GROUNDWATER RESOURCE INVESTIGATION
BEALETON SERVICE DISTRICT
Bealeton, Virginia

RESULTS OF PUMPING TESTS on WELLS B-3, B-4 and MS-5

Submitted to

COUNTY OF FAUQUIER
and
FAUQUIER COUNTY
WATER AND SANITATION AUTHORITY

VOLUME I -- REPORT

November, 1994

Presented by

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December 8, 1994

Mr. David Binning
Director
Fauquier County Water & Sanitation Authority
Rt. 3, Box 239BB, Meetze Road
Warrenton, VA 22186

Dear Dave,

Emery & Garrett Groundwater, Inc. (EGGI) is pleased to submit to you our summary report describing the results of our Phase II groundwater resources investigation conducted in the Bealeton study area.

As you are aware, we believe our findings are very favorable relative to the development of new groundwater resources to serve the public water supply needs of the Bealeton Service Area. Enclosed within this technical report are descriptions of our approach to this groundwater testing program, methods of investigation, conclusions, and recommendations.

I hope you find this document responsive to your needs. If you have any questions, please do not hesitate to contact me.

Best regards,

JmE

James M. Emery
President

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I. INTRODUCTION / BACKGROUND

A. Background of the Project

Groundwater resources have historically been, and still remain today, the exclusive sources of water serving the public needs of Fauquier County. In 1951, Fauquier County created the Fauquier County Water and Sanitation Authority (FCWSA) as a public utility to furnish water to selected service districts, one of which includes the rural community of Bealeton, Virginia. Bealeton is located in southern Fauquier County and has experienced increased residential development and associated growth around the intersection of Routes 17 and 28 (Figure 1A). This growth has increased the demand for potable water resources within the Bealeton Service District.

Emery & Garrett Groundwater Inc. (EGGI) was retained by the County of Fauquier in a joint effort with the FCWSA to conduct a phased comprehensive groundwater resource investigation of the Bealeton water service area. The goals of this project were several fold:

- **Phase IA** -- To assess the availability of groundwater resources within the Bealeton Service District and to identify "areas" (zones) considered favorable for groundwater development.
- **Phase IB** -- To specifically locate test well drilling targets within selected groundwater development "areas" through the use of geophysical surveys.
- **Phases II** -- To conduct test well drilling, yield testing, and water quality analyses sufficient to confirm the "best" sources of groundwater available within the Bealeton Service District.

The results of this investigation are intended to provide critically needed hydrogeologic data enabling the County and the FCWSA to proceed in developing new sources of groundwater resources to meet *existing* and *future* water demands, *protect* future water supplies, and to establish a means to better *manage* groundwater resources within the Bealeton Service area. To that end, EGGI conducted an extensive groundwater exploration program which delineated four favorable zones for groundwater development. These zones are identified as Zones A, B, C, and D (Figure 1B, Plate 1). The approach, methods of investigation, and results of Phases IA and IB of this groundwater exploration program are presented in EGGI's previously submitted report entitled, *Groundwater Resource Investigation, Bealeton Service District, Bealeton, Virginia* submitted to the FCWSA in July of 1992.

The contents of this report serves to present collected hydrogeologic data related to Phase II of this investigation and documents the installation of nine test wells, conversion of test wells to production wells, completion of pumping tests, and water quality analyses. All supporting data is included in a series of appendices. The conclusions and findings of this study have also been illustrated on color plates to help with the interpretation of the collected hydrogeological data and the implementation of the proposed recommendations.

B. Hydrogeologic Considerations for Developing Additional Groundwater Resources in the Bealeton Service District

The Bealeton water service district is located entirely within the geologic province of the Culpeper Basin (Figure 1A, Plate 1). The area is typified by relatively flat topography and is underlain by a complex series of sedimentary and intrusive igneous rocks. These rock types include sandstones, siltstones, conglomerate, basalt, and diabase. The geologic conditions of the Bealeton service area dictate that water resources developed here must be derived from fractured bedrock sources. Inasmuch as bedrock is generally impermeable at the time of its origin, its water-bearing properties are dependent upon the later development of discontinuities, the association of different rock types, and fracturing, etc., which provide pathways for the transmission of groundwater.

Regional stresses have caused the bedrock in the Bealeton service area to be disturbed. In addition, the sequence of bedrock formations have been intruded by mafic dikes (diabase) and further disrupted by faulting and fracturing. Erosion of these faulted and fractured rock units exposed the complex geology observable at ground surface today. The great variation of rock types and bedrock structure which exists below Bealeton greatly complicate the availability and quality of groundwater resources.

A variety of wells have historically been used in Bealeton to supply potable water to the local community (see EGGI 1992 report). Some of those wells are still in use, but several have been discontinued due to low yields and poor quality. In general, the quality of groundwater resources previously developed in Bealeton were typically high in sulfate, hardness, and total dissolved solids (TDS). Therefore, an important goal of this exploration program was to develop high-yielding wells which also contained the best water quality available. Groundwater quality is a function of the local geology, well construction, pumping schemes, availability of recharge and local groundwater flow patterns. It is impossible to describe the occurrence of poor groundwater chemistry completely, but EGGI developed several conceptual models which guided the exploration program to those areas thought to have the best available water quality (see EGGI 1992 report).

II. TEST WELL DRILLING IN FAVORABLE ZONES A, B, C, AND D

A. Test Well Drilling Program

A total of nine wells were drilled in the four Favorable Zones identified in EGGI's Phase I Report (July, 1992). This included two wells in Zone A (A-1 and A-3), four wells in Zone B (B-1, B-2, B-3, and B-4), two wells in Zone C (C-1 and C-2), and one well in Zone D (D-2) (Figure 1B, Figure 2, and Table I). All wells were drilled using air rotary methods and were 6 inches in diameter. A minimum of 20 feet of temporary steel casing was installed from the ground surface into bedrock and was used to stabilize the test well while drilling. Samples of rock fragments in each well were collected every 10 feet and cataloged for rock type, mineralization along fractures, effects due to contact metamorphism, and degree of fracturing. An EGGI geologist supervised the drilling of all test wells and recorded variations in bedrock lithology and location of fractures which were intercepted during the drilling program. Total depths of test wells ranged from 320 to 520 feet, with an average of 419 feet. Detailed geologic logs for all test wells were prepared and are presented in Appendix A.

Water samples were collected at each water-bearing fracture zone encountered during drilling and at the bottom of each well. These water samples were tested for sulfate, dissolved iron, manganese, pH, hardness, and specific conductivity in the field (Table IIA and Table IIB). In addition, water samples, taken at the conclusion of drilling each test well, were sent to WaterCheck, a division of National Testing Laboratories, Inc. in Cleveland, Ohio, for a complete chemical analyses (Appendix B). Water chemistry variations observed in each well were used to determine the final depth and construction (i.e., casing depth) for each of the test wells.

"Blow tests" (air lift yield) of each test well were measured at each water-bearing fracture zone, where substantial increases in yield had occurred, and at the conclusion of drilling (Table I). "Blow tests" involve using the drilling rig to air lift the water out of the well so that a volumetric measurement of yield can be made. Blow test results indicated the *potential* yield of a test well and provide a means of comparing the productivity of each test well and identifying those wells which deserved further testing.

Cumulative "blow test" yields measured from the nine test wells drilled produced approximately 1700 gallons per minute (gpm) (2.42 million gallons per day [gpd]). Final air-lift yields from *test* wells ranged from 85 to 275 gallons per minute, averaging 189 gpm (Table I). Based upon average well yields in the Bealeton area, these test well yields are considered to be exceptional. All of the wells were completed with locking caps to help prevent future vandalism of the boreholes.

B. The Use of Well MS-5

Well MS-5 was originally installed in the Meadowbrooke subdivision by EGGI in 1990 to supplement the water needs of this expanding residential subdivision. This well had a high yield (blow test of 214 gpm) and good water quality, making it a good candidate for a public supply well (Table I). Its ownership and "dedicated" well lot was recently transferred to the FCWSA and was included as part of this investigation. Well MS-5 is located in EGGI's Groundwater Favorability Zone B (Figure 1B, Figure 2, and Plate 1).

C. Water Quality of Test Wells

1. Variations in Groundwater Chemistry with Depth During Drilling

Groundwater samples were collected from each water-bearing fracture zone as drilling proceeded in each borehole. Continuous chemical data provided a clearer understanding of the vertical distribution of groundwater high in TDS, hardness and sulfate in the Bealeton area while providing real time input into final well construction decisions.

Vertical changes in groundwater chemistry varied substantially among the test wells, with some wells showing higher quality water near to the ground surface (Table II). In general, groundwater quality diminished with depth, although there were exceptions to this (i.e., wells A-1 and B-4). This is understandable when one considers that the deeper the water-bearing fracture, the longer the water is in contact with the bedrock and, therefore, the higher the expected mineral content of the water.

2. Final Water Chemistry of Completed Test Wells

Results of water chemistry analyses of samples collected from the nine test wells varied widely. For example, sulfate concentrations recorded from test wells ranged between 29 (mg/l) in Well B-4 to 1401 (mg/l) in Well C-1 (Table I). (The EPA Recommended Maximum Contaminant Level [RMCL] for sulfate is 250 mg/l.) This is a secondary drinking standard as set forth by EPA's safe drinking water act. If sulfate exceeds 250 mg/l, the water can impart a bitter taste and act as a mild laxative. Five test wells exceeded the RMCL at the completion of test well drilling. The construction of these five wells could not be modified to effectively reduce the levels of sulfate in the water, so they were not considered as immediate candidates for production wells during *this* investigation.

Hardness is a common nuisance in bedrock groundwater supplies, especially in the rocks in the Bealeton area. Hard water creates scaling on pipes and fixtures and prevents soap suds from forming while washing. The best quality water withdrawn from test wells following drilling had a hardness of 65-155 mg/l, which is moderately hard, but good for this area. In general, all groundwater with high sulfate also contained high hardness (and as a result, high total dissolved solids; Table I).

Test wells having the best water quality included Wells A-1, B-1, B-3, B-4, and MS-5. All had concentrations of sulfate at less than 60 mg/l and moderate hardness (Table I). These five wells had acceptable levels of iron, but manganese exceeded the secondary standard of 0.05 mg/l in Well A-1. All the wells in Zones C and D had lower groundwater quality as did Well A-3. Based on the results of test well drilling, Wells A-1, B-1, B-3, B-4 and MS-5 were considered the best candidate choices for conversion to production wells and subsequent yield and water quality testing.

Wells with lower water chemistry such as A-3, C-1, C-2, and D-2 may be valuable in the future to the FCWSA as these wells could serve as irrigation water sources or be used if a water treatment plant is built in this service area in future years which is capable of removing elevated levels of sulfate and hardness.

III. CONVERSION OF TEST WELLS TO PRODUCTION WELLS

A. Reaming of 6-inch Test Wells to 8-inch Production Wells

The construction of large diameter production wells (i.e., 8 inch) are more desirable for permanent use than smaller diameter wells (i.e., 6 inch) for the following reasons:

- The larger diameter well provides greater flexibility in pump selection (i.e., large diameter pumps with slower rotation speeds can be used, thereby minimizing wear and tear on the pump and pumping equipment).
- Increased drilling diameter often leads to increased well capacity and efficiency of well performance.
- The larger-diameter wells reduce the entrance velocity of water entering the borehole from fracture zones, thereby reducing the degree to which mineral precipitates will form on the pump and borehole surface.
- Larger-diameter wells provide a greater annulus space for pump clearance, reducing the potential for pumps to become lodged in the well.

Four of the nine test wells installed during this investigation were deemed sufficiently favorable for use as production wells or backup production wells; these included: Wells A-1, B-1, B-3 and B-4. Each of these wells was reamed to 8-inches in diameter to a depth below the major water-bearing fractures (Table I, Appendix A). During the reaming process the first 57 feet of each of these wells was drilled to 12 inches in diameter to allow for 8-inch, permanent, heavy-wall steel casing to be installed according to Virginia Waterworks Regulations. A pressure-grout seal was installed for the entire 57 feet to ensure that no leakage could occur around the outside of the casing. A Fauquier County Health Department representative inspected each of the wells to ensure that the grouting process met Virginia Waterworks Regulations. The final air-lift capacities (blow test yields) of the four wells following reaming were 140, >300, >300 and 300 gpm, for wells A-1, B-1, B-3 and B-4, respectively. This represents a 60 percent average increase in productivity attributable to the reaming process, as determined from air-lift yields of the 6-inch test well(s). (These air lift yields do not, however, represent long-term sustainable yields which were determined through the evaluation of pumping tests.)

B. Re-Installation of Well MS-5 as an 8-inch Production Well

On April 26, 1994, a brief pumping test was conducted on Well MS-5 to ensure that its capacity had not decreased since its installation in December, 1990. Upon start-up, the well quickly dewatered and clearly could not support a 40 gpm pumping capacity, far less than its original air-lift yield of 214 gpm. Further investigation revealed that a foreign plug and other materials were present in the well. EGGI attempted to remove the plug and re-develop the well using an air rotary drilling rig, however, the original yield could not be recovered. The loss of capacity could not be attributable to natural causes under *non-pumping* conditions and it is suspected that vandalism of the well created the blockage and ultimate loss of its yield capacity.

On July 19 to 21, 1994, Well MS-5 Old was replaced with a new 8-inch production well, identified as well MS-5 New. This well was drilled 10 feet away from the existing well and was granted a permit from the Fauquier County Health Department. Drilling continued to a total depth of 500 feet with a final air-lift yield of 160 gpm (Table I).

C. Re-development of Well A-1 Following Vandalism

Well A-1 was also vandalized during the summer of 1994; it was found with debris of unknown origin floating on the water surface. In addition, a blockage was discovered at about 100 feet down below ground surface. In an effort to try and salvage the productivity of Well A-1, an air rotary rig was remobilized to the site on October 8, 1994, and used to re-develop the well. The drilling rig encountered an extensive blockage of what appears to be some type of cement, mixed with rock chunks and other debris. Following re-development of the well, the yield could only be recovered to 15 gpm. The major water-bearing fracture has been sealed off by vandals and the well is no longer useable and will have to be re-drilled at some future date.

IV. REVIEW OF PUMPING TEST PROGRAM -- WELLS B-3, B-4, AND MS-5

A. Purpose of Pumping Tests

A multiple phase pumping test was designed to evaluate the productivity of wells B-3, B-4, and MS-5. Pumping tests are conducted to estimate the actual withdrawal capacity and quality of a well or aquifer. Therefore, the objectives of the pumping test program conducted at the Bealeton study area included the following:

- To determine the long-term sustainable pumping capacity (yield) of each well.
- To assess the quality of groundwater under long-term pumping conditions.
- To evaluate the hydraulic characteristics of the water-bearing bedrock systems.
- To assess the nature of recharge to the bedrock aquifer (i.e., rate of recovery of the water levels in wells after pumping has ceased).
- To determine the potential impacts of pumping high capacity wells on local groundwater users.

B. Selection of Monitoring Well Locations -- Domestic Wells

An extensive domestic well monitoring program was established to observe the potential impact that pumping proposed production wells might have on existing local users of groundwater resources. The selection of domestic wells for monitoring was based on observations in the field, geologic site conditions and landowner permission. Fluctuations in water levels were recorded from a total of five domestic wells, four existing monitoring wells and the existing Meadowbrooke production well before, during and following the pumping test on Wells B-3 and B-4 (Plate 1, Figure 1B, and Table III). A slightly different groundwater monitoring program was used for the pumping test on Well MS-5, which occurred later and will be discussed separately in this report.

