GEOLOGICAL SURVEY OF ALABAMA
Berry H. (Nick) Tew, Jr.
State Geologist

GROUNDWATER ASSESSMENT PROGRAM
Gregory M. Guthrie, Director

WELL REHABILITATION FOR A NATIONAL GROUNDWATER MONITORING NETWORK TREND WELL

Open-File Report 2403

by

Gregory M. Guthrie

Submitted in partial fulfillment of
U.S. Geological Survey Grant No. G21AC10472-00

Tuscaloosa, Alabama
2024

CONTENTS

FIGURES

TABLES

WELL REHABILITATION FOR A NATIONAL GROUNDWATER MONITORING NETWORK TREND WELL

By

Gregory M. Guthrie

BACKGROUND INFORMATION

AGENCY DESCRIPTION AND MONITORING PURPOSE

The Geological Survey of Alabama (GSA) has provided services and information to Alabama and its citizens as a natural resource data gathering and research agency since its establishment in 1848 (GSA, 2018). As part of its mission, the GSA explores and evaluates the mineral, water, energy, biological, and other natural resources of the State of Alabama, and conducts basic and applied research in these fields (GSA, 2018). Natural resource investigations of both groundwater and surface water began in 1898 when the GSA, in cooperation with the U.S. Geological Survey (USGS), began a systematic evaluation of the state's water resources (Johnston, 1933). These evaluations have continued over the succeeding decades and resulted in an extensive collection of published reports on the groundwater and surface water resources of the state.

The GSA Groundwater Assessment Program (GSA-GAP) operates two monitoring programs, real-time and periodic, in support of these efforts. Water-level data collected from these networks are critical for evaluating natural and anthropogenic groundwater stressors that impact the state's groundwater resources. As an example, data from the real-time network is used by the GSA and other state entities such as the Alabama Drought Monitoring and Impact Group (MIG) of the Alabama Drought Assessment and Planning Team to make informed decisions about climatic impacts on groundwater levels during months of the year typically stressed by drought conditions. In addition, semi-annual water level data collected from the periodic monitoring program are used to create snapshots of local and regional aquifers that have been impacted by pumping, land use, and/or drought stressors. The data collected from the networks are made available to the public and to other state agencies through online portals:

- https://gsa.state.al.us/gsa/groundwater/realtime and
- https://gsa.state.al.us/gsa/groundwater/periodic.

Detailed descriptions of these networks are presented in a publication entitled *An Assessment of Groundwater Resources in Alabama, 2010-2016* (GSA, 2018), which contains a compilation of aquifer characteristics and groundwater wells monitored across the state.

The GSA-GAP began systematically installing real-time monitoring equipment in wells throughout the state in 2010 to support these purposes. Beginning in 2020, real-time water level data was made available to the USGS National Groundwater Monitoring Network (NGWMN). Water-level data from the periodic network was made available to the NGWMN starting in 2022. The NGWMN is a national database of vetted groundwater level and quality data presented in an on-line web portal format that can facilitate regional hydrologic evaluation and research. Information provided by the GSA through the NGWMN portal can be viewed readily alongside adjacent states and has the potential to reveal spatiotemporal aquifer conditions across the southeastern region of the United States. This knowledge can lead to a better understanding of groundwater conditions, support water management decisions, and provide insight about groundwater responses to climatic changes in the region.

PREVIOUS PROJECTS WITH NGWMN

The GSA was awarded a two-year project with the USGS NGWMN, Award #G18AC00066 in September 2018. The project had two goals: to select and classify Alabama wells for inclusion in the NGWMN and to establish services with the USGS web data portal for wells added to the network. Wells were added to the NGWMN following criteria presented in a report by the Advisory Committee on Water Information Subcommittee on Ground Water (2013). The project resulted in 29 real-time wells being added to the NGWMN trend network, with wells in the background and suspected/anticipated changes subnetworks identified. The background subnetwork contain wells with no, or minimal, anthropogenic effects, and the suspected/anticipated subnetwork contains wells that may have been impacted by anthropogenic effects. Well GSA125622 in Limestone County, Alabama is no longer in service after it was destroyed by the municipality during a paving operation. Permission has not been received to date to reinstall the well. Historical data for the well is still available through the NGWMN web portal. A comprehensive report on the project results was submitted at the end of the two-year project period in November 2020 (Arnold, 2020).

