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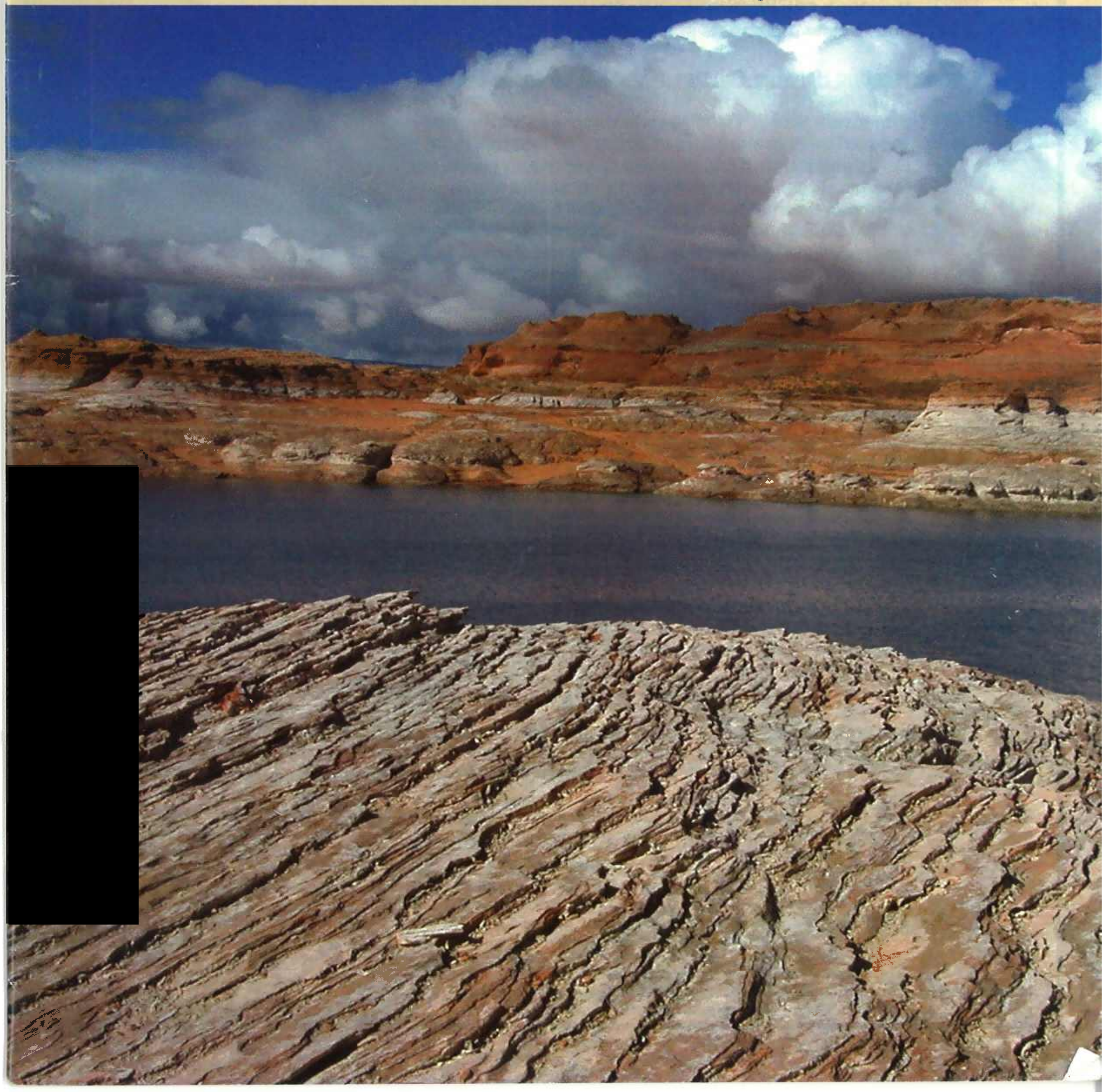

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Installation of the Artesian Tolan Farm Well
Montague, Massachusetts