A Letter of Intent was sent to those landowners located proximal to the proposed wells to be tested requesting permission to install automated water level recorders in their domestic wells (Appendix C). In addition, efforts were made to contact homeowners by phone and personal visits were made to individual homes to inform local groundwater users of the monitoring program. Automated water level monitoring equipment was installed in each of the observation wells. (Data collected from all monitoring wells are presented in Appendices E and G.) All the monitoring wells were secured to prevent foreign substances from entering the wells during the pumping tests.

C. Pumping Test Design

Pumping test designs vary depending on the ultimate goals of the project. For the purposes of this groundwater supply development project, a three-phase design for the pumping test program was selected. This included step tests, constant rate tests, and recovery tests. The first phase included short term "step" drawdown tests on two of the three production wells (B-3 and B-4). Step tests requires that the wells be pumped at a number of incrementally higher pumping rates, each for a pre-determined amount of time. During each step, the pumping rate was held constant. Step tests are used to determine the efficiency of a pumping well at varying pumping rates and provide hydraulic information necessary to select a pumping rate for the long-term pumping test. Step tests also serve to check the discharge system, pumps, and power source to the pumps to ensure all is in working order for subsequent long-term pumping tests.

Short-term step tests were followed by long-term (3-4+ days) constant rate pumping tests. During long-term pumping tests, water levels in the pumping wells and the selected off site and on-site monitoring wells were recorded to the nearest .01 foot. During the pumping tests of B-3 and B-4, water level data was collected for approximately 7.5 days prior to pumping, during the pumping period, and 7.3 days after pumping was terminated. (For a total of nearly 19 days.) During the pumping of Well MS-5, water level data was collected from monitoring wells for a period of 6 days prior to pumping, during the pumping test, and for 12 days after the pumping test was terminated (i.e., 21 days). Water level data plotted against time of pumping provides information on the response of the bedrock aquifer to the withdrawal of groundwater from individual production wells.

It was initially intended that all three wells (B-3, B-4, and MS-5) be pumped at the same time. However, due to vandalism of Well MS-5 this was not possible. At the conclusion of pumping, recovery water levels were collected until near static (pre-pumping) water levels were reached (full recovery).

It should be noted that in Virginia, constant rate tests are required to continue for a minimum of 48 hours for public water supplies; however, for this project, pumping tests were continued for 72 hours for Well MS-5, 95 hours for Well B-4, and 98 hours for Well B-3. These pumping tests were extended so that the bedrock aquifer system could be fully stressed, thus allowing for a more accurate evaluation of the safe yield of the bedrock aquifer system.

D. Pumping Test Set-up

Wells B-3, B-4, and MS-5 were tested using submersible, electric pumps powered by portable, diesel generators. Flow was restricted on the discharge line using a gate valve to control the discharge rate (Figure 3). The flow rate was monitored using an in-line flowmeter which was calibrated with volumetric measurements at the discharge point to ensure accurate yield measurements. Discharging water was carried to nearby streams and not allowed to flow over the ground surface. A spigot was provided on each discharge line to allow for easy collection of water samples. Finally, a 1-inch diameter access tube was attached to the drop pipe to allow access to the well for water level probes during the test (Figure 3). Following the installation of all pumping equipment, chlorine tablets were added to both wells to disinfect the wells prior to starting the pumping test. All water levels were recorded to within one hundredth of a foot using both manual and automated equipment.

On-site climatic data were collected using a standard, 4-inch raingauge and a barometer attached to automated dataloggers.

V. STEP DRAWDOWN TESTS ON PUMPING WELLS B-3 AND B-4

Simultaneous, step drawdown tests were conducted on Wells B-3 and B-4 on April 25, 1994. At the conclusion of the step tests, the pumps in both wells were shut off together. Pumping both wells at the same time was accomplished to assess the potential interference effects between the wells but none was observed. Raw water level data collected during the step tests are presented in Appendix D.

A. Step Drawdown Response in Pumping Well B-3

The step drawdown test conducted on Well B-3 consisted of pumping the well at five discrete steps of incrementally increased pumping rates. Each step was 90 minutes in duration and progressed in the following manner: Step #1 -- 80 gpm, Step #2 -- 125 gpm, Step #3 -- 175 gpm, Step #4 -- 225 gpm, and Step #5 -- 310 gpm (Figure 4). The specific capacity (a measure of yield productivity determined as the pumping rate divided by the induced water level drawdown) of the pumping well started at 7.7 gpm/ft at 80 gpm (Step #1) and decreased to 5.6 gpm at 310 gpm (Step #5). A reduction in specific capacity at higher pumping rates is expected for any pumping well; as entrance velocities increase, the efficiency of a well decreases. Losses of efficiency in Well B-3 were relatively small and changed little during the final steps of the test. Such results, in addition to the availability of large amounts of drawdown and no increases in turbidity, suggest that pumping at the maximum rate of the step test is reasonable. (One small fracture at 80 feet will have to be dewatered during routine pumping, but the major water-bearing fracture is at a depth of 272 feet.) Therefore, it was determined that the long-term constant pumping rate for Well B-3 would be approximately 300 to 325 gpm.

B. Step Drawdown Response in Pumping Well B-4

A step drawdown test was also performed on Well B-4. Five incremental pumping rate steps of 85 gpm, 126 gpm, 175 gpm, 225 gpm, and 296 gpm were carried-out over a 90 minute period each (Figure 5). Specific capacities for Well B-4 were lower than B-3 as the elevation of water-bearing fractures put more strict limitations on the availability of drawdown in Well B-4. Specific capacities ranged from a high of 4.6 (85 gpm) to a final value of 1.7 gpm/ft (295 gpm). A water-bearing fracture located at 93 feet below ground level restricts the available drawdown to this level. During step test #4 (225 gpm), the water level in the well held steady just above the 93 foot fracture; however, when increasing the pumping rate to 295 gpm (Step #5), a dramatic increase in drawdown occurred and the fracture zone at 93 feet was dewatered (Figure 5). This response suggests that water levels in Well B-4 should be maintained above 93 feet at all times to minimize drawdown, loss of well efficiency, and to prevent cascading of large volumes of water into the well which may result in the degradation of water quality. Based upon the results of the step test, the pumping rate chosen for the long term pumping test was 170 to 190 gpm.

VI. LONG-TERM CONSTANT RATE PUMPING TESTS ON WELLS B-3 AND B-4: DRAWDOWN RESPONSES

A. Test Format

Wells B-3 and B-4 were pumped simultaneously for a period of 98 and 95 hours, respectively. A total of ten observation wells were used for monitoring during the pumping test program (five domestic wells and five selected observation wells -- Table III). Pertinent pumping test data collected during the pumping tests are presented in Table IV. Raw data of pumping and recovery water levels collected for all monitoring wells are presented in Appendix E. In-field and laboratory samples were collected periodically throughout the pumping tests and the results are presented in Table V and Appendix B.

B. Well B-3: Response to Pumping

1. Pumping Phase -- Well B-3

Well B-3 was pumped at an average rate of 320 gpm for 98 hours, starting on April 28, 1994. The total volume of water withdrawn from this well during the test was 1,881,600 gallons. One minor shutdown was necessary at 570 minutes into the pumping test where pumping was discontinued for seven minutes to switch generators. The static water level (pre-pumping level) of Well B-3 was measured at 9.15 feet below the top of the casing. Plots of water level versus pumping time for Well B-3 indicate that water levels declined gradually throughout the test to a maximum water level of 107.10 feet below casing (Figures 6 and 7). *This is equivalent to a total of only 97.95 feet of drawdown.* At the conclusion of the test, *only 41 percent* of the available drawdown had been utilized, leaving 165 feet of drawdown still remaining above the major water-bearing fracture at 272 feet. The specific capacity at the end of pumping was 3.27 gpm/ft (Table IV). The water level response related to the pumping of Well B-3 at 320 gpm is shown as a straight line on a semilogarithmic plot (i.e., water level versus time) suggesting that the cone of depression is expanding in a near-radial manner (Figure 7).

The transmissivity of the bedrock aquifer around B-3 was calculated using the Jacob approximation of the non-equilibrium well equation to be 5,150 gallons per day per foot (gpd/ft). Although the aquifer in question violates several of the underlying assumptions of the Jacob model, the transmissivity value calculated in such a manner can be useful when comparing the productivity of one well to another. This value is relatively high when compared to wells in similar geologic environments suggesting that the bedrock aquifer at this location is very transmissive to groundwater flow, a favorable condition for developing high yield wells.

2. Recovery Phase -- Well B-3

After pumping ceased, recovery water levels were recorded. The water level recovery rate in Pumping Well B-3 was somewhat subdued when compared to wells with recharge capacities exceeding the pumping rate (Figure 7). The recovery response on the semilogarithmic plot mimics the pumping curve with a very steady radial response. Eighty-seven percent of the drawdown recovery occurred in the first 23% of the total pumping time. However, at 5880 minutes after pumping was terminated (the time equal to the pumping time) the water level in Well B-3 had recovered to 14.24 (or only 95%) suggesting that some volume of water had been taken from storage in the aquifer. At 10,620 minutes into recovery, the aquifer was still 2.29 feet lower than when the pumping test began. Some of the decrease in aquifer water levels can be attributed to seasonal decreases in groundwater levels and barometric fluctuations as projected from plots of the pre-pumping groundwater level data (Figures 6, 7, and 8). Since full recovery was not observed following the pumping test, pumping this well at 320 gpm, 24 hours per day, 365 days per year, should not be considered as the desirable pumping management schedule.

C. Well B-4: Response to Pumping

1. Pumping Phase -- Well B-4

Well B-4 was pumped at an average rate of 180 gpm for 95 hours, starting on April 28, 1994. During this time, 1,026,000 gallons of water were removed from this well (Table IV). Pumping began three hours after the start of Well B-3 due to logistical considerations and the desire to see if any significant interferences was observable between Wells B-3 and B-4. Well B-4 did respond to pumping B-3, two hours after pumping began. During the hour immediately prior to starting the pumping test of B-4, 0.23 feet of interference drawdown was recorded. Plots of water level data versus pumping time for Well B-4 indicate that water levels progressively decreased throughout the test to a maximum of 92.62 feet (Figures 9 and 10). Since the static (pre-pumping) water level was measured at 11.05 feet, the total drawdown observed in this well was only 81.57 feet. The specific capacity at the conclusion of pumping was 2.21 gpm/ft. Very close to 100 percent of the recommended available drawdown had been used at the end of the pumping test, assuming that water levels should not go below the fracture zone at 93 feet. Long term, continuous drawdown below 93 feet may result in degraded groundwater quality and decreased performance, so it is strongly discouraged.

The response of Well B-4 was a slightly downward curving line on a semilogarithmic plot of water level versus time suggesting that the cone of depression is expanding in a quasi-radial manner, but that recharge is insufficient to support the withdrawal of 180 gpm on a continued 24 hour per day basis, 365 days per year.

The transmissivity of the bedrock aquifer which Well B-4 penetrates was calculated using the Jacob approximation the non-equilibrium well equation to be 2,900 gpd/ft or about one-half of the transmissivity calculated for Well B-3.

2. Recovery Phase -- Well B-4

The water level recovery rate observed in Pumping Well B-4 was very similar in nature to that of Well B-3. Water levels recovered 54% within the first 30 minutes of recovery time. However, recovery water levels never reached original water table conditions within the time equivalent to the length of pumping. This indicates that some groundwater was removed from storage within the aquifer. At 10,680 minutes into recovery, the aquifer was still 2.23 feet lower than when the pumping test began. As observed during the tests for Well B-3, some of the decrease in aquifer water levels can be attributed to seasonal decreases in groundwater levels and barometric fluctuations.

D. Observed Water Level Fluctuations in Local Domestic Wells and Other Monitoring Wells as a Result of Pumping Wells B-3 and B-4

During the pumping tests of Wells B-3 and B-4, 10 observation wells were used to monitor the impacts that the simultaneous pumping of Wells B-3 and B-4 had on local groundwater conditions. Five of these wells were local domestic wells, one well was the existing FCWSA production well known as the Meadowbrooke Well, two were test wells drilled at the Meadowbrooke Subdivision (MS-3 and MS-5) and two others were high yield test wells installed by EGGI (Table III and Plates 1, 2, and 3).

In general, water levels in the monitored domestic wells and other observation wells showed a response to the simultaneous pumping of Wells B-3 and B-4 at a combined rate of 500 gpm (Plate 1). The only exceptions to this were the White and Weaver domestic wells located west of Wells B-3 and B-4 which showed no confirmable interference response to the two pumping wells. The lack of response in the White and Weaver wells may be a result of well construction. If both wells are shallow, they may be tapping upper level fractures which are poorly connected with deeper bedrock aquifer system.

The water levels in all other monitoring wells responded to the pumping of Wells B-3 and B-4 (Plate 1, Plate 3, and Appendix F). The Hodgson Well responded with the most drawdown of over 30 feet. The drawdown response in monitoring wells to the north, east and south of the pumping wells suggests that near radial flow is occurring around the pumping wells and that drawdowns can be projected with confidence in all directions. For example, Figure 11 shows the level of interference drawdown effects on the Cheatham domestic well. Plate 3 illustrates the maximum drawdown observed in all monitoring wells which is associated with the simultaneous pumping of Wells B-3 and B-4.

Although the domestic well monitoring program has shown that domestic wells did respond to pumping along Route 17 (from Route 28 north to its northern intersection with Old Marsh Road), it is unlikely that local homeowners will be negatively impacted since it is anticipated that all affected domestic wells exceed 100 feet in depth. The high yield of the bedrock aquifer and substantial saturated portion of the aquifer leave sufficient water for use for local homeowners. However, as a conservative precaution to prevent any potential disruptions of service to local domestic wells, EGGI recommends that the FCWSA consider the following:

1) Install a permanent automated groundwater monitoring device in the Hodgson domestic well. This was the domestic well that responded the most to the simultaneous pumping of Wells B-3 and B-4 at a combined rate of 500 gpm. Collection of water levels in this well over time will allow the FCWSA to closely monitor the anticipated maximum groundwater level fluctuations in the local area that would be associated with pumping the new production wells. This data can then be used to estimate water level fluctuations in other domestic wells. If excessive lowering of the water table appears to be threatening domestic well supplies, pumping management schemes of FCWSA wells can then be modified or domestic wells can be drilled to a deeper level.

or ....

2) Install one or two permanent observation wells at strategic locations between pumping wells and selected domestic wells so that continued groundwater monitoring of the local water table can be accomplished. Data collected from this monitoring could be used to investigate potential interference with local domestic water supplies, if necessary.

E. Existing Meadowbrooke Pumping Well - Response to Pumping Wells B-3 and B-4

The FCWSA currently utilizes the Meadowbrooke Production Well as one of its key water supply wells in Bealeton (Plate 1). The Meadowbrooke Well lies 2850 feet west from Well B-3 and 3050 feet southwest from Well B-4. During the pumping test, an automated water level data logger recorded daily use at the Meadowbrooke Well (Figure 12). The simultaneous pumping of Wells B-3 and B-4 did incur 20 feet of additional drawdown in the Meadowbrooke Well (Plates 1 and 3). Permanent drawdowns on this order of magnitude will not adversely impact the productivity of the Meadowbrooke Well, as long as pumping water levels in the Meadowbrooke Well are maintained above the highest water bearing fracture zone.

VII. LONG-TERM CONSTANT RATE PUMPING TEST ON WELL MS-5: DRAWDOWN RESPONSES

A. Well MS-5: Response to Pumping

1. Pumping Phase -- Well MS-5

Well MS-5 was pumped continuously at 135 gpm for 72 continuous hours beginning on October 17, 1994. During this time, 583,200 gallons of water were removed from this well (Table IV). Plots of water level drawdown versus pumping time illustrate a gradual flattening of the drawdown curve indicating that available recharge nearly equals the groundwater withdrawal rates from the pumping well (Figures 13 and 14). The gradual trend toward flattening observed on the semi-logarithmic plot is typical of a "leaky recharge boundary" where the expanding cone of depression is slowly intercepting more and more leakage (from above or from other contributing bedrock fracture systems). Eventually the cone of depression will expand to a point where leakage to the lower bedrock fracture system equals withdrawals and the system will be in equilibrium. The availability of recharge to the site is very favorable, because it suggests that the aquifer can support withdrawals on the order of what was pumped during the test (i.e., 135 gpm) for extended periods of time.

