAY | silty, greenish-gray, (Bedrock -- Hell Creek - Fox Hills?) |

**162-075-07BBB4**

NDSWC 15037

| | | | |
|---|---|---|---|
| Date Completed: | 08/26/2003 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 1894.9 | Well Type: | 2 in. - PVC |
| Depth Drilled (ft): | 100 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 69-74 | Data Source: | |

Completion Info:

Remarks:

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-6 | SAND | (50%), v.f. to v. cse. and gravel (50%) up to 1-inch diam., subangular to well rounded, comprised of carbonates, shale, silicates, quartz, yellow stained, oxidized. |
| 6-13 | TILL | clay, silty, sandy, pebbly, up to 1-inch diam. pebbles, pale yellow-grray-brown, soft, oxidized. |
| 13-28 | TILL | clay, as above, olive gray, unoxidized. |
| 28-40 | SAND | v. fn. to v. cse., predom. medium, subangular to well rounded, comprised of silicates, carbonates, shale, quartz, lignite, no bit chatter, drilled smooth and fast, good recovery, no fines in back of mud tub. |
| 40-46 | SAND | v.fn. to v. cse., predom. med. to cse, gravelly (5-10%), up to 1/4-inch diam., mostly less than 1/8-inch diam., drills smooth and fast, no bit chatter, good recovery, composition as above, no fines in back of mud tub. |
| 46-51 | SAND | as in interval from 40 to 46 Ft., possibly a little coarser section, slight to moderate bit chatter, drills as stratified. |
| 51-74 | SAND | v.fn to v.cse., predom. fn. to med. no gravel, composition as above, drills smooth and fast, no fines in back of mud tub. |
| 74-82 | SAND | as in interval from 51 to 74, but possibly interbedded with silty, sandy, clays, poor clay recovery, bit still moved relatively fast, occas. slower interval. |
| 82-88 | SAND | v.fn. to fn., silty, clayey, greenish gray, soft, poor sample recovery, bit slowed somewhat (Bedrock -- Hell Creek - Fox Hills?) |
| 88-100 | CLAY | silty, dark brown, soft, sl. greasy, bit slowed, good sample recovery. (Bedrock -- Hell Creek - Fox Hills?) |

**162-075-07BBB5**

NDSWC 15039

Date Completed: 08/26/2003
L.S. Elevation (ft): 1878
Depth Drilled (ft): 60

Purpose: Test Hole

Data Source:

Completion Info:

Remarks:

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-2 | TILL | clay, silty, sandy, pebbly, yellow-gray-brown, soft, cohesive |
| 2-4 | SAND | v.fn., to v.cse., predom. med. to cse., gravelly, up to 1-inch diam. |
| 4-11 | TILL | clay, as above |
| 11-14 | TILL | clay, as above, olive gray, unoxidized |
| 14-21 | TILL | clay, as above, olive gray to gray brown. |
| 21-49 | SAND | v.fn.to med., predom. fn. to v.fn., soupy intervals, possible interbedded silty, sandy, clay layers, poor recovery, good sand recovery, does not take water, not a very clean section |
| 49-55 | SAND | v.fn., to cse., predom. fn. to med., clean section, bit moved faster, comprised of carbonates, shale, and silicates. |
| 55-60 | CLAY | silty, dark brown, (Bedrock -- Hell Creek - Fox Hills?) |

**162-075-07BBB6**

NDSWC 15040

Date Completed: 08/25/2003
L.S. Elevation (ft): 1883
Depth Drilled (ft): 100

Purpose: Test Hole

Data Source:

Completion Info:

Remarks:

## Lithologic Log

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-14 | TILL | clay, silty, sandy, pebbly, yellow-gray-brown, oxicized, soft. |
| 14-17 | TILL | as above, olive gray. |
| 17-18 | SAND | v.fn. to v. cse., predom. med., yellow stained, oxidized. |
| 18-26 | TILL | as above, olive gray. |
| 26-36 | CLAY | silty, sandy to sand, v.fn.to fn., claey, silty, soft, cohesive, yellow-gray-brown to greenish-gray, looks like bedrock. |
| 36-40 | SAND | v.fn. to cse., predom. fn., clean, sl. gravelly, at 40 ft., comprised of quartz, shale, carbonates, silicates, lignite, subangular to well rounded. |
| 40-51 | SAND | as above, but coarser section, predom. med. to cse., 5% gravel < 1/4-inch diameter, lots of rounded detrital shale, very light to smooth bit chatter. |
| 51-55 | SAND | interbedded with gravel, sand as above, sandstone layers?, lots of angular greenish-gray sandstone chips, possibly some interbedded silty clay, moderate bit chatter. |
| 55-61 | CLAY | silty, sandy, brown,looks like bedrock. |
| 61-67 | SAND | v.fn. to v.cse., predom. medium, comprised of shale, quartz, silicates, carbonates, bit moved mod. fast, no chatter, good recovery appears to be a clean section. |
| 67-77 | CLAY | silty, sandy?, greenish-gray, bit slowed, looks like bedrock. |
| 77-78 | SANDSTONE | light greenish-gray, hard, indurated, hard bit chatter, good recovery of sandstone chips. |
| 78-80 | CLAY | silty, brown, soft, appears like bedrock. |
| 80-82 | SANDSTONE | as from 77 to 78 ft. |
| 82-89 | SAND | v.fn. to med., pedom. fn. to med., clean, good recovery, bit moved moderately fast, composition as from 61 t 67 ft., glaciofluvial not bedrock. |
| 89-100 | CLAY | silty, dark brown, soft, good recovery, (Bedrock -- Hell Creek - Fox Hills) |

**162-075-07BBB7**

NDSWC 15048

| | | | |
|---|---|---|---|
| Date Completed: | 08/28/2003 | Purpose: | Test Hole |
| L.S. Elevation (ft): | 1897 | | |
| Depth Drilled (ft): | 80 | | |
| | | Data Source: | |

Completion Info:

Remarks: Core hole set up about 10 feet west of piezometer 07BBB4(#15037). Used 10-foot core barrel which would not hold unconsolidated sands and gravels. Samples dropped out of barrel during retreival from hole. See log for 07BBB4.

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|

**162-075-07BDC1**

City of Bottineau

| | | | |
|---|---|---|---|
| Date Completed: | 1967 | Purpose: | Observation Well |
| L.S. Elevation (ft): | N/A | Well Type: | 6 in. - Steel |
| Depth Drilled (ft): | 57 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 50-57 | Data Source: | Simpson & Sons, Bisbee, ND |

Completion Info:

Remarks: Site of Municipal Well #1 - 162-075-07BDC2

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|

**162-075-07BDC2**

City of Bottineau

| | | | |
|---|---|---|---|
| Date Completed: | 04/25/1968 | Purpose: | Municipal Well |
| L.S. Elevation (ft): | N/A | Well Type: | 10 in. - Steel |
| Depth Drilled (ft): | 57 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 54.3-63.3 | Data Source: | |

Completion Info:

Remarks: Bottineau Municipal well #1
MP is top of 1-inch diameter pvc pipe extending 1.28 feet above top of well seal inside manhole.

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-0.5 | TOPSOIL | |
| 0.5-4.5 | ROCK | gray, clay |
| 4.5-5.5 | CLAY | gravelly, yellow, rocks |
| 5.5-21 | CLAY | sandy, gray, rocks |
| 21-24 | ROCK | |
| 24-26 | CLAY | gravelly, gray |
| 26-38 | SAND & GRAVEL | very clayey |
| 38-40 | SAND | fine, clayey |
| 40-44 | CLAY | blue, very gravelly |
| 44-46 | GRAVEL | clayey, with water |
| 46-57 | SAND & GRAVEL | somewhat clayey |

**162-075-07CBB1**

NDSWC 33-738

| | | | |
|---|---|---|---|
| Date Completed: | 06/27/1962 | Purpose: | Test Hole |
| L.S. Elevation (ft): | 1825 | | |
| Depth Drilled (ft): | 42 | | |
| | | Data Source: | |

Completion Info:

Remarks:

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-5 | SAND | medium to coarse, with fine to coarse gravel, pebbles, cobbles, and boulders |
| 5-10 | SAND | fine, silty, moderate olive brown, subangular to subrounded, oxidized, noncalcareous |
| 10-24 | SAND | fine, silty, dark greenish-gray, noncalcareous |
| 24-31 | SILT | dark greenish-gray, compact |
| 31-42 | SAND | fine, silty, dark greenish-gray, more indurated with depth |

**162-075-07CBB2**

Gary Hasenwinkel

| | | | |
|---|---|---|---|
| Date Completed: | 1994 | Purpose: | Domestic Well |
| L.S. Elevation (ft): | N/A | Well Type: | 5 in. - PVC |
| Depth Drilled (ft): | 85 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 65-85 | Data Source: | |

Completion Info:

Remarks:

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-40 | GRAVEL | |
| 40-60 | CLAY | gray, yellow |
| 60-81 | SAND | very fine |
| 81-85 | CLAY | gray |

**162-075-07DAA1**

Bottineau

Date Completed: 11/1980
L.S. Elevation (ft): 1950
Depth Drilled (ft): 140

Purpose: Test Hole

Data Source:

Completion Info:

Remarks: Simpson 1980-4

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-1 | TOPSOIL | sandy |
| 1-12 | CLAY | yellow, with fine to coarse sand |
| 12-18 | CLAY | blue with gravel and pebbbles |
| 18-20 | CLAY | blue, very gravelly |
| 20-24 | GRAVEL | somewhat clayey |
| 24-26 | CLAY | |
| 26-30 | GRAVEL | pebbles |
| 30-33 | CLAY | blue |
| 33-38 | CLAY | yellow, gravelly, rock |
| 38-49 | SAND & GRAVEL | fine to coarse, nice |
| 49-61 | CLAY | gray |
| 61-78 | SAND | fine to coarse, gravelly, some clayey, upper part fine |
| 78-88 | CLAY | gray, some pebbles, some shale particles |
| 88-110 | SAND & GRAVEL | some clay, not much fines |
| 110-140 | CLAY | |

**162-075-07DAA2**

Bottineau

Date Completed: 11/01/1980
L.S. Elevation (ft): 1935
Depth Drilled (ft): 100

Purpose: Test Hole

Data Source:

Completion Info:

Remarks: Simpson 1980-5A

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-2 | TOPSOIL | black |
| 2-16 | CLAY | gray |
| 16-24 | CLAY | yellow with a few pebbles |
| 24-33 | SAND & GRAVEL | rocks |
| 33-56 | CLAY | gray, pebbles |
| 56-69 | SAND & GRAVEL | 50% shale, with clay chunks and layers, took water used drilling mud |
| 69-72 | CLAY | yellow |
| 72-77 | SAND & GRAVEL | |
| 77-82 | CLAY | |
| 82-86 | SAND & GRAVEL | |
| 86-94 | CLAY | losing fluid, no sample recovery |
| 94-96 | ROCK | soft |
| 96-100 | CLAY | |

**162-075-07DAB**

Bottineau

| | | | |
|---|---|---|---|
| Date Completed: | 11/01/1980 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 1912 | Well Type: | 1.25 in. - PVC |
| Depth Drilled (ft): | 100 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 51-55 | Data Source: | |

Completion Info:

Remarks: Simpson 1980-1

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-3 | TOPSOIL | black |
| 3-14 | CLAY | yellow |
| 14-50 | CLAY | blue, with a few pebbles |
| 50-62 | SAND & GRAVEL | small and large pebbles and rocks, from 60-62 feet somewhat finer with clay chunks |
| 62-64 | SHALE | boulder |
| 64-100 | CLAY | blue with a few small gravel, some rocks |

**162-075-07DAC**

Bottineau

Date Completed: 1980
L.S. Elevation (ft): 1883
Depth Drilled (ft): 120

Purpose: Test Hole

Data Source:

Completion Info:

Remarks: Simpson 1980-2

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-1 | TOPSOIL | |
| 1-10 | CLAY | somewhat sandy |
| 10-20 | SAND & GRAVEL | pebbles, quite a few shale particles, with some clay |
| 20-25 | SAND | fine, gray |
| 25-82 | CLAY | gray, some gravel |
| 82-96 | SAND | very fine, gray |
| 96-120 | CLAY | or shale?, gray, no sand |