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Abstract

The Tolan Farm well site is located in Montague, Massachusetts on property owned by the Turners Falls Fire District. This well site is unique to the Connecticut Valley because of the extraordinary hydraulic pressure within the Tolan Farm Aquifer. The static water level at the well site is approximately 26 feet above ground surface and the "free-flow" from the well is approximately 1,000 gallons per minute. The Tolan Farm Aquifer is situated within a north-south oriented valley that is approximately 3.5 miles long. It is flanked on the east and west by till covered bedrock hills and bounded on the north and south by Montague Plain and Mount Toby, respectively. The subsurface stratigraphy at the well site includes the Tolan Farm Aquifer which is a layered, gray, fine to coarse sand and cobble gravel unit that is a least 57 feet thick. The aquifer is overlain by an approximately 130 foot thick confining layer which is composed of gray silt, fine sand, and clay horizons. The confining layer is overlain by a brown, fine to coarse sand unit that is of variable thickness.

In order to minimize the effects of the hydraulic pressure contained within the Tolan Farm Aquifer, the well casing was telescoped to a depth approximately 8 feet above the bottom of the confining layer. The well casing was extended to a height of approximately 10 feet above ground surface and clean fill brought in to build a new working surface. The drill rig was positioned on the new working surface and the casing was extended to a height of 30 feet above the original ground surface. Once the confining layer was pierced, the water level in the casing rose to a height of approximately 26 feet above the original ground surface. The 18-inch diameter, stainless steel well screen was then installed under "water table" conditions.

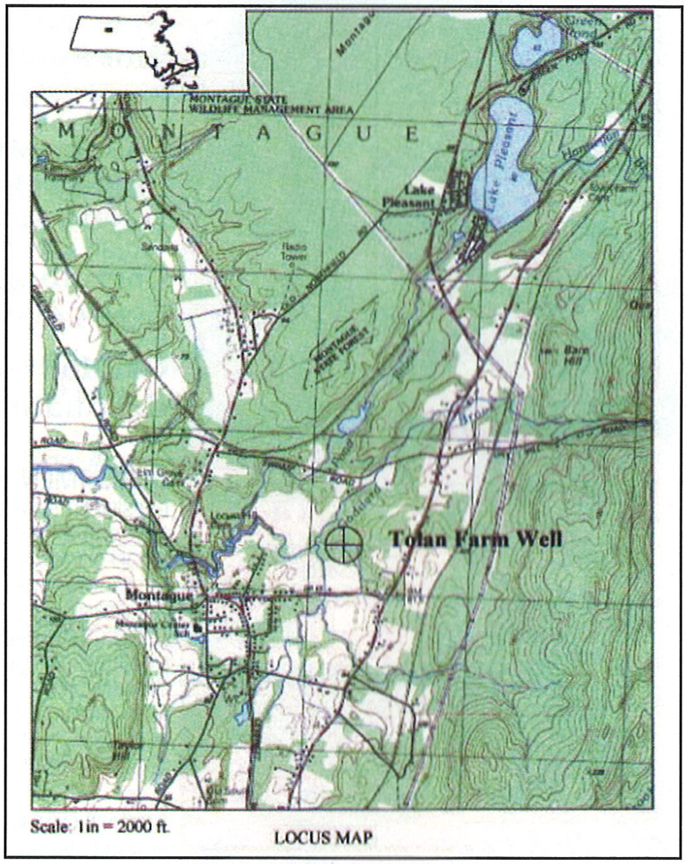


Figure 1. Location of the Tolan Farm well, Montague, Massachusetts.

Introduction

The Tolan Farm well site is located in Montague, Massachusetts on property owned by the Turners Falls Fire District (Figure 1). In order to supply future and current water demands, the Turners Falls Fire District needed to maximize the groundwater withdrawal from the Tolan Farm Aquifer. The original district supply well, a 26-inch by 34-inch gravel developed well, was installed to a depth of 117.5 feet below ground surface (bgs) in 1964 (Figure 2). The performance of this well dropped off throughout the years from a yield of approximately 1,000 gallons per minute (gpm) to a yield of 250 gpm. This reduction in the yield was caused by a collapse of the confining layer as evidenced by the filling of the well screen with the silt from the confining layer. In 1975, an 8-inch diameter, naturally developed well was constructed to a depth of 158 feet bgs (Figure 2). The screen length for this well was 10 feet. This well was driven to a depth of 204 feet then pulled back to 158 feet in order to set the screen in coarse to very coarse sand and gravel. The 8-inch diameter well yields 500 gpm and was in service almost continuously for fifteen years while maintaining an approximately 26-foot positive hydraulic head (Figure 3).