The transmissivity calculated for Well MS-5 earlier was 1,700 gpd/ft (Table IV). This was the lowest transmissivity value calculated from the three pumping wells. The specific capacity value calculated at the completion of the pumping test was 0.75 gpm per foot of drawdown. The first significant water-bearing zone was intercepted at a depth of 400 feet in Well MS-5, so a substantial 185 feet of available drawdown remained at the conclusion of pumping. Withdrawing 135 gpm for 72 hours only utilized 45% of the available drawdown.

2. Recovery Phase -- Well MS-5

Nearly 90% of the drawdown incurred during the long-term MS-5 pumping test recovered within the first 100 minutes following termination of the pumping period (Figure 14). For the remainder of recovery, water levels increased steadily. A continuous recorder in Well MS-5 Old, located 10 feet from the pumping well, was used to monitor the end of recovery and showed that one week into recovery the aquifer was still approximately 2 feet lower than at the start of the test. Seasonal variations and barometric fluctuations can account for a portion of these differences observed in water levels between the end of recovery and the beginning of pumping (Figures 14 and 15).

B. Water Level Responses Observed in Domestic and Monitoring Wells When Pumping Well MS-5

The response to pumping Well MS-5 was widespread, but the overall impact was subdued compared to the simultaneous testing of Wells B-3 and B-4. The greatest impact of the cone of depression was measured in Wells B-3 and B-4, with smaller impacts in Well MS-3 and the existing Meadowbrooke Well (Figure 16, Plates 2 and 3, Appendix G and H). Water levels in the White and Weaver Wells, directly along strike of bedrock bedding and the closest wells to MS-5, did not respond during the pumping test. Well A-1, vandalized such that the lower fractures were plugged, also did not respond during the pumping test, lending some credence to the suggestion that the White and Weaver Wells may be shallow and not responding to deeper groundwater movement.

Overall, the response of all monitoring wells suggests that pumping Well MS-5 would create little impact on surrounding groundwater users and should be an integral part of the overall usage groundwater resources in this area.

C. Water Level Responses Observed in Meadowbrooke Well -- Pumping Well MS-5

The existing Meadowbrooke Pumping Well (existing FCWSA production well) goes through a daily cycle during which the water level fluctuates approximately 20 feet (Figure 16). During the pumping test, the well was pumped continuously for extended periods of time so that it did not go through a typical daily cycle. This change in the normal cycle may have covered up the impact of pumping MS-5 on the existing Meadowbrooke Well. However, we do know that if an impact occurred, interference drawdown between these two wells was on the order of a few feet or less. If an impact of several feet occurred, it would have no bearing on the performance or quality of water from the Meadowbrooke Well. Therefore, both wells MS-5 and Meadowbrooke can operate together in an integrated groundwater withdrawal management plan.

VIII. WATER QUALITY MONITORING PROGRAM

Water quality samples were collected from Wells MS-5, B-3, and B-4 throughout the test using field testing equipment for indicator parameters, such as specific conductivity, sulfate, iron, manganese, and pH. Shortly before the conclusion of the pumping tests, a complete set of water samples were collected and submitted to the Virginia State Laboratory for analysis (Appendix B). In addition, duplicate samples were collected and submitted to National Testing Laboratories, Inc. at the conclusion of each pumping test. These laboratory samples were analyzed for all drinking water parameters as set forth by the EPA Safe Drinking Water Act. A summary of pertinent water chemistry parameters for all three tested wells (MS-5, B-3, and B-4) is presented in Table V.

A. Field Chemistry Tests of All Three Pumping Wells (MS-5, B-3, and B-4)

Field analyses of hardness, sulfate, conductivity, temperature and pH were collected eleven times during the B-3 pumping test. The results of the continuous water quality testing showed no *significant* variations in water chemistry parameters throughout the pumping period. Hardness varied up and down within 40 milligrams per liter (mg/l or part per million), between 190 and 230 mg/l, which is considered hard water.

Ten field chemistry samples were collected during the B-4 pumping test. Water chemistry did not vary substantially during the test, although a minor decrease in sulfate was observed.

Five field chemistry samples were collected during the 72-hour test on MS-5. Water quality actually improved following the first day of the test with minor decreases in specific conductivity, pH and hardness. Water chemistry observed in this well remained constant throughout the last 50 hours of the test.

B. Results of Laboratory Analyses of Water Quality from Well B-3

1. Inorganic Analyses

No inorganic parameters in Well B-3 exceed the EPA Safe Drinking Water Act, Maximum Contaminant Levels (MCL) or Recommended Maximum Contaminant Levels (RMCL) for drinking water supplies. The water is hard (Virginia State Laboratory detected total hardness = 198 mg/l) and has relatively high value of total dissolved solids (TDS), and therefore local residents may want to choose installing a water softener system in their homes. National Testing Laboratories (a private Virginia-approved laboratory) measured a significantly lower hardness level of 150 mg/l in Well B-3. Sulfate is very low in this well and was measured at a level of 56.1 mg/l.

2. Metals

Nuisance metals such as iron and manganese, which can often exceed RMCL and cause staining and objectionable taste, were found at extremely low concentrations in Well B-3. Iron was detected at only 0.01 mg/l and manganese at levels of 0.02 mg/l, far below the RMCL of 0.3 mg/l and 0.05 mg/l, respectively. No other metals were found at elevated levels of concern.

3. Bacteriological Results

All of the nine bacteria samples collected from Well B-3 at the conclusion of the test were void of bacterial contamination, with MPN < 2 colonies per 100 milliliter for each sample. This confirms that there are no direct connections between the deep fractures providing water to the well and surface water bodies and that the grout seal installed during the production well drilling program is effective.

4. Volatile Organic Compounds and Pesticides

No regulated or unregulated volatile organic compounds (VOC) were detected in the State laboratory or private laboratory samples. Likewise, scans of various pesticides and herbicides also came up with no remnant compounds in the groundwater.

5. Radiological Results

Radiological results were very favorable, with gross alpha of 2.0 pCi/l (picoCuries per liter) and gross beta of 1.6 pCi/l. Both levels are well below any action levels for radiological parameters. Niton Corporation of Bedford, Massachusetts, was used to analyze radon in the groundwater of Well B-3. Radon levels measured in this well were at concentrations of 1,100 pCi/l. This radon level may require future treatment depending on an upcoming decision of the U.S. EPA regarding action levels for radon in drinking water.

C. Results of Laboratory Analyses of Water Quality from Well B-4

1. Inorganic Analyses

The groundwater withdrawn from B-4 was similar to that from B-3, although not as hard (total hardness = 179). Sulfate levels were slightly higher than observed in B-3, with a concentration of 82.2 mg/l, well beneath the EPA RMCL of 250 mg/l.

2. Metals

No primary drinking water standards for metals were exceeded in Well B-4 and levels of both iron and manganese are less than their respective RMCL. Iron was undetected and manganese was found at concentrations of 0.04 mg/l, slightly below the RMCL of 0.05 mg/l.

3. Bacteriological Results

Results from the testing of coliform bacteria in Well B-4 indicate that no coliform exists in the groundwater, confirming the proper construction of the production well and the lack of direct surface water influence.

4. Volatile Organic Compounds and Pesticides

No regulated or unregulated volatile organic compounds (VOC) were detected in the State laboratory or private laboratory samples. Likewise, scans of various pesticides and herbicides also resulted with no identified remnant compounds in the groundwater.

5. Radiological Results

Gross alpha was measured at 3.5 pCi/l in Well B-4, while gross beta was 1.6 pCi/l, equal to Well B-3. These concentrations present no concerns for public water supply wells and require no action be taken. Radon was slightly higher in B-4, with a concentration measured at 1,300 pCi/l.

D. Final Water Chemistry of Well MS-5

Upon completion of this report, only the bacteria and radiological portions of the Virginia State Laboratory results were available for Well MS-5. Apparently, other samples sent to the Virginia laboratory were not received in property order and were disposed of. Fortunately, a back-up water sample was taken to a private lab. All other discussion is thus based upon results from duplicate samples collected and submitted to National Testing Laboratories, a Virginia-approved laboratory in Cleveland, Ohio.

1. Inorganic Analyses

Well MS-5 represents the best water chemistry available from the three pumping wells. The final hardness was 115 mg/l and sulfate was very low, with a level of only 14 mg/l, very favorable for the Bealeton area. No other inorganic parameters of concern were detected.

2. Metals

Iron was found to be non-existent and manganese levels were 0.033 mg/l, below the RMCL of 0.05 mg/l. No other metals were found at levels of concern.

3. Bacteriological Results

All of the bacteria samples submitted to the Virginia State Laboratory for Well MS-5 were determined to be free of coliform bacteria, with MPN values of <2 for each.

4. Volatile Organic Compounds and Pesticides

No regulated or unregulated volatile organic compounds (VOC) were detected in the State laboratory or private laboratory samples. Likewise, scans of various pesticides and herbicides also came up with no remnant compounds in the groundwater.

5. Radiological Results

Gross alpha was measured at 1.0 pCi/l in Well MS-5, while gross beta was measured at 1.4 pCi/l. These concentrations present no concerns for public water supply wells and requires no action to be taken. A radon sample collected at the conclusion of the test contained 1,600 pCi/l of radon which may require future treatment pending the results of legislation governing the control of radon levels in drinking water.

IX. CONCLUSIONS / RECOMMENDATIONS FOR GROUNDWATER SUPPLY DEVELOPMENT IN BEALETON PRODUCTION WELLS B-3, B-4, AND MS-5

The results of this comprehensive groundwater exploration and development program conducted in Bealeton, Virginia, has led EGGI scientists to reach the following conclusions and to provide subsequent recommendations.

1) Water Quality Considerations

The water quality observed from the three production wells (MS-5, B-3, and B-4) are considered excellent. In all cases, the water meets Primary and Secondary Drinking Water Standards as set forth by EPA's Safe Drinking Water Act. Of particular importance for this local Bealeton area, sulfate (an inorganic parameter) was found in low concentrations for all wells as follows:

Well B-3	56.1 mg/l
Well B-4	82.0 mg/l
Well MS-5	14.0 mg/l

(See Table V and Appendix B for more information)

Although there are no current regulations set forth by EPA for levels of radon gas, it is likely that some future treatment will be required for Wells B-3, B-4, and MS-5. These wells had radon levels ranging from 1100-1600 pCi/l and it is expected that in the future EPA *may* require treatment for wells exceeding 1000 pCi/l. Should this be the case, simple aeration of the water should be adequate to reduce the radon levels to meet the proposed 1000 pCi/l levels.

2) Selection of Wells for Incorporation into Bealeton's Water System

Based upon the pumping test data collected and analyzed from the extended testing of Wells B-3, B-4, and MS-5, EGGI recommends that Wells B-3 and MS-5 be *immediately* incorporated into the Bealeton water distribution system. These two wells can be pumped simultaneously to supplement existing water supply demands and can be used on a daily basis. Well B-4 should also be incorporated into the water system but used only as a backup well.

3) Pumping Rates / Schedules

Although Well B-3 can be pumped at a sustainable rate of 300-320 gpm for extended periods of time (i.e., 3-5 days), it should not be pumped at this rate 24 hours per day, 365 days per year. For best operational usage, pumping this well for 13 hours "on" and 11 hours "off" of each day would be considered most desirable. This would allow sufficient recovery of water levels in the bedrock aquifer system and prevent water quality degradation.

Well MS-5 can be pumped between 135 gpm and 140 gpm on a sustainable basis. Based upon the hydrogeologic data collected during this pumping test program, this well can be pumped simultaneously with Well B-3, but should not be pumped simultaneously with Well B-4. Again, for daily operational usage, pumping this well for 13 hours "on" and 11 hours "off" would be preferred.

Well B-4, which is capable of producing 180 gpm for extended periods of time, should be maintained as a backup well or used during periods when Well MS-5 is not pumping. This well could be pumped simultaneously with Well B-3 but should not be pumped for extended periods while Well MS-5 is pumping.

Therefore, in summary, EGGI recommends the following:

Simultaneous Pumping of	Recommendation
Wells B-3 and MS-5	Best Practice
Wells B-3 and B-4	Recommended for short time intervals only
Wells B-4 and MS-5	Not Recommended

4) Continued Groundwater Monitoring of Local Wells

Although the domestic well monitoring program has shown that local wells responded to pumping along Route 17 (from Route 28 north to its northern intersection with Old Marsh Road), it is unlikely that local homeowners will be negatively impacted under the proposed pumping schedules outlined in **2)** and **3)** above. It is anticipated that all affected domestic wells exceed 100 feet in depth. The high yield of the bedrock aquifer and substantial saturated portion of the aquifer leaves sufficient water for use for local homeowners. However, as a conservative precaution, EGGI recommends that the FCWSA consider the following:

1) Install a permanent automated groundwater monitoring device in the Hodgson domestic well. This was the domestic well that responded the most to the simultaneous pumping of Wells B-3 and B-4 at a combined rate of 500 gpm. Collection of water levels in this well over time will allow the FCWSA to closely monitor the anticipated maximum groundwater level fluctuations in the local area that would be associated with pumping the new production wells. This data can then be used to estimate water level fluctuations in other domestic wells. If excessive lowering of the water table appears to be threatening domestic well supplies, pumping management schemes of FCWSA wells can then be modified or domestic wells can be drilled to a deeper level.

or ....

2) Install one or two permanent observation wells at strategic locations between pumping wells and selected domestic wells so that continued groundwater monitoring of the local water table can be accomplished. Data collected from this monitoring could be used to select appropriate mitigation measures, if necessary.

4) Pump Settings

Selected pumps should be installed at the following depths in each well:

Well B-3	260 feet below ground level
Well B-4	275 feet below ground level
Well MS-5	300 feet below ground level

These pump settings are selected on the basis of well performance and presence of fracture zones observed during the drilling of each well.

5) Development of Additional Groundwater Supplies in the Bealeton Area (Zones A, C, and D) Please provide prelim yield and quality results for these wells, in this section.

These are in the ... should ... included ...

This report documents the completion of the testing and analyses of groundwater supplies developed in Zone B (Figure 1B and Plate 1) as defined in the Bealeton study area. It should be recognized, however, that other test wells drilled in Zones A, C, and D yield substantial volumes of water and are available for future use. In fact, EGGI estimates that over 1 million gallons per day (mgd) could be collectively developed from these additional areas.

The majority of wells in these areas contain water of lower quality including elevated levels of sulfate, hardness, and total dissolved solids. Therefore, prior to full development of these water supplies, it will be necessary that the water be treated to meet EPA Recommended Drinking Water Standards.

6) The Use of Other Test Wells in Zone B

Well B-1 is a very high yielding well (i.e., 300 gpm), however, based upon the results of the pumping tests, EGGI does *not* recommend that it be included for future use unless used strictly as a backup well. The interference effects observed from the pumping tests preclude this well from providing additional new water to the water system. EGGI recommends that either this well be abandoned or that it is purchased for use as an emergency backup well, or used as an observation well. In addition, test Well B-3 should also be abandoned or used as an observation well (Figure 2).

7) Other

EGGI highly recommends that the permanent pumping system installed for Wells B-3, B-4, and MS-5 be equipped with the means to monitor water level fluctuations and production rates on a daily basis. This can be accomplished using automated data loggers. Long-term records of water levels and pumping rates within each pumping well are very valuable for properly maintaining the well over the lifetime of its use.