**162-075-07DBA**

Bottineau

Date Completed: 01/01/1980
L.S. Elevation (ft): 1883
Depth Drilled (ft): 100

Purpose: Test Hole

Data Source:

Completion Info:

Remarks: Simpson 1980-3

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-1 | TOPSOIL | |
| 1-10 | CLAY | yellow |
| 10-39 | CLAY | blue with a few stones |
| 39-45 | SAND & GRAVEL | some shale particles |
| 45-48 | CLAY | gray |
| 48-49 | SHALE | rock |
| 49-60.5 | CLAY | with a few small gravel, gray |
| 60.5-61 | CLAY | very gravelly |
| 61-100 | CLAY | or shale?, gray, petrified wood at 95 ft. |

**162-075-07DBB2**

| | | | |
|---|---|---|---|
| Date Completed: | 1980 | Purpose: | Observation Well - Destroyed |
| L.S. Elevation (ft): | 1888 | Well Type: | 1.25 in. - PVC |
| Depth Drilled (ft): | 61 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 52.5-55.5 | Data Source: | |

**162-075-07DBB1**

Bottineau

| | | | |
|---|---|---|---|
| Date Completed: | 1980 | Purpose: | Test Hole |
| L.S. Elevation (ft): | 1877 | | |
| Depth Drilled (ft): | 100 | Data Source: | |

Completion Info:

Remarks: Simpson 1980-8

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-1 | TOPSOIL | black |
| 1-3 | CLAY | gray, a little sandy |
| 3-7 | CLAY | yellow |
| 7-10 | GRAVEL | |
| 10-22 | CLAY | blue, gray |
| 22-30 | SAND | fine, clayey |
| 30-41 | CLAY | blue |
| 41-70 | SAND | fine, clayey, with shale particles |
| 70-91 | CLAY | blue, soft |
| 91-100 | CLAY | blue |

**162-075-07DDA**

Bottineau

Date Completed: 1980
L.S. Elevation (ft): 1878
Depth Drilled (ft): 81

Purpose: Test Hole

Data Source:

Completion Info:

Remarks: Simpson 1980-14

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-0.5 | TOPSOIL | black |
| 0.5-21 | CLAY | yellow |
| 21-23 | CLAY | blue |
| 23-27 | SAND | blue, fine |
| 27-68 | CLAY | blue |
| 68-75 | SHALE | blue, hard |
| 75-81 | SHALE | blue, sandy |

**162-075-07DBB2**

| | | | |
|---|---|---|---|
| Date Completed: | 1980 | Purpose: | Observation Well - Destroyed |
| L.S. Elevation (ft): | 1888 | Well Type: | 1.25 in. - PVC |
| Depth Drilled (ft): | 61 | Aquifer: | Bottineau |
| Screen Int. (ft.): | 52.5-55.5 | Data Source: | |

Completion Info:

Remarks: Simpson 1980-9A

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-1 | TOPSOIL | |
| 1-3 | CLAY | gray |
| 3-5 | CLAY | yellow |
| 5-16 | GRAVEL | |
| 16-39 | CLAY | blue |
| 39-40 | ROCK | |
| 40-49 | CLAY | blue |
| 49-58 | GRAVEL | shale rock layers |
| 58-61 | CLAY | blue |

**162-075-07DDC**

City of Bottineau

Date Completed: 01/01/1980
L.S. Elevation (ft): 1852
Depth Drilled (ft): 101

Purpose: Test Hole

Data Source:

Completion Info:

Remarks: Simpson 1980-11

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-1 | TOPSOIL | |
| 1-18 | CLAY | yellow |
| 18-26 | CLAY | blue |
| 26-27 | ROCK | white |
| 27-30 | SAND | green, fine, some small clay layers |
| 30-51 | CLAY | blue |
| 51-69 | SAND | fine, blue, with small clay layers |
| 69-71 | SANDSTONE | |
| 71-101 | SHALE | blue |