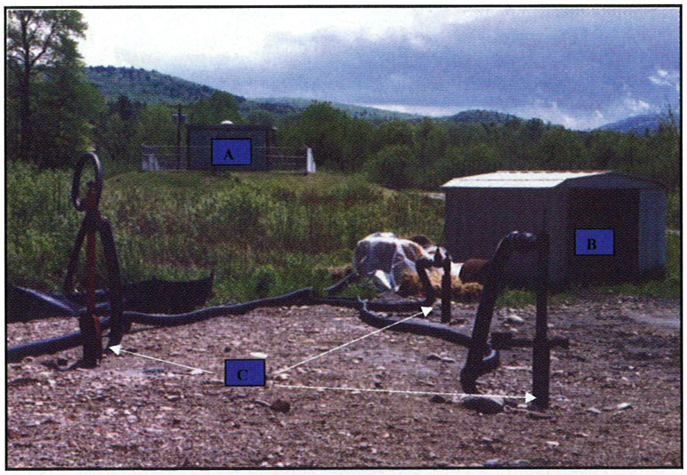


Figure 2. Locations of the existing production wells at the Tolan Farm well site. A = 26-inch by 34-inch gravel well. B = 8-inch diameter well. C = 2 ½ - inch diameter steel cased observation wells.

Figure 3. Water squirting into the air to a height of approximately 26 feet above ground surface caused by the hydraulic head in the confined aquifer.

The new 18-inch by 24-inch well "free flows" at approximately 1,000 gpm with 26 feet of positive hydraulic head (Figure 4). This well was driven to a depth of 187 feet with 37 feet of varying slot-size screen. Refusal was not encountered. A five-day pumping test was performed at a pumping rate of 1,560 gpm (Figure 5). The drawdown in the well was 27.5 feet or 1.5 feet below the original ground elevation.

Figure 4. "Free flow" discharge from the Tolan Farm well. Free flow rate is approximately 1,000 gallons per minute. The discharge line from the well is 12-inches in diameter.

Figure 5. (below) Tolan Farm well pumping test discharge of 1,560 gallons per minute during the 5-day aquifer-pumping test.

The purpose of this paper is to present information on the installation method of the artesian Tolan Farm well.

Regional Geology and Hydrogeologic Setting

The Tolan Farm well site is situated within a north-south oriented, V-shaped valley. The north-south orientation of the valley approximately parallels the major fault-bounded troughs that formed as a result of tensional stresses during the early stages of rifting of North America from Africa approximately 200 million years ago. This trough or valley is underlain by predominantly red sedimentary sandstone, conglomerate, and arkose, whereas the hills to the east of the site are composed of Pre-Ordovician schists and gneiss of the Pelham Dome (Willard, 1951). These metamorphic rocks border the fault-bounded troughs. The bedrock is not exposed at the well site, but highly fractured sedimentary rocks crop out approximately 5,000 feet to the south. The metamorphic basement rocks crop out approximately 1,000 feet east of the well site.

The surficial geology of the area is composed of unconsolidated glacial and post-glacial sediments of Quaternary age that include glacio-fluvial, glacio-lacustrine, and ice deposits (Jahns, 1966; 1951). These deposits filled a pre-glacial valley in the area to the south of the well site. Till covered drumlins

INSTALLATION OF THE TOLAN FARM WELL (continued)

Figure 6. Piece of gray clay confining layer material removed during the installation of the 24-inch diameter well casing for the Tolan Farm well.

Figure 7. Gray, fine to coarse sand and gravel aquifer material removed from the well screen area during the installation of the Tolan Farm well.

Figure 8. Close-up of aquifer material from the well screen area of the Tolan Farm well. Size of cobbles are up to 6-inches.