Monitoring of water quality for all drinking water standards should also be completed at a minimum of once every six months. However, certain parameters such as sulfate can be monitored easily using field testing kits and tests could be completed as often as once per month as a general indicator of the water quality of the bedrock aquifer.

This groundwater investigation and report were prepared for the use of the FCWSA, County of Fauquier, and pertinent regulatory review agencies. The findings and conclusions provided by EGGI in this report are based solely on the information contained and referenced within this document. The report has been prepared in accordance with professionally accepted hydrogeologic practices; no warranty, expressed or implied, is made herein.

TABLES

Table I

SUMMARY TABLE OF TEST WELL AND PRODUCTION WELL DRILLING DATA
for the Fauquier County Water and Sanitation Authority, Bealeton Service District
Bealeton, Virginia

WELL #	DATE DRILLED	TOTAL DEPTH (feet)	DEPTH TO BEDROCK (feet)	WELL DIAMETER (inches)	CASING LENGTH (feet)	AIR-LIFT YIELD (gpm)	WATER-BEARING ZONES (depth [ft] / yield [gpm])	WATER QUALITY - National Testing Laboratories, Inc.*					
								SO4 (mg/l)	HARDNESS (mg/l)	TDS (mg/l)	Iron (mg/l)	Manganese (mg/l)	Aluminum (mg/l)
A-1	11/17/93	440	12	6		85	70/30,189/85	40	100	224	0.21	0.27	0.49
REAMED		225	12	8	57	140							
A-3	10/18/93	340	6	6	20	275	55/12,336/275	1230	1170	1839	0.348	0.294	0.18
B-1	7/26/93	379	5	6		230	142/30,185/188,260/205,379/230	56	155	276	0.12	0.045	0.27
REAMED		379	5	8	57	>300							
B-2	7/28/93	400	5	6	105	170	192/31,290/68,312/79,352/81,385/170	488	460	872	0.32	0.14	ND
B-3	7/27/93	475	4	6		200	79/20,272/130,389/175,480/200	59	155	298	0.035	0.032	ND
REAMED		320	4	8	57	>300							
B-4	10/19/93	520	10	6		150	70/30,93/65,300/100,416/130,457/150	29	139	183	0.07	0.041	0.13
REAMED		470	10	8	57	308							
C-1	7/29/93	320	5	6	105	250	200/5,240/14,295/215,308/250	1401	1220	2240	0.35	0.23	ND
C-2	7/30/93	457	4	6	21	215	160/20,253/40,275/55,302/80,334/105,457/215	333	240	588	1.1	0.065	ND
D-2	10/18/93	440	16	6	20	130	230/75,343/90,413/130	438	746	1172	0.443	0.221	0.93
DRILLED FOR MEADOWBROOKE ESTATES													
MS-3	12/13/90	360	3	8	71	225	215/35,337/80,355/225	257	240	663	0.046	0.03	**
MS5-OLD	12/10/90	500	5	8	54	214	315/22,375/43,495/214	ND	65	158	0.045	0.011	**
MS5-NEW	7/21/94	500	5	8	56	160	400/100, 440/160	---	---	---	---	---	---

** Water samples collected at the conclusion of drilling or reaming.*
*** Not included in laboratory analytical procedures.*

TABLE IIA

Variation in Groundwater Chemistry with Depth During Drilling									
WELL ID	Water Zone Depth (feet)	Depth of Water Sample (feet)	Well Yield (gpm)	Sulfate (SO4) mg/l	Conductivity uS	Hardness mg/l	Iron (Fe) mg/l	Manganese (Mn) mg/l	pH
B-1	142	160	30	0	210	100*	0.04	0.08	8.3
	185	200	188	20	363	130*	0.08	0.06	8.4
		260	205	10	380	120*	0.04	0.06	8
		320	200+	10	390	110*	0.08	0.07	8
	361?	361	230	75	440	120*	0.1	0.05	7.6
B-1 Final		**379**	**230**	**100**	**450**	**240**	**0.09**	**0.05**	**7.3**
B-2	48-50	60	20	250	735	300	-	-	-
	78	80	35	300+	1110	600	0.55	0.21	7.9
	192	200	66	275	919	340	0.5	0.17	7.75
	215	220	77	260	805	350	0.4	0.12	7.7
	set 105' temp	220	58	270	725	350	0.68	0.1	7.7
	6" casing	220	60	230	630	260	-	-	-
	blew 15 min.	220	61	210	590	200	-	-	-
	blew 10 min.	220	60	220	575	280	-	-	-
	297, 312	320	79	220	610	260	0.65	0	7.95
	352-353	380	90	200	597	260	0.65	0.08	8.1
B-2 Final	**385, 391**	**400**	**170**	**300+**	**1101**	**440**	**0.67**	**0.2**	**8**
B-3	78-80	80	20	10	430	300	0.07	0.18	8.05
		180	36	30	410	260	0.18	0.14	7.85
	272	280	130	68	453	200	-	-	-
		340	130	70	479	220	-	-	7.9
	390	400	175	70	463	200	-	-	7.8
		440	175	65	468	190	0.01	0.02	7.75
		460	200	72	470	200	-	-	7.55
B-3 Final		**475**	**200**	**65**	**470**	**200**	**0.18**	**0**	**7.7**
B-4	70	80	30	60	345	200	-	-	-
	90	100	65	-	365	210	-	-	8.05
	170	180	85	75	369	180	-	-	7.95
	300	300	100	75	370	180	-	-	7.91
	380	380	120	-	338	-	-	-	7.96
	380	400	120	-	310	-	-	-	-
	416	420	130	60	297	180	-	-	8.02
	457	460	150	-	307	-	-	-	8.03
B-4 Final		**500**	**215**	**50**	**294**	**180**	**-**	**-**	**8.05**
MS-5	317	320	30	0	243	-	0.02	0.1	7.43
	380	380	43	0	233	-	0	0.04	8.11
	440	440	110	0	224	-	0	0.04	8.23
MS-5 Final	**500**	**500**	**140**	**0**	**227**	**-**	**0**	**0.055**	**8.32**

TABLE IIB

Variation in Groundwater Chemistry with Depth During Drilling									
WELL ID	Water Zone Depth (feet)	Depth of Water Sample (feet)	Well Yield (gpm)	Sulfate (SO4) mg/l	Conductivity uS	Hardness mg/l	Iron (Fe) mg/l	Manganese (Mn) mg/l	pH
A-1	72	80	30	0	540	280	0.1	-	8.04
	140	140	75	20	415	240	0.045	-	8.03
	189	200	85	10	389	-	-	-	7.90
A-1 Final		**360**	**85**	**10**	**394**	**180**	**-**	**-**	**8.00**
A-2	55	60	12	60	559	>260	0.2	0.04	8.08
	160	160	30	65	490	320	0.3	0.06	8.03
	320	320	55	200	717	340	0.32	0.15	7.87
A-2 Final	**336**	**340**	**275**	**300**	**1907**	**>1000**	**-**	**-**	**7.5**
C-1	55, 70-80	80	35	300	870	300	0.1	0.15	8
	95	100	50-60	270	850	280	-	-	-
	set 105' temp	240	14	400	1450	460	-	-	8.4
	6" casing	280	43	450+	2110	860	1.4	0.3	7.9
	281, 291	300	215	500-600	2570	1160	0.7	0.32	7.9
C-1 Final	**308**	**320**	**250**	**500-600**	**2680**	**1360**	**-**	**-**	**-**
C-2	160	160	20	-	340	-	-	-	-
	180	180	30	-	340	-	-	-	-
	212	220	33	10	350	-	-	-	-
	253	260	40	-	312	-	-	-	-
	275	280	55	-	305	-	-	-	-
	300	301	80	<50	297	-	-	-	-
	334	340	105	40	360	120	-	-	8
	383	400	120	-	437	-	-	-	-
		420	120	80	350	100	0.15	0.05	7.8
C-2 Final	**457**	**457**	**215**	**260-270**	**880**	**300**	**0.2**	**0.14**	**7.75**
D-2	120	120	15	<50	409	240	-	-	7.88
	230	240	75	400	1202	430	-	-	8.04
	360	360	90	400	1528	700	-	-	7.93
D-2 Final	**413**	**420**	**130**	**>400**	**2210**	**>700**	**-**	**-**	**7.89**
Hydrant Water at Miller School (7/31/93) (used about 4-7gpm during drilling of all test wells)				**280-300**	**1097**	**580**			

BEALQUAL.XLS

Table III

Domestic Wells and Monitoring Wells Used During the Pumping tests
Bealeton Service District
Bealeton, Virginia

Name	Owner	Lot #	Total Depth (feet)	Well Type	Location
Domestic Wells					
Cheatham	Mr. Russell Cheatham	6990.03 6126	no data	6" Drilled	South of Farmhouse, East of Tenants
Hodgson	Robert and Ruby Hodgson	6899.01 3742	120 ?	6" Drilled	West of House, Center of Yard
Carroll	Charles E. Carroll, Trustee	6899.09 4995	no data	6" Drilled	Inside Tool Shed, Near Barn
White	Richard and Eyvonne White	6889.02 8201	no data	6" Drilled	Along Driveway, West of House
Weaver	Mr. Ellsworth Weaver	6889.02 5299	100	6" Drilled	In Well House, Between Three Homes
Monitoring Wells					
B-1	Mr. Russell Cheatham	6899.01 6126	379	8" Drilled	500' North of Pumping Well B-3
B-2	Mr. Russell Cheatham	6980.04 6126	400	6" Drilled	1100' North of Pumping Well B-4
MS-3	Meadowbrooke Subdivision	6899.09 0789	360	8" Drilled	500' North of Rte 28, South of Blake Lane
Meadowbrooke	Fauquier County WSA	6889.12 2915	405	6" Drilled	Inside Well House, West of Blake Lane
MS-5 (Old)	Fauquier County WSA	6889.02 2751	500	8" Drilled	10' Southwest of Pumping Well MS-5

Reference Plates 1, 2, 3 and Figures 1 and 2.

Table IV

Long-Term Pumping Test Information
Fauquier County Water and Sanitation Authority, Bealeton Service District
Bealeton, Virginia

Pumping Well	Static Water Level (feet below top of casing)	Pumping Rate (gpm)	Maximum Drawdown (feet) (% available)	Specific Capacity (gpm/ft)	Transmissivity (gpd/ft)	Start Date and Time	Shutdown Date and Time	Pumping Test Duration (hours)	Total Volume Pumped (gallons)
Well B-3	9.15	320	97.95 (41 %)	3.27	5,150	4/28/94 8:00	5/2/94 10:00	98	1,881,600
Well B-4	11.05	180	81.75 (100 %)	2.21	2,900	4/28/94 11:00	5/2/94 10:00	95	1,026,000
Well MS-5	33.85	135	180.75 (45 %)	0.75	1,700	10/17/94 12:00	10/20/94 12:00	72	583,200

Table V

Summary of Water Quality Results for Pumping Wells B-3, B-4 and MS-5
Fauquier County Water and Sanitation Authority, Bealeton Service District
Bealeton, Virginia

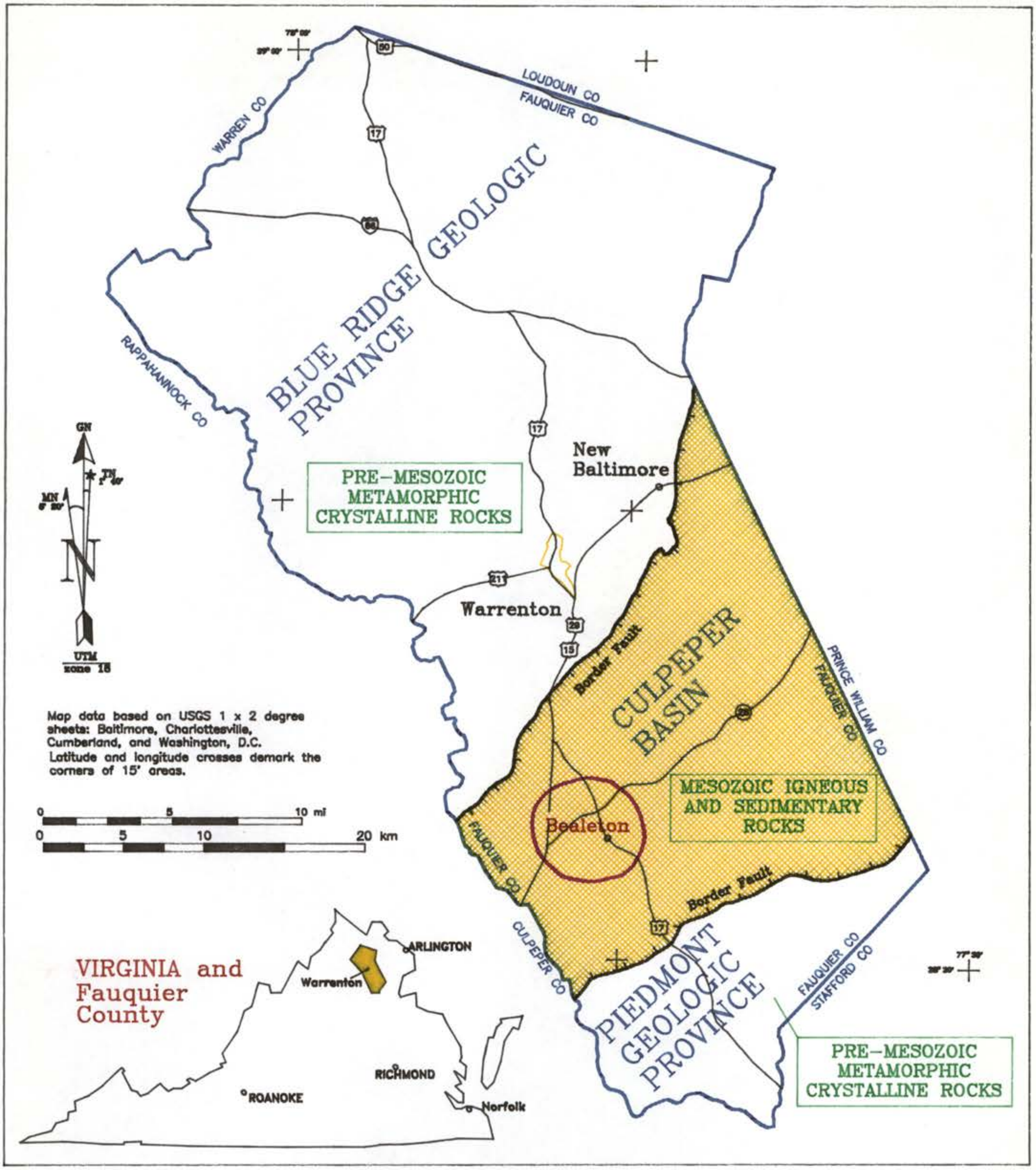
	Bacteria	*Inorganics*						*Metals*			*Organic Compounds*		*Radiologicals*		
Pumping Well	**Bacteria** (Yes or No)	**pH**	**Turbidity** (ntu)	**Hardness** (mg/l)	**Total Dissolved Solids** (mg/l)	**Sulfate** (mg/l)	**Nitrate** (mg/l)	**Dissolved Iron** (mg/l)	**Dissolved Manganese** (mg/l)	**Sodium** (mg/l)	**Volatile Organic Compounds** (Yes or No)	**Pesticides** (Yes or No)	**Gross Alpha** (pCi/l)	**Gross Beta** (pCi/l)	**Radon** (pCi/l)
Well B-3	No	8.38	0.57	198	307	56.1	0.42	0.01	0.02	37	No	No	2	1.6	1100
Well B-4	No	8.27	0.48	179	273	82.2	0.42	<0.01	0.04	16	No	No	3.5	1.6	1300
Well MS-5	No	7.5	ND	115	173	14	ND	ND	0.033	18	No	No	1.0	1.4	1600

Values provided are from the Virginia State Laboratory when available: Well MS-5 results are from duplicate samples sent to National Testing Laboratories, Inc.