During the initial project completed by the GSA-GAP, 172 monitoring wells were identified for inclusion in the NGWMN. The USGS subsequently awarded to GSA a second one-year project, Grant #G21AC10422 (July 2021 to July 2022), to characterize and establish well services for the wells identified during the first year project. Wells were evaluated using the following three-step process:

Step One - Elimination

- Eliminated wells with access issues or no detailed lithologic or construction data on record

Step Two – Evaluation

- Years of data
- Distance from public supply wells
- Proximity to other monitoring wells
- Distance from real-time wells
- Proximity to stream gages

Step Three - Ranking

- Greater number of years of water-level elevation data
- Further distance from public supply well
- Number and proximity of monitoring wells within a 5-mile radius
- Further distance from an existing real-time well
- Close proximity to a monitored stream gage

Items in Step Three are weighted factors that improve priority ranking. The project resulted in 172 wells from the GSA periodic network being added to the NGWMN surveillance network and assigned to the appropriate subnetwork, background, suspected/anticipated, and known changes, based on the identification of anthropogenic effects on water levels due to land use and development and withdrawal due to pumping, as detailed in the final report submitted at the end of the two-year project period in November 2022 (Arnold, 2022).

The GSA received funding from the USGS NGWMN for a two-year project under Grant #G20AC00378, performance period November 16, 2020, to November 15, 2022, to support persistent data services (Objective 2) and perform well maintenance (Objective 4) on six trend wells served to the NGWMN: GSAL125301, GSAL125344, GSAL118672, GSAL125687, GSAL125719, and GSAL125622. Objective 2 tasks were performed to assure that water level services, construction services, and lithology services from all wells served by the GSA to the NGWMN were functioning as required by USGS standards. These tasks were accomplished within the project framework. Well maintenance for four of the six trend wells identified above was performed during the project. This work included replacing well covers, locking mechanisms, and replacing a well housing. The sixth well, GSA125622, Limestone County, was removed from the NGWMN because it was destroyed by the local municipality during a paving operation. A final report was submitted at the end of the two-year project period (Arnold, 2023).

EXISTING GROUNDWATER MONITORING NETWORKS IN ALABAMA REPORTING TO THE NGWMN

The GSA-GAP has been actively monitoring groundwater conditions in eight of the state's principal aquifer systems established by the USGS (2003) since the early 1950s through a network of observation wells. Initially, this network was operated in conjunction with the USGS; however, the GSA-GAP currently has full responsibility for maintenance and operation of the networks. Real-time water-level data collection began in 2010, with the installation of the first transducers and data loggers in a selection of observation wells used for periodic monitoring. Since 2010, the GSA-GAP has focused on expanding the network, which now includes 30 wells that monitor daily water-level changes across the state. The current real-time network incorporates wells in which water levels are recorded every two hours and reported twice daily to the GSA-GAP FTP server. Twenty-nine wells from the real-time network serve data to the NGWMN trend network (table 1; fig. 1).

Water levels in approximately 468 wells across the state are manually recorded in the periodic network (table 1; fig. 2). The total number of wells varies because of changes in property ownership, which can limit access to a well, and/or changes in the condition of a well, which may limit its usefulness for monitoring purposes. Prior to 2020, every well in the network was visited yearly in the Spring and Fall months. In 2020, due to staff limitations, the sampling schedule was adjusted to alternating years, following the same bi-yearly schedule. One hundred seventy-two wells from the periodic network report data to the NGWMN surveillance network.

Table 1. Monitoring wells in the Geological Survey of Alabama real-time and periodic network and their principal aquifer system (USGS, 2003).