**162-075-07DDD**

NDSWC 7-738

| | | | |
|---|---|---|---|
| Date Completed: | 05/21/1962 | Purpose: | Test Hole |
| L.S. Elevation (ft): | 1854 | | |
| Depth Drilled (ft): | 63 | | |
| | | Data Source: | |

Completion Info:

Remarks:

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-2 | TOPSOIL | black |
| 2-7 | GRAVEL | fine to coarse, sandy, subrounded |
| 7-13 | CLAY | silty to gravelly, dark yellowish orange, cohesive, oxidized, calcareous, till |
| 13-38 | CLAY | silty to gravelly, dark greenish gray, cohesive, till |
| 38-40 | GRAVEL | fine to medium, sandy, subrounded to rounded |
| 40-41 | CLAY | silty to gravelly, dark greenish gray, cohesive, till |
| 41-50 | SAND | very fine to medium, very silty, angular to subrounded |
| 50-63 | SILT | clayey to sandy, olive gray, noncalcareous |

**162-075-18BB**

NDSWC 16-738

| | | | |
|---|---|---|---|
| Date Completed: | 06/11/1962 | Purpose: | Test Hole |
| L.S. Elevation (ft): | 1780 | | |
| Depth Drilled (ft): | 52.5 | | |
| | | Data Source: | |

Completion Info:

Remarks:

**Lithologic Log**

| Depth (ft) | Unit | Description |
|---|---|---|
| 0-1 | TOPSOIL | sandy, black |
| 1-6 | SAND | medium, dark yellowish brown, subangular to rounded, well sorted |
| 6-9 | GRAVEL | very coarse, no samples |
| 9-17 | SAND | fine to medium, with some silt and fine gravel, light olive gray, well rounded |
| 17-22 | SAND | fine to coarse, silty to gravelly |
| 22-43 | SAND | fine, dark greenish gray, well rounded, well sorted, noncalcareous |
| 43-52.5 | SHALE | olive black, thinly laminated, platy, noncalcareous |

**APPENDIX II**

# Chemical Analyses of Water Samples

# Appendix II — Chemical analyses of 5 ground-water samples collected from municipal test well 162-075-07ADD6

| Location | Screened Interval (ft) | Date Sampled | (milligrams per liter) $SiO_2$ | Fe | Mn | Ca | Mg | Na | K | $HCO_3$ | $CO_3$ | $SO_4$ | Cl | F | $NO_3$ | B | TDS | Hardness $CaCO_3$ | as NCH | % Na | SAR | Spec Cond (µmho) | Temp (°C) | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 162-075-07ADD6 | 39-49 | 08/10/04 | 28.1 | 0.100 | 1.85 | 184. | 61.3 | 44.0 | 7.6 | 580. | <1 | 335. | 3.14 | 0.249 | 0.09 | | 923. | 712. | 236. | 11.7 | 0.72 | 1200 | | |
| 162-075-07ADD6 | 39-49 | 08/11/04 | 27.3 | 0.221 | 1.79 | 179. | 59.7 | 42.3 | 7.3 | 570. | <1 | 348. | 3.24 | 0.246 | 0.13 | | 922. | 693. | 226. | 11.5 | 0.70 | 1175 | | |
| 162-075-07ADD6 | 39-49 | 08/12/04 | 28.0 | 0.023 | 1.85 | 184. | 61.6 | 43.5 | 7.6 | 567. | <1 | 351. | 3.24 | 0.253 | <0.09 | | 932. | 713. | 248. | 11.5 | 0.71 | 1175 | | |
| 162-075-07ADD6 | 39-49 | 08/17/04 | 28.9 | 0.276 | 1.89 | 192. | 63.6 | 44.0 | 7.7 | 588. | <1 | 353. | 3.32 | 0.255 | <0.09 | | 955. | 742. | 259. | 11.2 | 0.70 | | | |
| 162-075-07ADD6 | 39-49 | 08/24/04 | 27.1 | 0.281 | 1.79 | 179. | 59.7 | 41.9 | 7.4 | 583. | <1 | 357. | 3.31 | 0.244 | 0.09 | | 938. | 693. | 215. | 11.4 | 0.69 | | | |