ND = None Detected in the Sample.

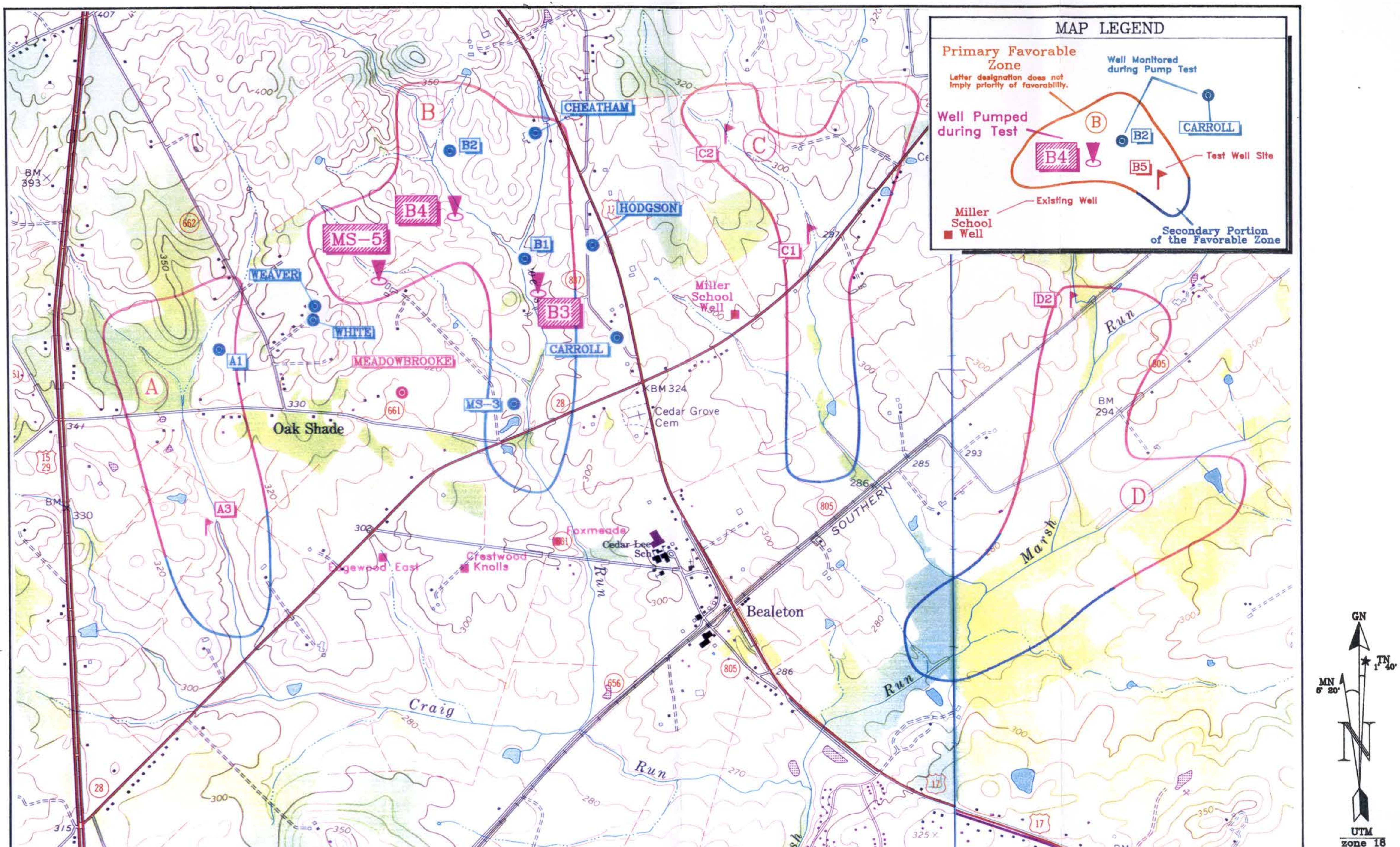
FIGURES

FIGURE 1a. REGIONAL GEOLOGIC SETTING OF FAUQUIER COUNTY, VIRGINIA



Approximate Limits of the Bealeton Service District Study Area.

FIGURE 1b. Favorable Zone and Test Well Locations, Bealeton Service District, Bealeton, Virginia.



Scale is 1" = 1500' (1:18000)

Emery & Garrett Groundwater, Inc.

FIGURE 2. Aerial Photograph of the Bealeton Study Area

Scale is 1" = 1208' (1:14500)

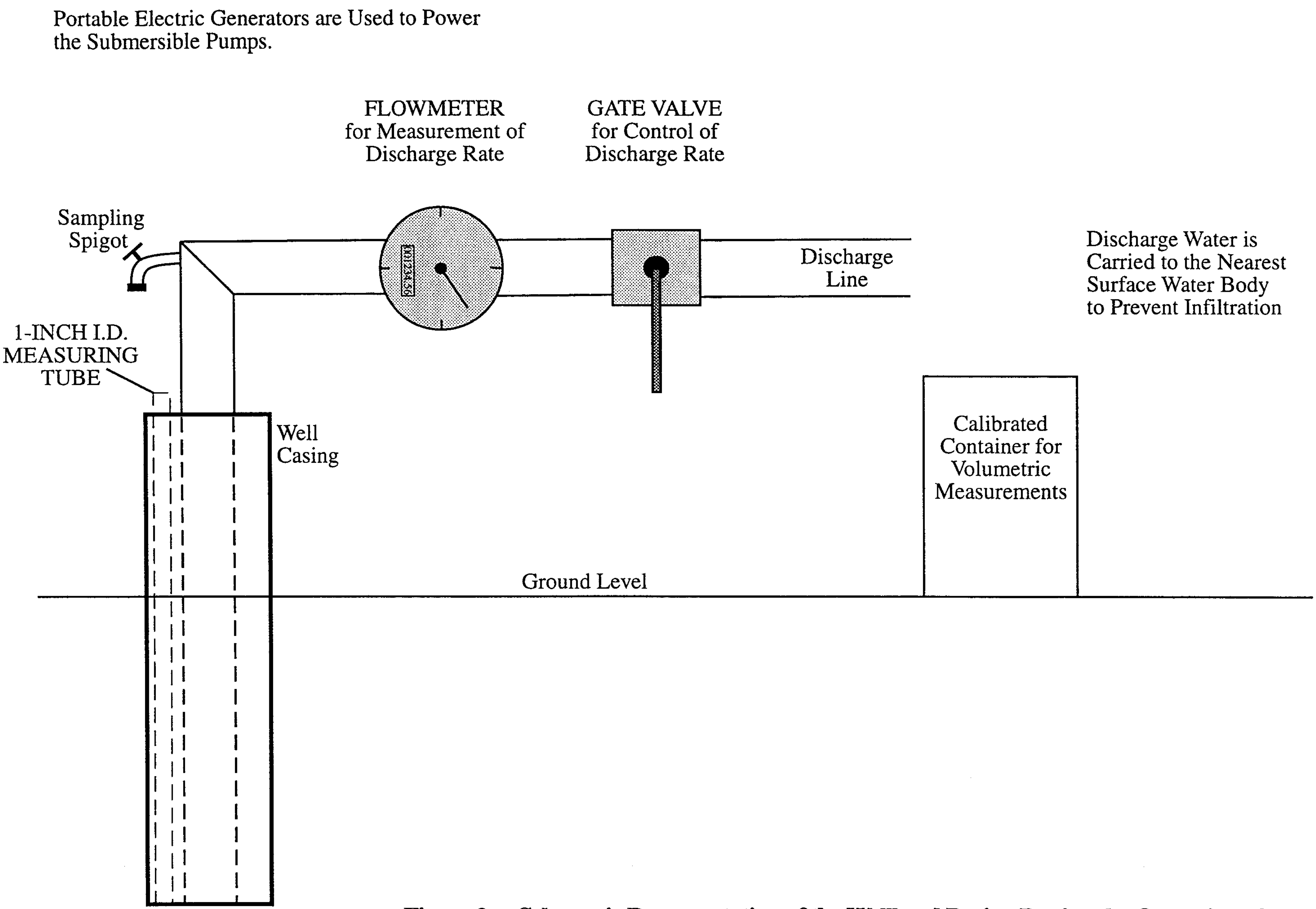


Figure 3 -- Schematic Representation of the Wellhead Design During the Operation of Pumping Tests in Bealeton, Virginia.

Pumping Well B-3 Step Drawdown Test

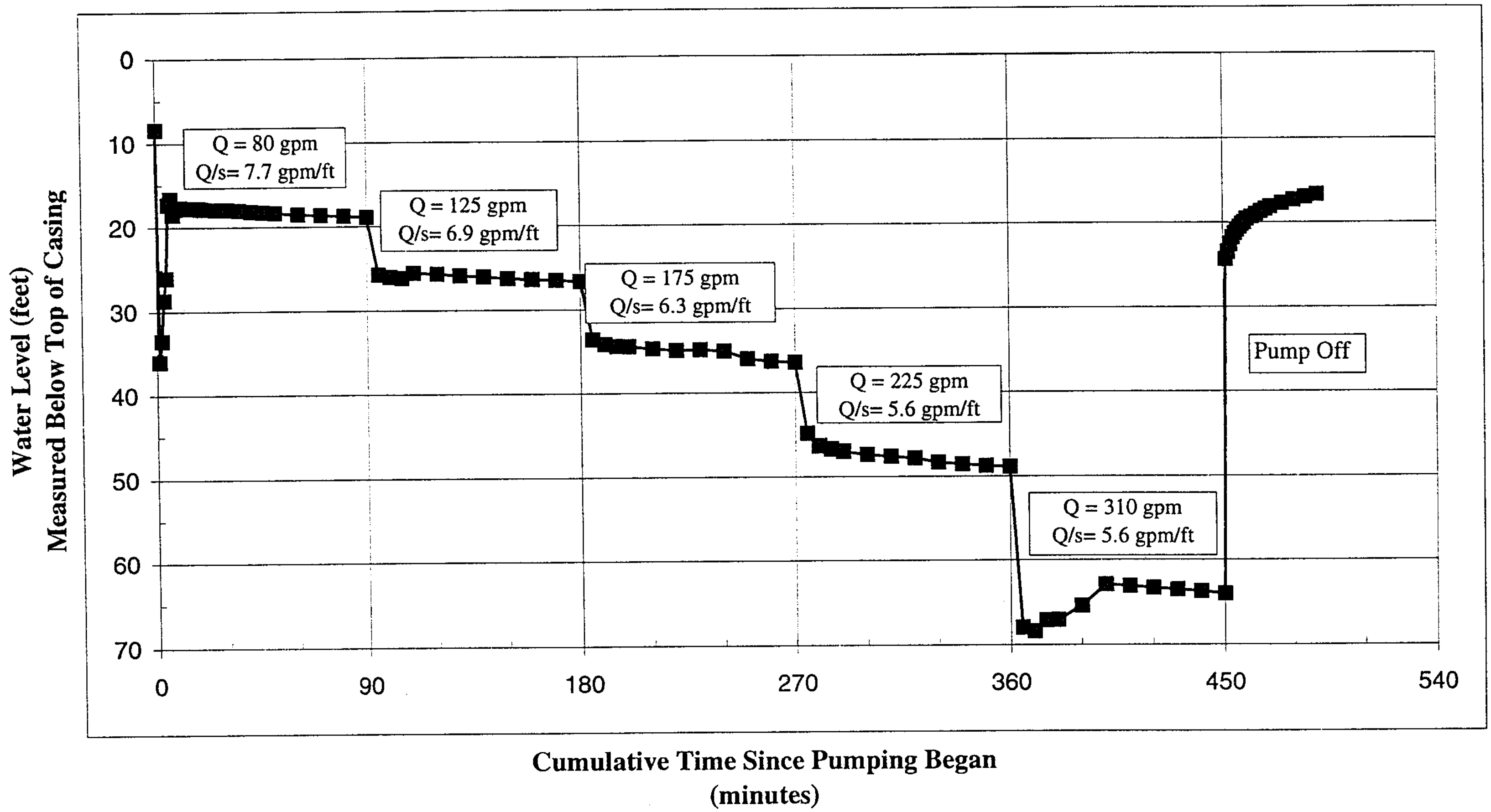


Figure 4. Step Drawdown Test Results for Pumping Well B-3, April 25, 1994, Bealeton, Virginia

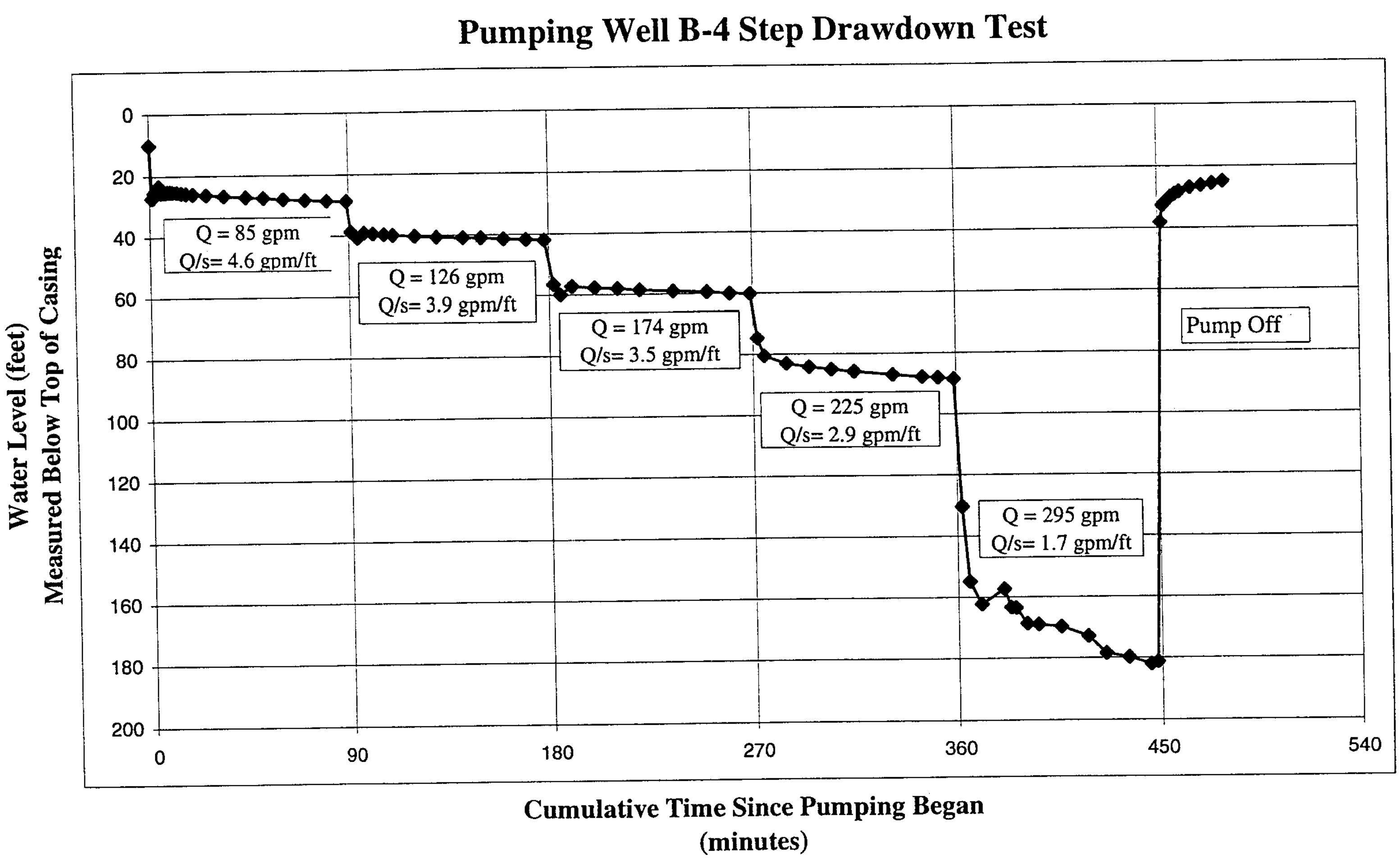


Figure 5. Step Drawdown Test Results for Pumping Well B-4, April 25, 1994, Bealeton, Virginia