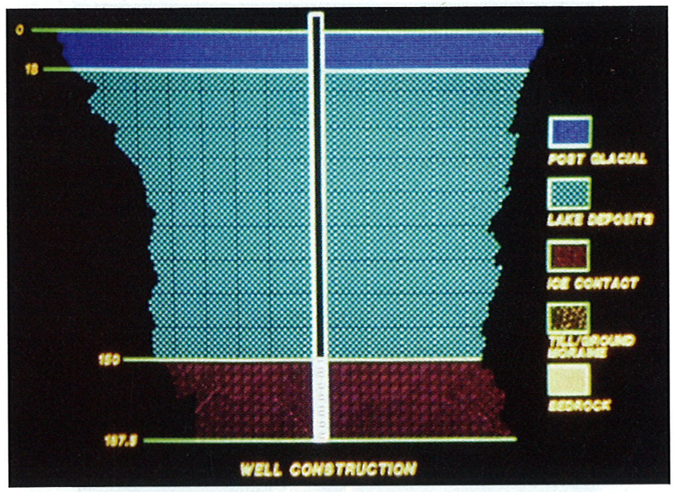


Figure 9. Generalized geologic cross-section through the Tolan Farm well site.

crop out in the area surrounding the site and act as impermeable (no flow) boundaries. The glacial deposits at the well site are of two types: 1) brown, fine to coarse sand, which is interpreted as post-glacial; and 2) gray, clay to gravel, which is interpreted as glacial. The brown sand unit is fairly uniform and up to 10 feet in thickness. The gray clay to gravel deposits are divided into two major units: 1) gray silt, fine sand and clay unit that is approximately 120 feet thick (Figure 6); and 2) coarsely layered gray, fine to coarse sand and gravel unit that is at least 54 feet thick (Figure 7). The silt-clay unit is the confining layer, and the sand and gravel unit is the water-bearing formation that underlies the confining layer. The confining layer represents lake bottom deposits related to glacial Lake Hitchcock.

The water-bearing formation is composed of gray, fine to coarse-grained sand and gravel. Rounded to sub-rounded metamorphic cobbles up to 6-inches long were removed from a depth of 180 feet to 187 feet (Figure 8). Based on the well log for the 8-inch diameter well, refusal in the area of the well site is at a depth greater than 204 feet bgs. Aquifer sands and gravels were encountered down to this depth. Thus, the water-bearing horizon is at least 54 feet thick. A generalized geologic cross-section through the Tolan Farm well site is shown as Figure 9.

Based on the geologic relationships shown on the U.S.G.S. surficial geology maps for both the Greenfield and Mount Toby quadrangles, the pre-Lake Hitchcock ice-contact and glaciofluvial deposits that crop out to the east, west and south of the site should represent good recharge areas. These deposits are exposed from elevations of approximately 260 feet to 400 feet above seal level.

The regional groundwater flow is from south to north with a hydraulic gradient of 0.005 ft/ft.

There is leakage from the aquifer through the confining layer and into the overlying post-glacial material and along fractures in the bedrock that surround the aquifer.

Well Installation

The installation of the Tolan Farm well posed some interesting technical issues because of the confined aquifer conditions. The greatest challenge was how to control the hydraulic head conditions of the aquifer. Fire District personnel informed us that an attempt was made to install a well a short distance from the Tolan Farm well location. However, during drilling, the hole blew out and the drill rig was nearly destroyed. Once the drill rig was removed from the blow out, approximately 50 cubic yards of gravel were required to fill the hole. Fire District personnel did not recall other details of this drilling accident. In addition, no records were available for the installation of the other water supply wells at the Tolan Farm well site.

Several 2 ½-inch diameter observation wells were installed to obtain information on the thickness of the confining layer. This information proved to be very useful for the installation of the Tolan Farm well casing.

The cable tool drilling method was used for the installation of the Tolan Farm well. This method included the telescoping of the well steel casing (i.e. 36-inch, 24-inch, and 18-inch diameter casing), cleaning out of the well casing with the use of a sand pump, then the installation of the well screen.

A 36-inch diameter well casing was advanced to a depth of 71 feet bgs. This casing was advanced through the post-glacial deposits and into the silt-clay confining layer. This casing could not be driven any deeper into the confining layer because of the skin friction resistance with the clay and buckling of the well casing. Once the 36-inch diameter casing was cleaned out, the 24-inch diameter casing was installed and driven deeper into the confining layer to a depth of 113 feet bgs. The clay and silt was then removed from the casing. Due to the extreme hydraulic pressure in the aquifer, it was not adviseable to pierce the confining layer with the existing configuration of the drill rig. A cement sanitary seal was installed from the surface to a depth of 113 feet. It was installed to this depth to minimize the chance of a blow out of the well casing and loss of the well.