Principal aquifer system	Number of real-time monitoring wells	Approximate number of periodic monitoring wells
Coastal Lowlands aquifer system	4	34
Floridan aquifer system	2	13
Southeastern Coastal Plain aquifer system	12	230
Mississippi Embayment aquifer system	2	29
Piedmont and Blue Ridge crystalline-rock aquifers	1	39
Valley and Ridge aquifers	3	42
Pennsylvanian aquifers	2	48
Mississippian aquifers	3	33
Totals	29	468

OVERVIEW OF CURRENT PROJECT WORK

The major tasks for this project were performed under Objective 4, Well Maintenance and Repairs, as defined by the USGS, and included a down-hole camera survey and an aquifer test on well MTG-6 (GSAL111889), a GSA background well in the trend network that supplies data to the NGWMN. The MTG-6 well is located in Montgomery County, Alabama, latitude 32.0207, longitude -86.0304. The well was originally installed in June 1967 to provide potable water at an Alabama Department of Transportation public rest stop at the location. The site has since been abandoned, and a visit to the site in October 2008 revealed that it was no longer in use. The pump and piping were removed from the well by GSA personnel in November 2012.

Well construction consists of a 6-inch steel casing set from a surface elevation of 465 feet to a depth of 65 feet and a total well depth of 80 feet. It was unknown prior to this study whether a screen was incorporated in the well construction, or if it was completed open hole. Water is derived from a sand interval in the Ripley aquifer of the Southeastern Coastal Plain aquifer system. A static water level of 34.75 feet below ground surface was recorded in the well when it was installed in 1967 according to records on file at the GSA.