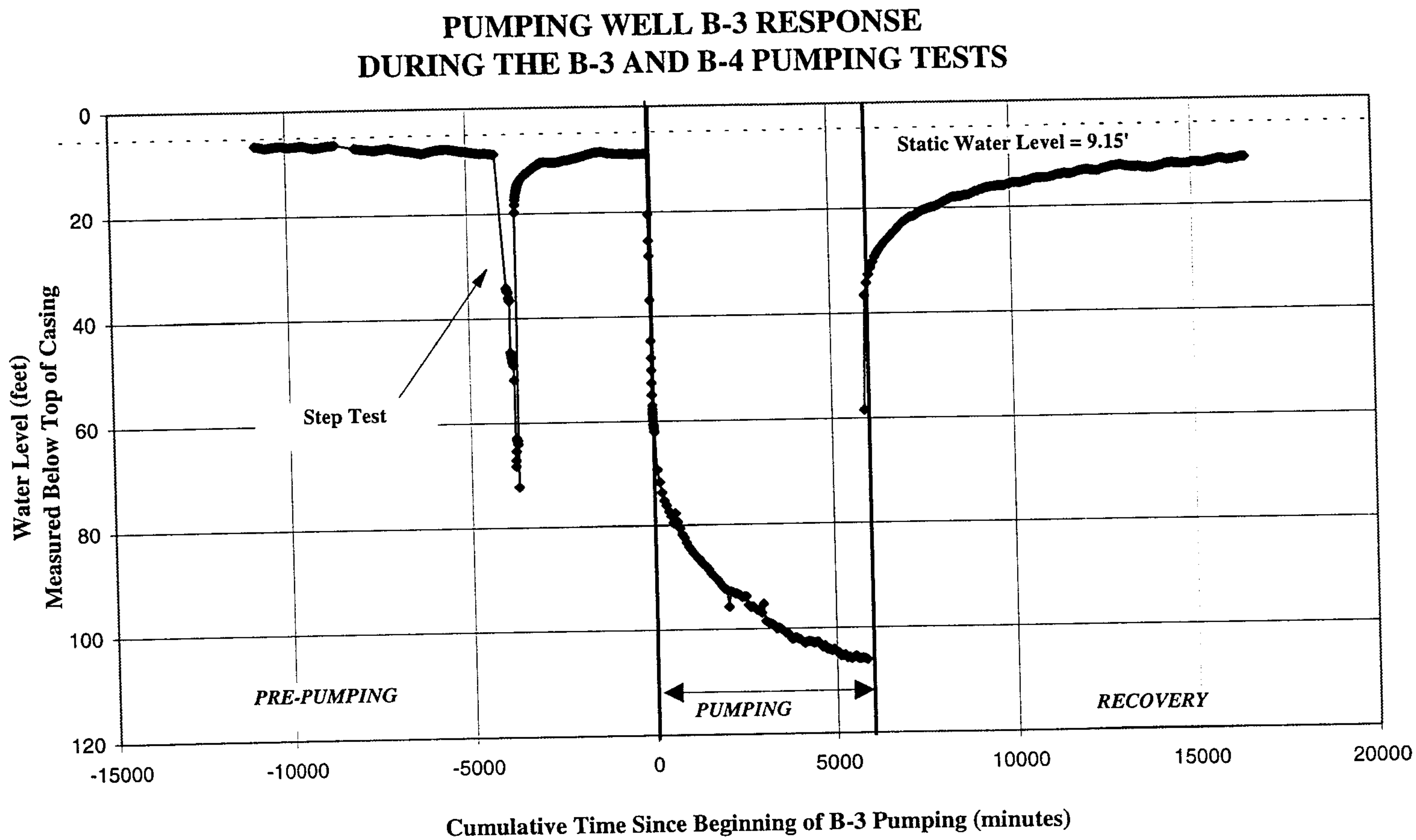
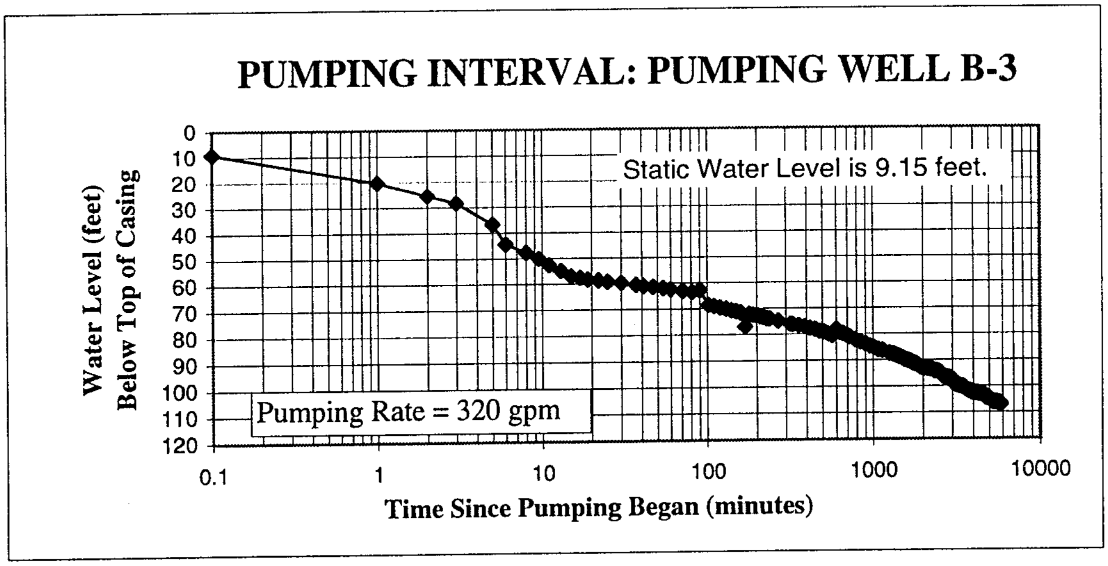


Figure 6. Arithmetic Time versus Water Level Plot of Pumping Well B-3 Throughout the Monitoring Period, April 20 to May 9, 1994, Bealeton, Virginia.



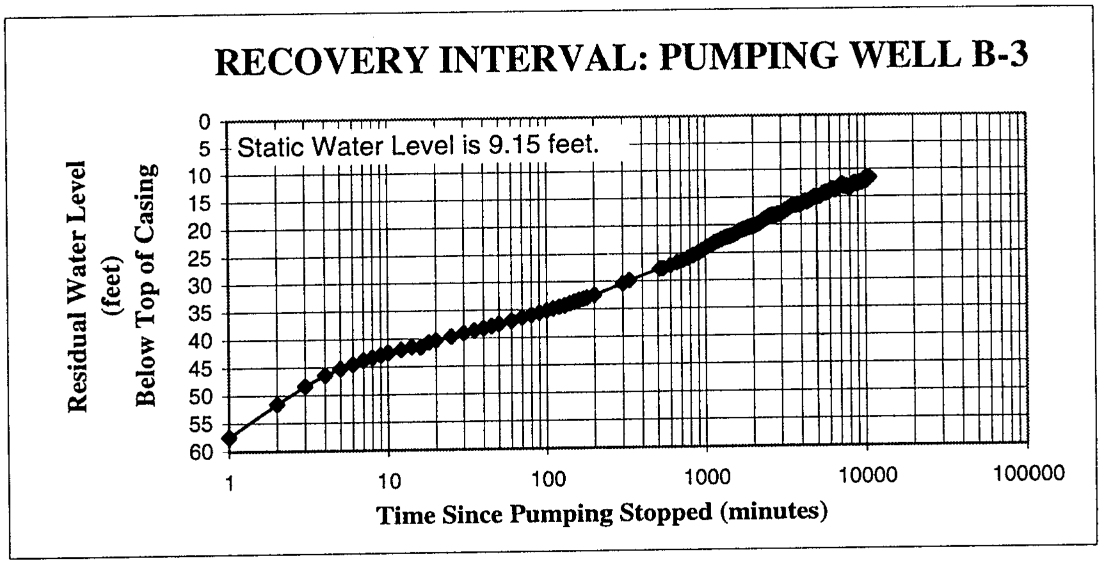


Figure 7. Semi-logarithmic Time versus Water Level Plot of Pumping Well B-3 During Pumping and Recovery, April 28 to May 9, 1994, Bealeton, Virginia.

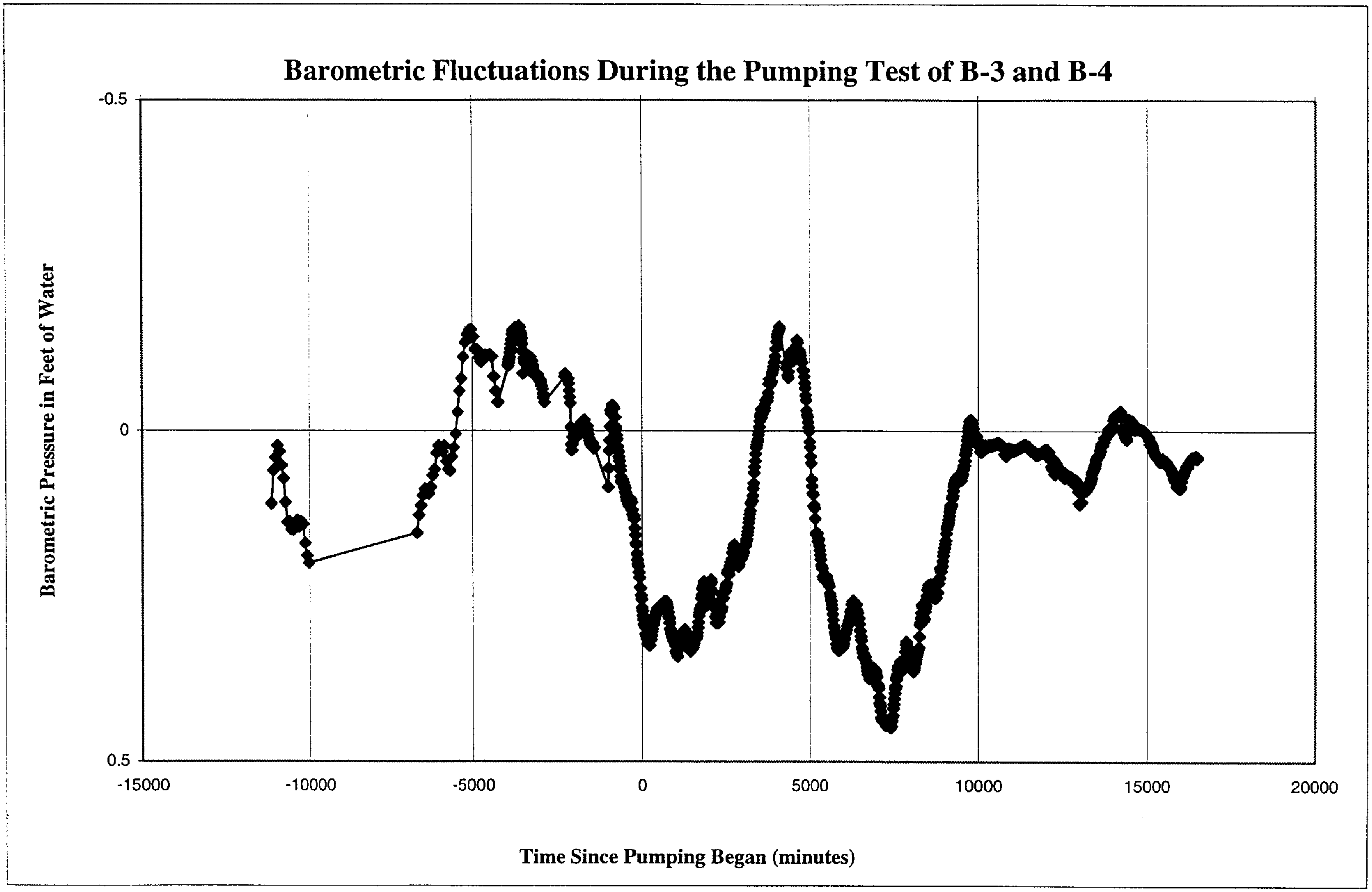


Figure 8. Arithmetic Time versus Barometric Pressure Plot Throughout the Monitoring Period, April 20 to May 9, 1994, Bealeton, Virginia.

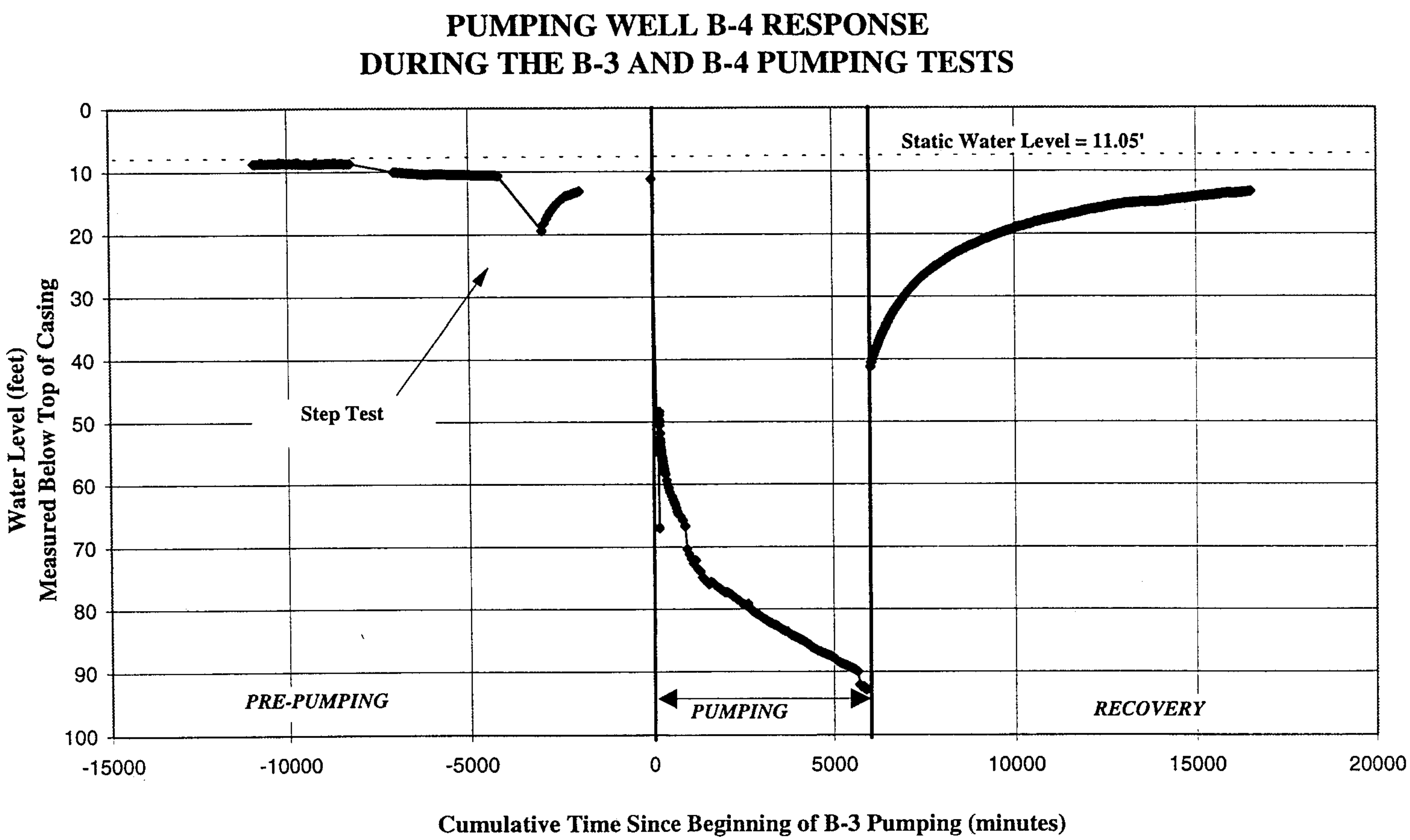
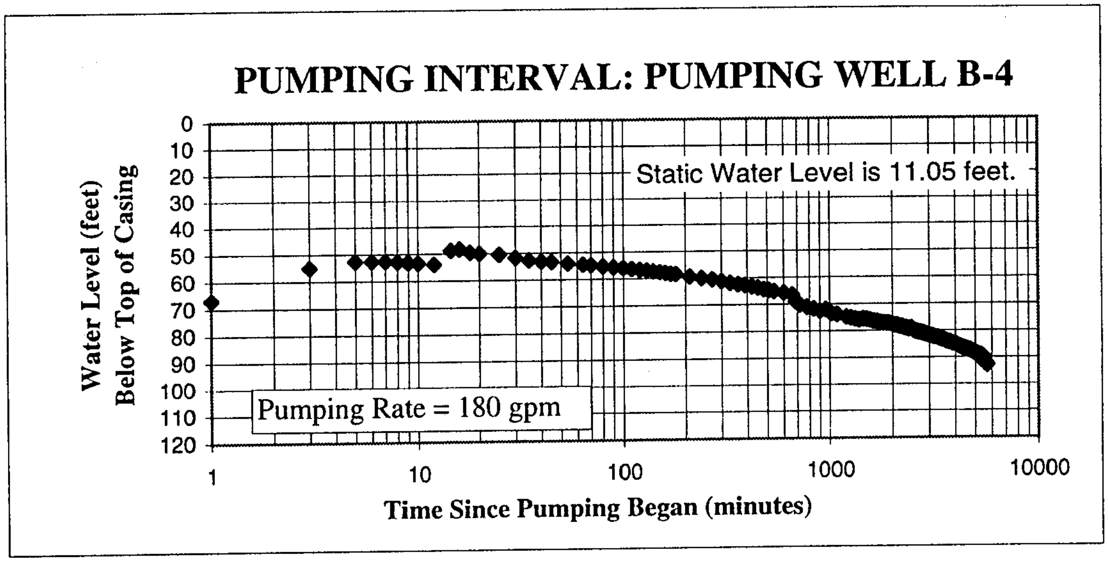