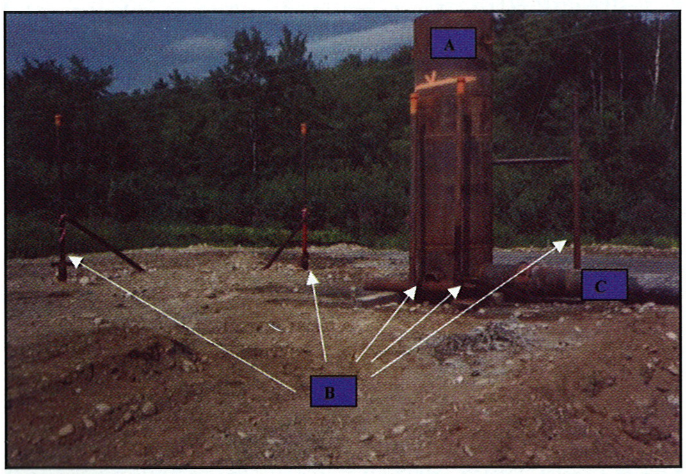
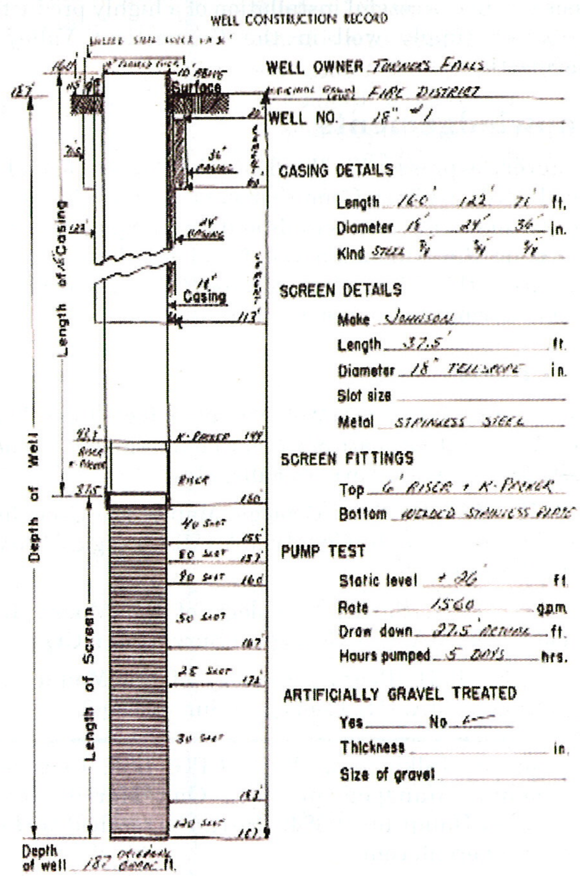


Figure 10. Steel risers attached to Tolan Farm well (A), 2 ½-inch diameter steel cased observations wells (B), and 12-inch diameter overflow pipe (C) prior to the placement of the clean fill to build new working surface.

In order to simulate water table conditions, the 36- inch and 24-inch diameter casings for the Tolan Farm Well and the casings for the 2 ½-inch diameter observation wells were extended to a height of approximately 10 feet above ground surface (Figure 10). A 12-inch diameter overflow pipe was attached to the 36-inch diameter well casing (Figure 10) in order to re-direct the flow of ground water once the confining layer was pierced. Clean fill was then brought to the site for the construction of a new working surface to complete the construction of the well. The drill rig was then driven onto the new working surface and positioned over the extended 36-inch and 24-inch diameter well casings (Figure 11). The 24-inch diameter casing was then extended to a height of approximately 30 feet above ground surface in order to account for the anticipated water level rise in the casing once the confining layer was pierced. The 18-inch diameter well casing was placed inside the 24-inch diameter well casing and advanced

Figure 11. View of drill rig on new working surface for Tolan Farm well.