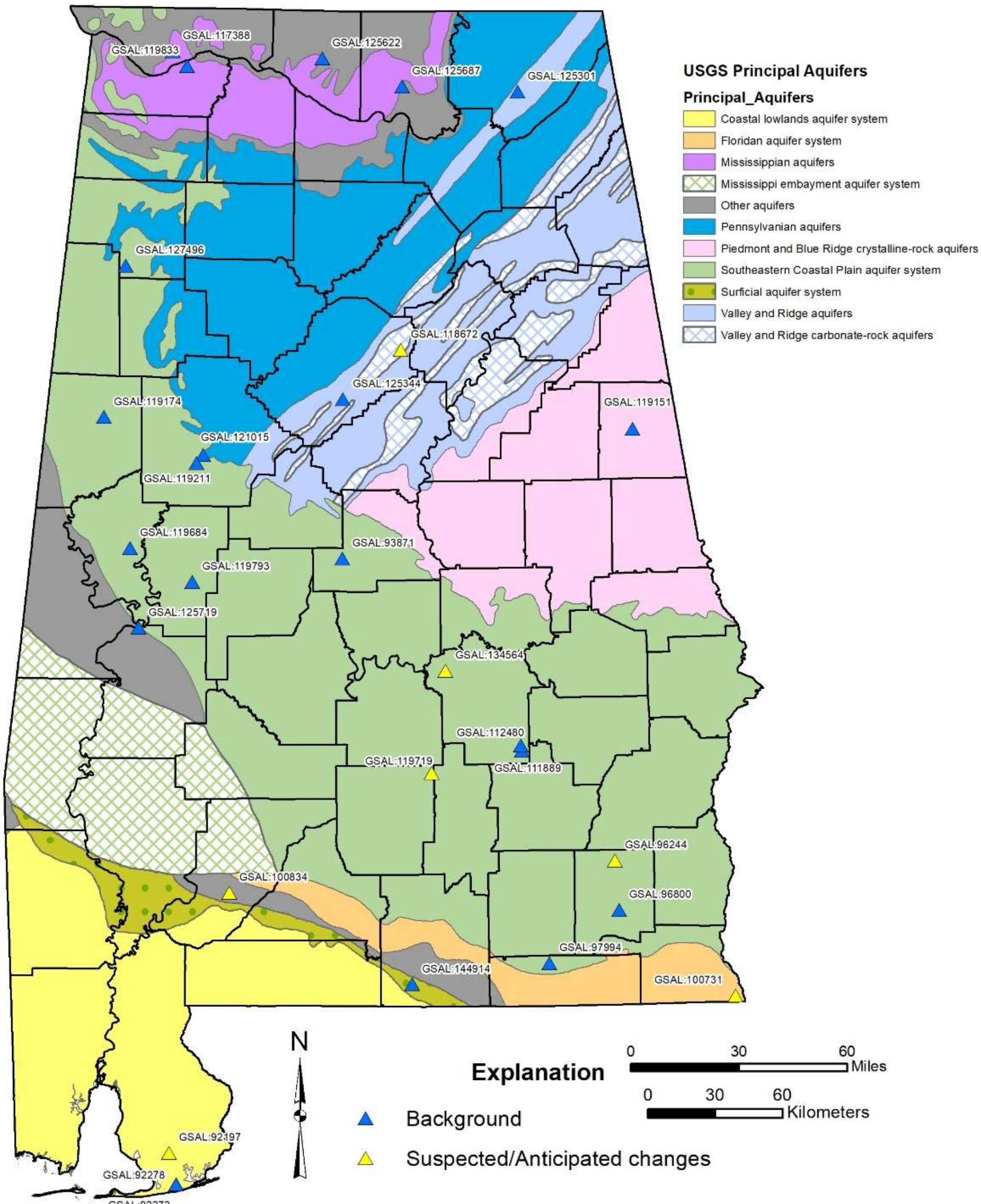


Figure 1.— Map showing locations of 29 real-time network wells served to the NGWMN trend network. Principal Aquifers basemap from U.S. Geological Survey (2003).