Figure 9. Arithmetic Time versus Water Level Plot of Pumping Well B-4 Throughout the Monitoring Period, April 20 to May 9, 1994, Bealeton, Virginia.



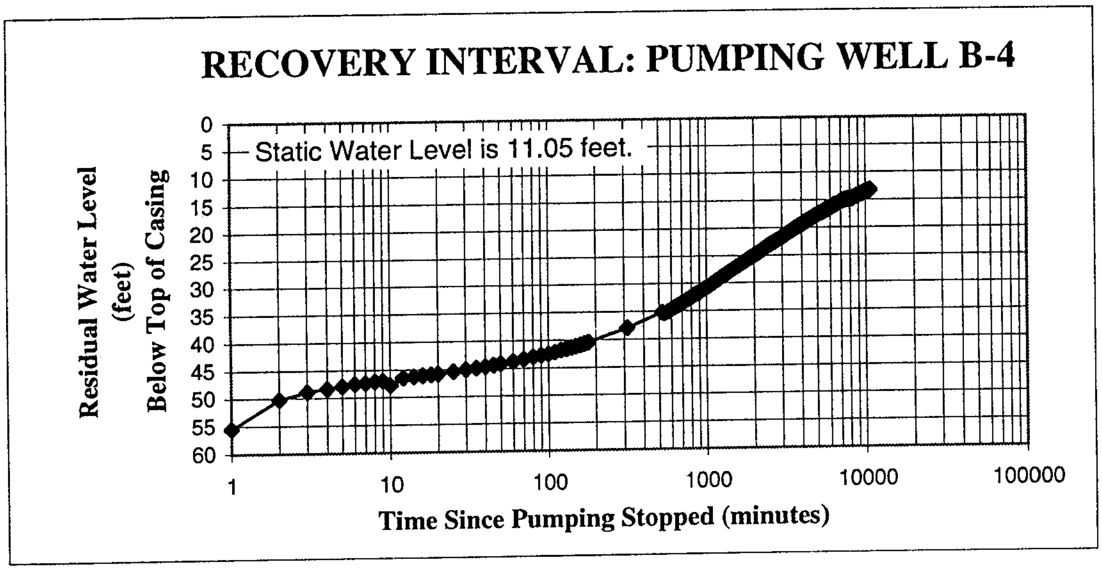


Figure 10. Semi-logarithmic Time versus Water Level Plot of Pumping Well B-4 During Pumping and Recovery, April 28 to May 9, 1994, Bealeton, Virginia.

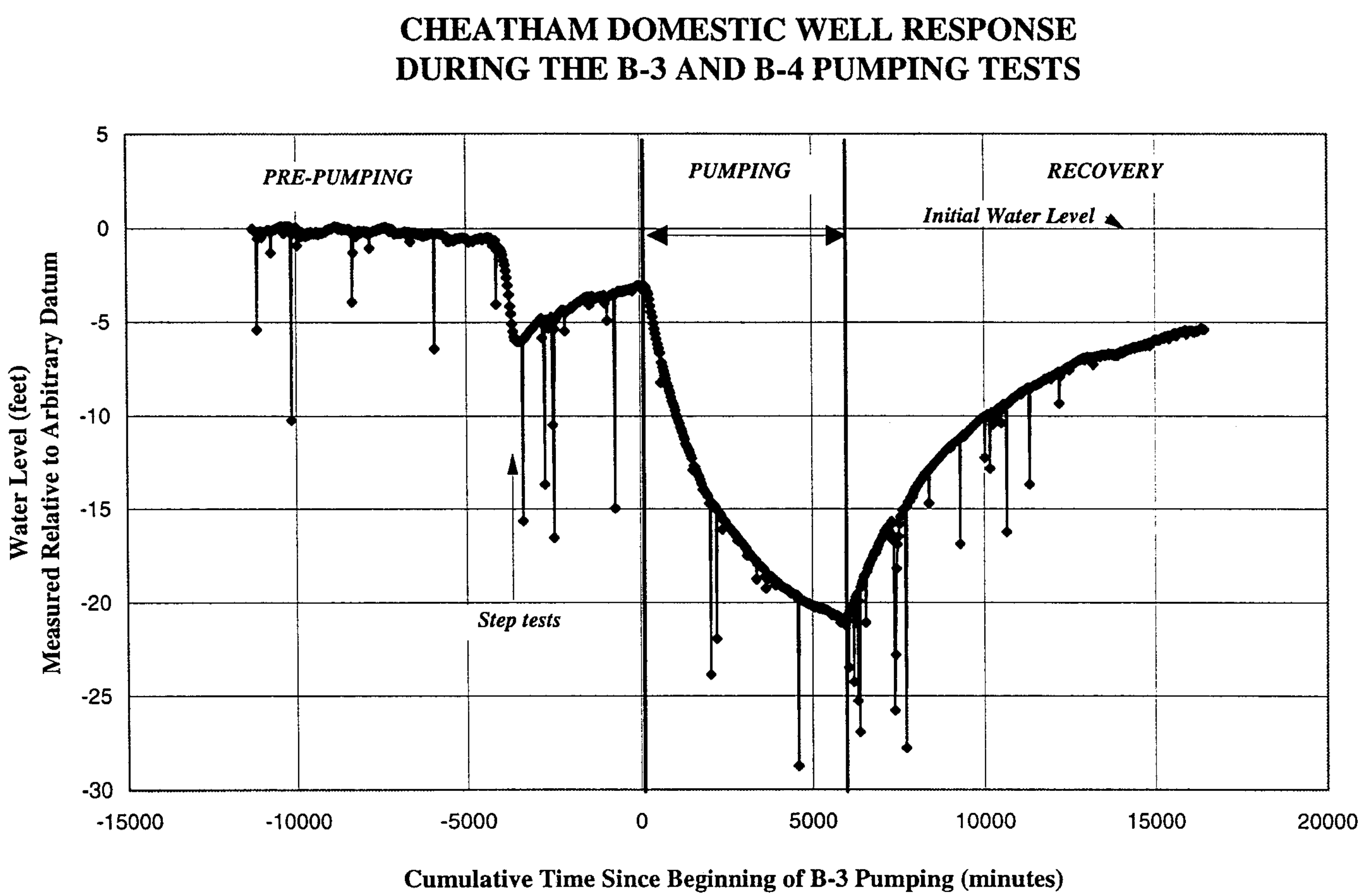


Figure 11. Arithmetic Plot of Time versus Water Level of Cheatham Domestic Well Throughout the Monitoring Period April 20 to May 9, 1994, Bealeton, Virginia

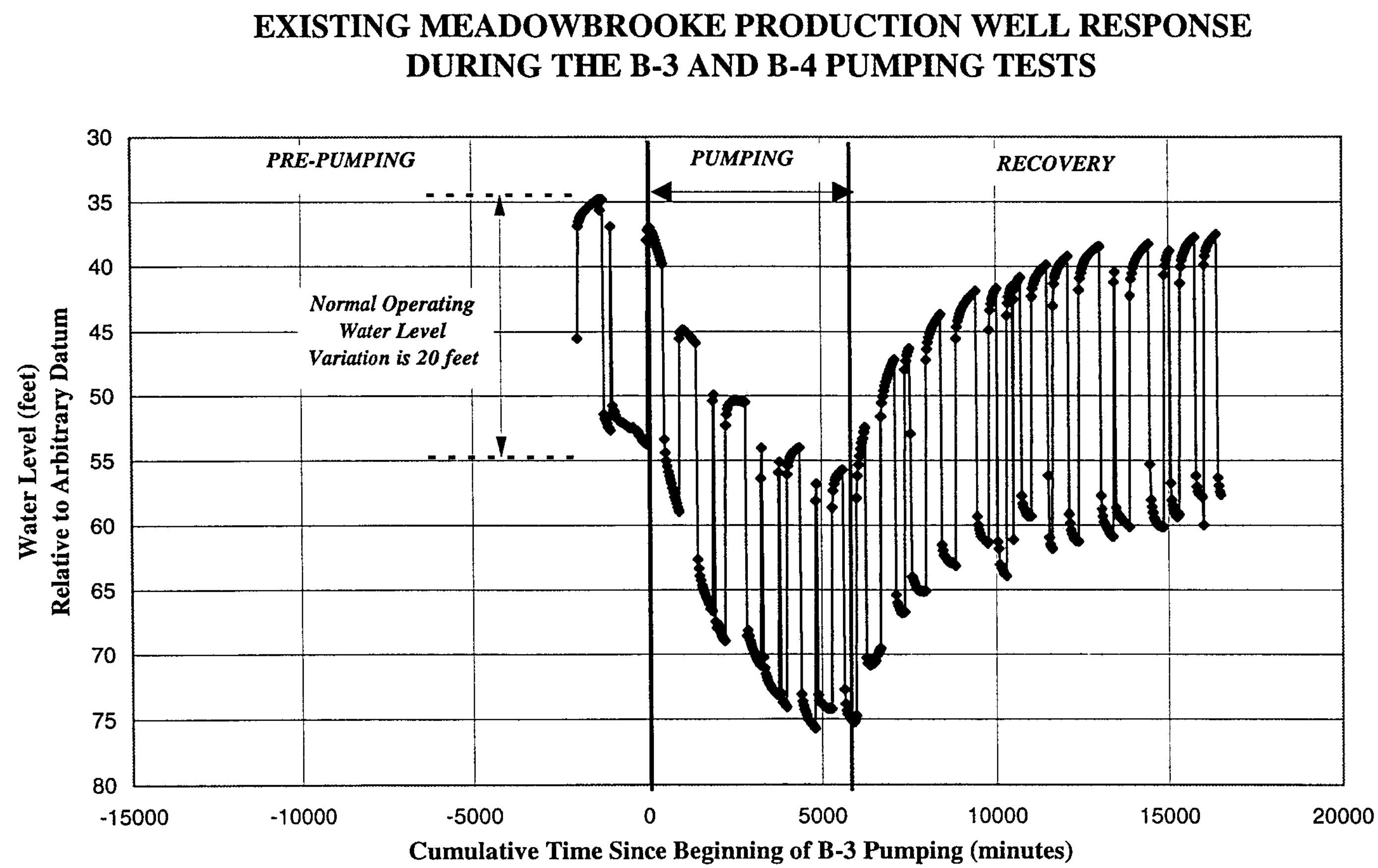


Figure 12. Arithmetic Plot of Time versus Water Level of Existing Meadowbrooke Subdivision Production Well Throughout the Monitoring Period April 20 to May 9, 1994, Bealeton, Virginia