Figure 12. (below) Driller's well construction log for the Tolan Farm well.



through the base of the confining layer (i.e. 130 feet bgs) and into the underlying aquifer to a final well depth of 187 feet below the original ground surface. As anticipated, when the confining layer was pierced, ground water flowed up the casings to a height of 26 feet above the original ground surface.

Samples of the aquifer material were collected from the base of the confining layer to the bottom of the well. Sieve analyses were performed on the aquifer samples to determine the slot size for the screen. Based on the sieve analysis results, a 37-foot long, 18-inch diameter stainless steel well screen with variable slot sizes was installed in the well from a depth of 150 feet to 187 feet bgs. The completed well construction is shown on Figure 12.

Once the well construction was completed, the 12-inch diameter overflow pipe was opened and the well allowed to "free flow." The free flow for the well was approximately 1,000 gpm. With the well free flowing, the casings were cut off to a height of three feet above the top of the new working surface.

A 5-day aquifer-pumping test was performed on the Tolan Farm well at a pumping rate of 1,560 gpm. The drawdown at the end of the pumping test was 27.5 feet or 1.5 feet below the original ground surface. The specific capacity for this well was 56.7 gpm/foot of drawdown.

Summary

The installation of the Tolan Farm well appeared to be a challenge few drilling contractors were willing to attempt and bid on. A strategy was devised based on available geologic information and drilling experience. This strategy provided the basis for the successful installation of a highly productive public water supply well in the Connecticut Valley of Massachusetts.

Acknowledgements

The author expresses his thanks to the Turners Falls Fire District Board of Water Commissioners. Installation of the production and observations wells and the pumping test were conducted by R.E. Chapman Co., Oakdale, Massachusetts. Discussions with Walter Allen, P.E. of R.E. Chapman were invaluable during the course of this project.

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University of the West Indies Environmental Engineering Class Made Possible Through Fulbright Grant

Environmental Engineering: Sampling, Assessment and Remediation (EM643) is a graduate level course in the Masters Degree Program in Water Resources Management at the University of the West Indies, Mona Campus, near Kingston, Jamaica. The program was developed by Dr. Jasminko Karanjac. The teaching of this class will be made possible through a Fulbright grant from the U.S. Department of State in partnership with the Council for International Exchange of Scholars. American Fulbright Senior Specialist James A. Jacobs will be teaching sampling, assessment and remedial technologies. Mr. Jacobs has 25 years of experience and specializes in in-situ remediation. The classes will occur from Monday through Friday from February 22 to March 20, 2004.

As part of the international exchange of scientists, the United States Embassy in Kingston will provide accommodations for two additional American lecturers who will teach on the subjects of Risked-Based Corrective Action, toxicology and risk assessment, and Remediation by Natural Attenuation Process. The guest lecturers are Dr. Ravi Arulanantham of Geomatrix Consultants in Oakland, California and Dr. Roger Brewer with the California Water Quality Control Board, San Francisco Bay Region.

Dr. Arulanantham is a nationally recognized scientist, Fulbright scholar and experienced regulator who is a leader in the field of Risk-Based Corrective Actions at contaminated sites. His expertise is in the areas of integrating land use and water quality issues that result in expeditious and cost-effective environmental compliance. Previously as the first Staff Toxicologist for the California Water Quality Control Board, San Francisco Bay Region, he was involved in providing risk assessment and risk management expertise in the areas of policy development and staff training. In June 2002 he joined Geomatrix Consultants as a Principal in their Toxicology and Risk Assessment practice.

Dr. Roger Brewer has been employed as a geologist with the California Water Quality Control Board, San Francisco Bay Region since 1999. His environmental experience includes regulatory compliance audits, field-based environmental investigations and human health and ecological risk assessments. He is mainly responsible for developing the comprehensive Environmental Screening Levels that is now widely used in the State of California. He was also previously employed by the State of Hawaii, where he worked with state toxicologists and the USEPA to develop an expedited risk assessment program for that state in the early 1990s.

The guest lectures will be presented on March 4, 5 and 8, 2004 at the University of the West Indies, Mona Campus. These special lectures will be free and open to industry, regulators, professors and students. Others wishing to participate or find out more information should contact James A. Jacobs by email at augerpro@sbcglobal.net An account of Mr. Jacobs' 2003 Fulbright grant to Jamaica is described in http://www.cies.org/specialists/ss_jjacobs.htm.