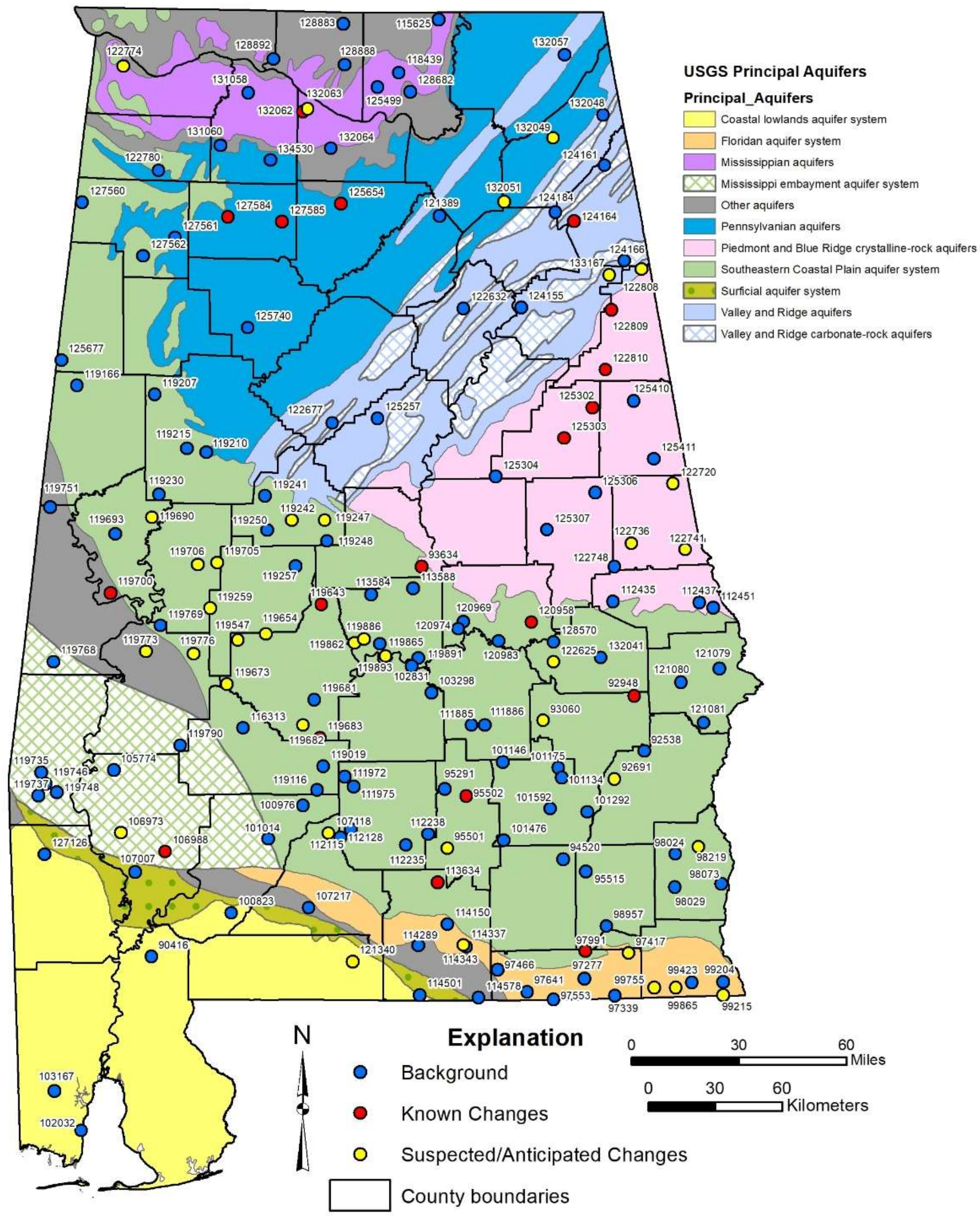


Figure 2.— Map showing locations of 172 periodic network wells served to the NGWMN surveillance network. Principal Aquifers basemap from U.S. Geological Survey (2003).

Periodic water levels were manually measured in the well from 1982 to 1993 by USGS personnel. Personnel from the GSA began manual measurements of water levels in the well beginning in 1984 and continuing through 2010. An OTT Orpheus Mini pressure transducer and data logger was installed in the well in November 2012 when the pump and piping were removed to enable continuous water level measurements. Two-hour data collection by the device continued until October 2017. Data was manually downloaded on a six-month schedule because the device did not have the capability to transmit data. The device was replaced by an OTT EcoLog 500 pressure transducer and data logger in October 2017, equipped with a 3G modem that allowed data to be collected every two hours and served to a GSA FTP site twice daily over a cellular network. This device was replaced by an OTT EcoLog 1000 and data logger equipped with a 4G modem (fig. 3) in April 2022 to support the ATT cellular network transition from 3G to 4G. This device is currently in operation providing data to the GSA real-time network, and subsequently to the NGWMN.

Figure 3.—Geological Survey of Alabama well MTG-6, GSAL111889, Montgomery County, Alabama. Image highlights OTT EcoLog 1000 pressure transducer, data logger, and locking collar and cap installed on the well casing.

A critical premise of the GSA real-time network and the NGWMN is that data collected from wells in the networks is of high quality and accurately reflects the groundwater conditions at a site at the time of measurement. Data can be compromised by many factors including equipment malfunctions, signal disruptions, well collapse, and fouled well screens. Equipment malfunctions and signal disruptions are easily diagnosed by constant observations of the delivered data and corrected by onsite visits and maintenance. Downhole problems with the well itself are more difficult to detect and correct.

Hydrograph analysis of water level data collected from well MTG-6 indicated that water levels demonstrated relatively consistent behavior prior to 2017. Post-2017, water level declines were inconsistent in the well compared to water levels measured in other area wells completed in the Ripley aquifer, of the Southeastern Coastal Plain aquifer system (fig. 4). Water level anomalies revealed in the hydrograph analysis may have resulted from the well not being discharged for more than 10 years, or from connectivity issues between the well and the aquifer due to fouling of the well bore or screen, if present, by sediment or bacteria-derived mineralization. The well is designated as a trend well in the background subnetwork and did not appear to be under the influence of anthropogenic stresses. Visits to the well had not found any equipment maintenance issues that may have caused inaccurate water-level measurements, and it was unclear whether downhole complications, such as wellbore collapse or screen fouling, may have resulted in the declining flows recorded in the well.

It is critical that data derived from the well accurately reflect the site's groundwater conditions as MTG-6 serves as one of nine wells used by the State of Alabama as an indicator of groundwater conditions during drought months. Data from the well is reported to the MIG and used to determine drought conditions for the state, in addition to serving data to the NGWMN portal and the GSA-GAP real-time network.