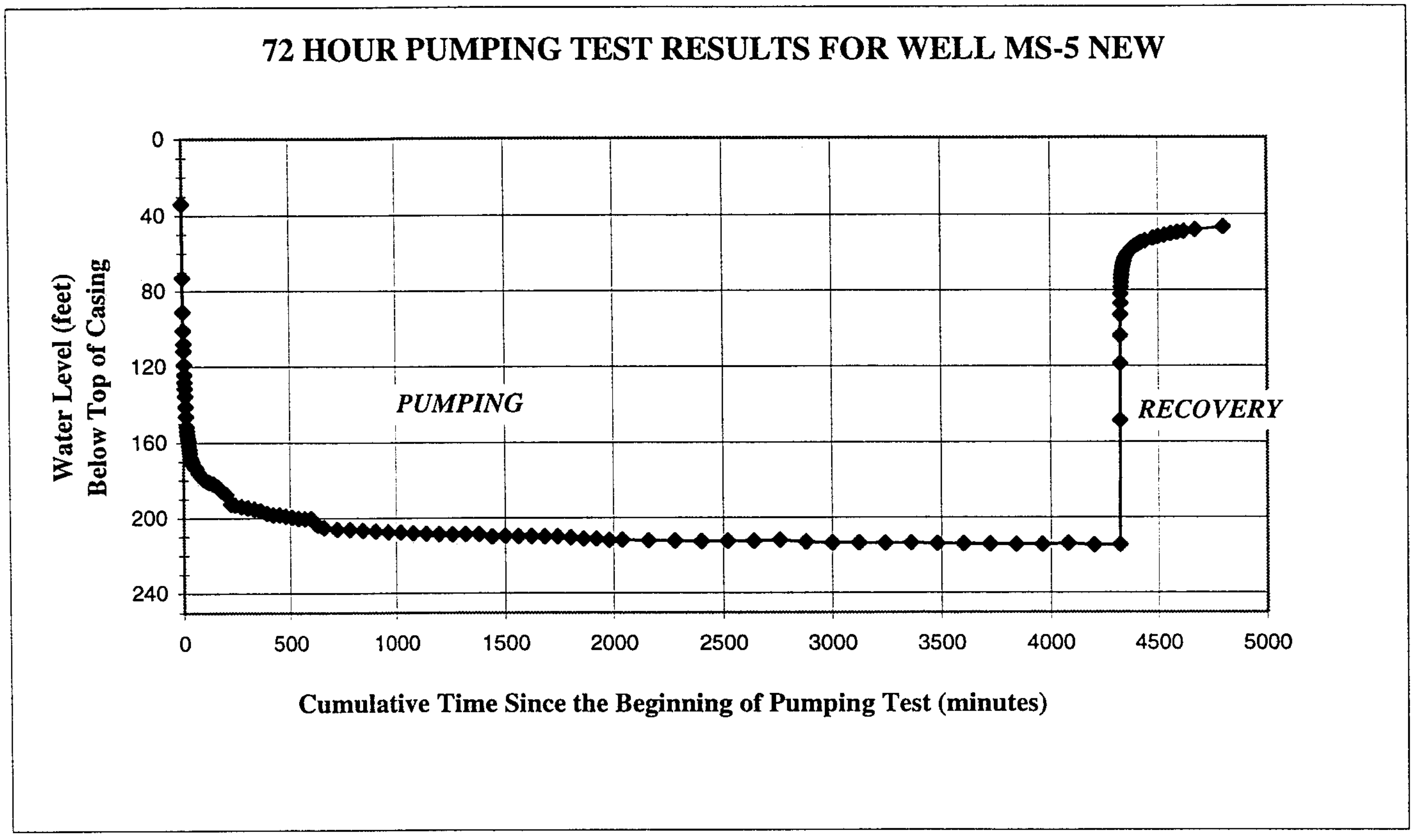
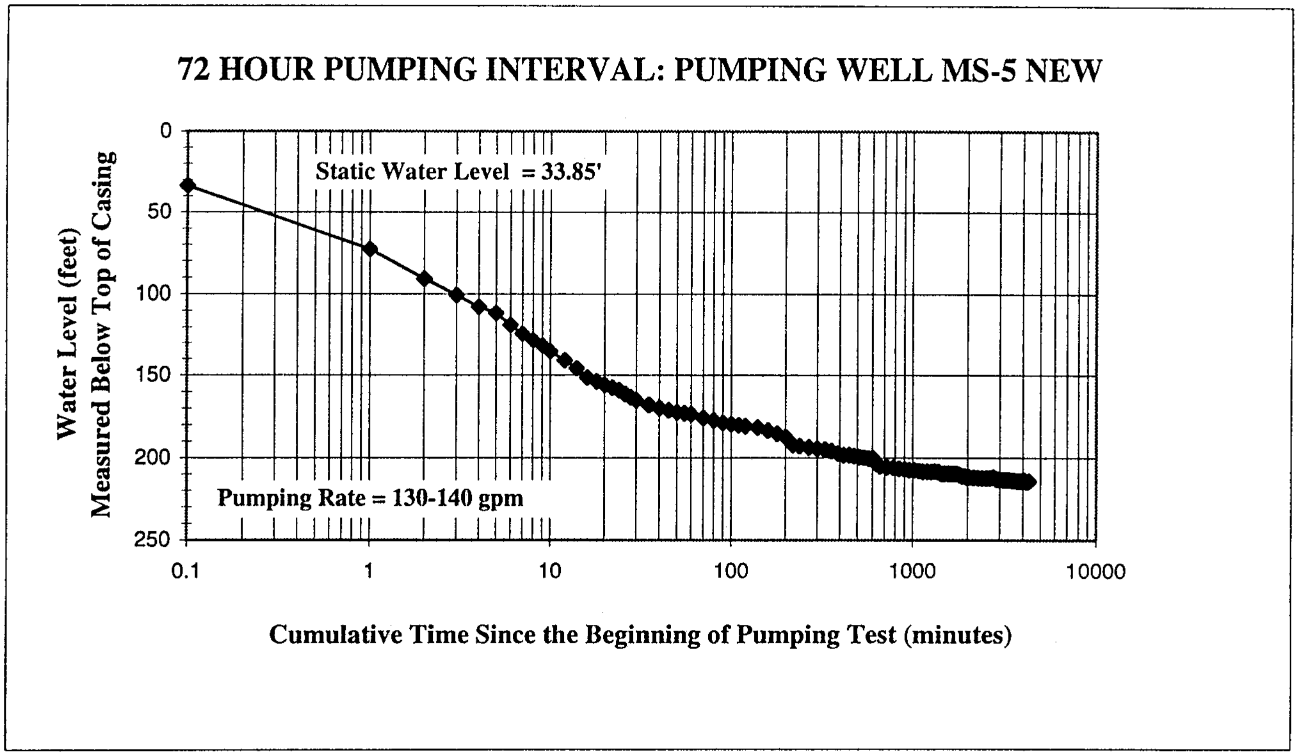


Figure 13. Arithmetic Plot of Time versus Water Level for Pumping Well MS-5 NEW During Pumping and Recovery, October 17 to 21, 1994, Bealeton, Virginia.



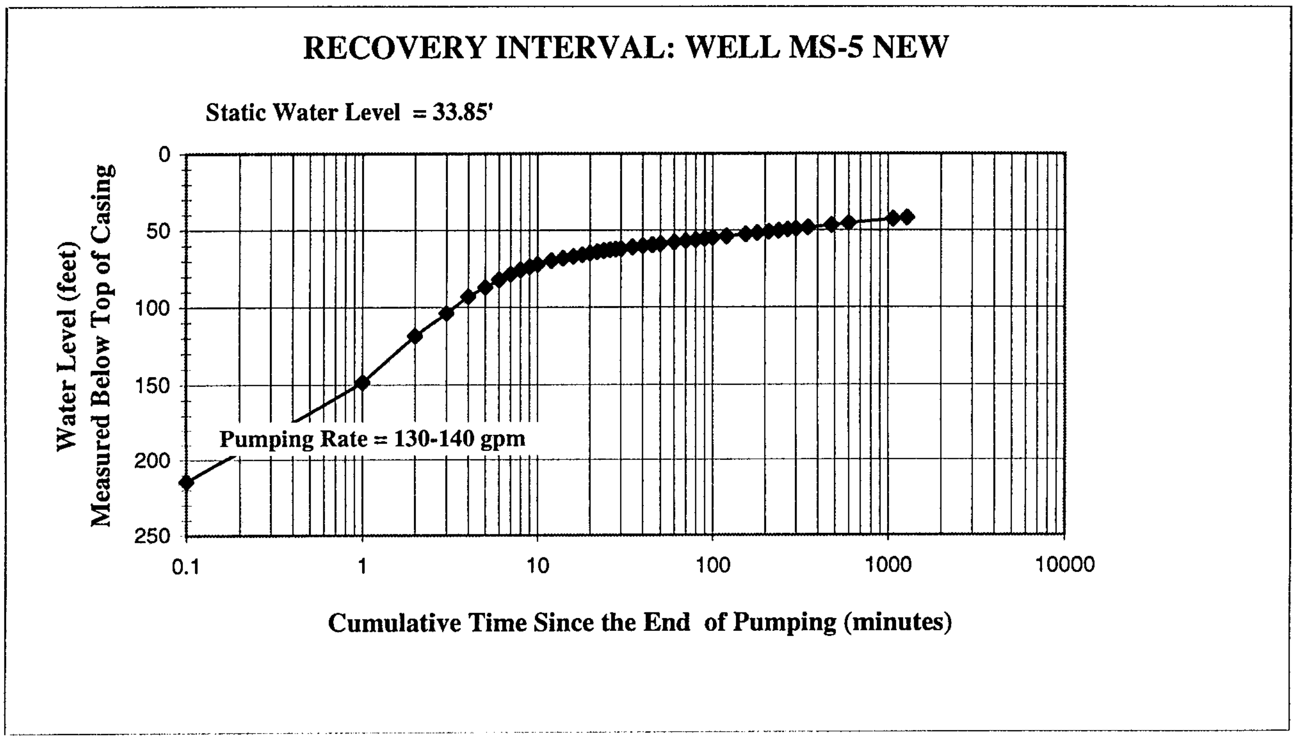


Figure 14. Semi-logarithmic Time versus Water Level Plot of Pumping Well MS-5 NEW During Pumping and Recovery, October 17 to 21, 1994, Bealeton, Virginia.

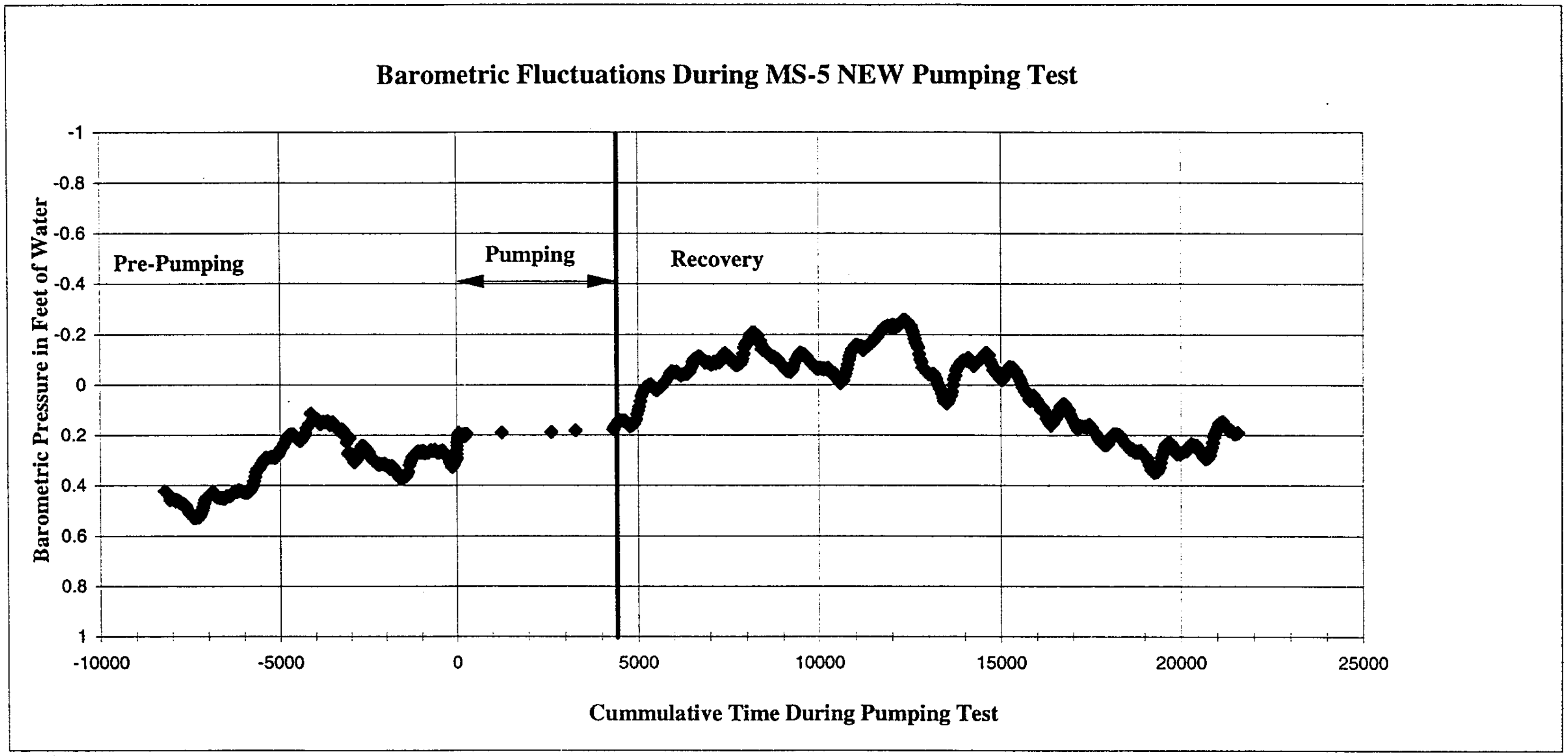


Figure 15. Arithmetic Time versus Barometric Pressure Plot Throughout the Monitoring Period October 17 to November 1, 1994, Bealeton, Virgina.

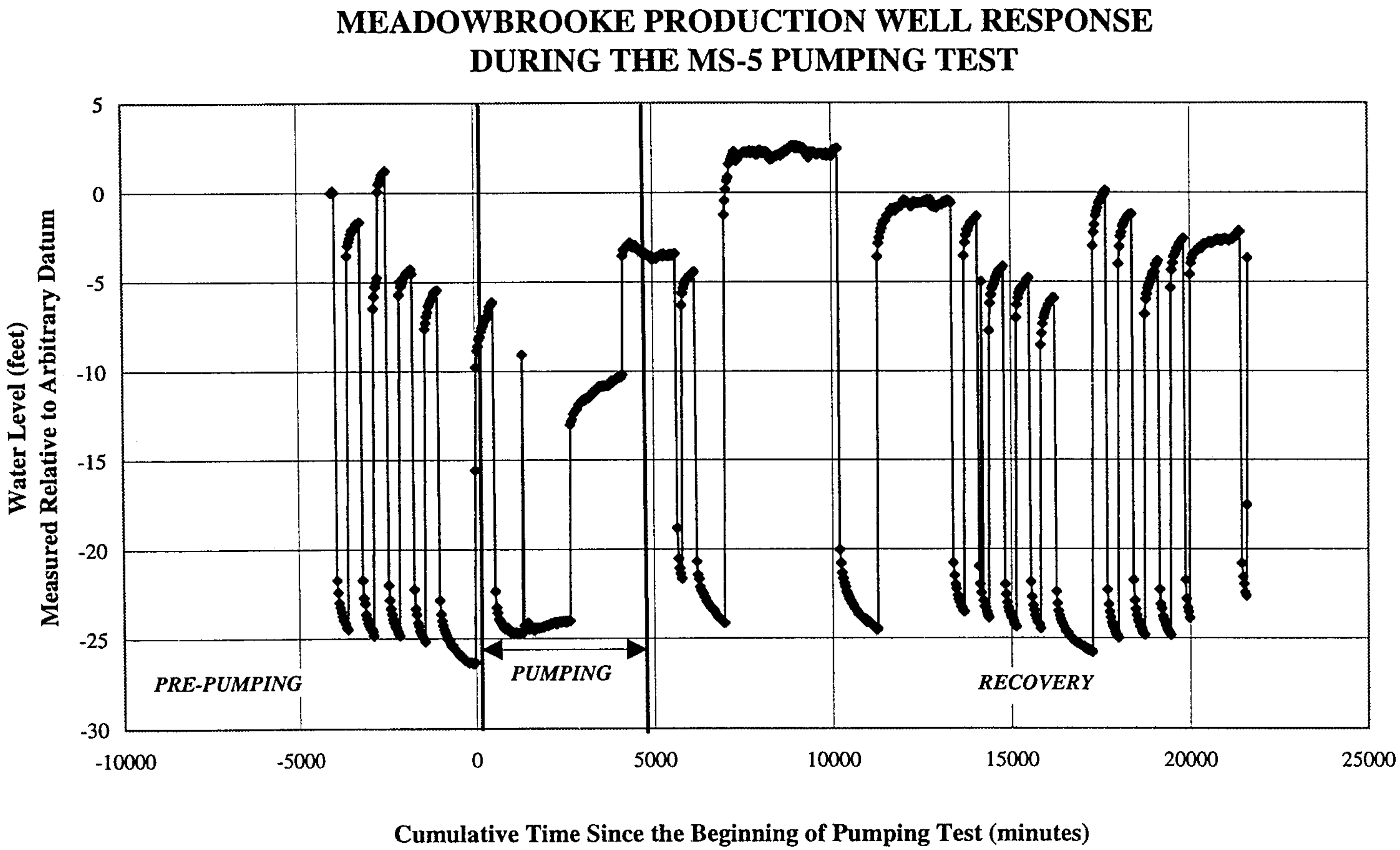


Figure 16
Arithmetic Plot of Time versus Water Level
for the Meadowbrooke Production Well Throughout the Monitoring Period October 11 to November 1, 1994
Bealeton, Virginia

PLATES