PLANNED PROJECT WORK

This project had three primary objectives: to conduct a downhole camera survey of well MTG-6 (GSAL111889), to rehabilitate the well if needed, and to conduct an aquifer test. A camera survey was used to verify the integrity of the casing, evaluate the presence or absence of a screen, and to establish whether the screen or open wellbore was fouled or if fine-grained detritus had invaded and obstructed the wellbore. This information was used to determine the requisite rehabilitation

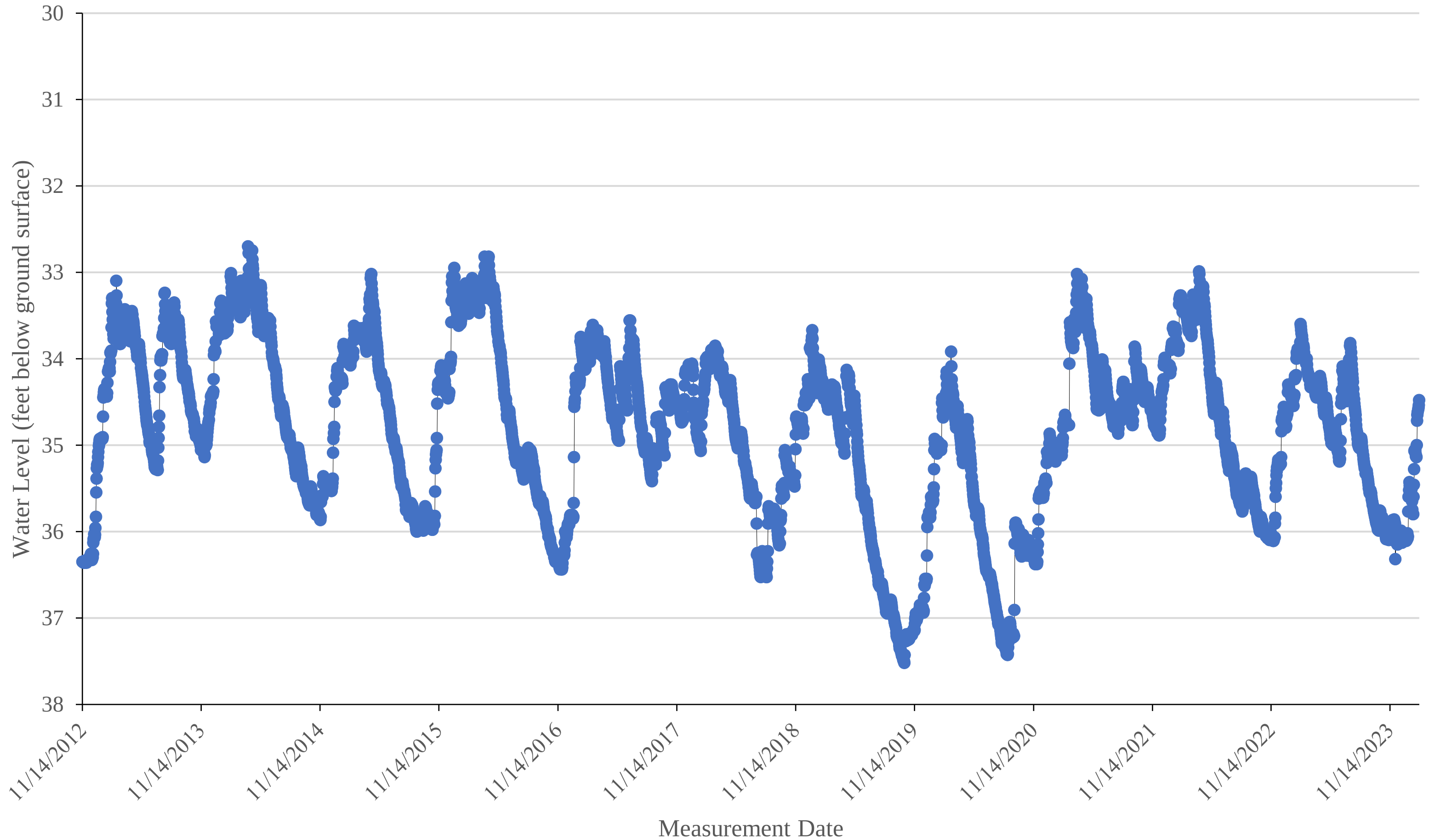


Figure 4.—Hydrograph of real-time water level measurements collected from well MTG-6, GSAL111889 during the period November 14, 2012, to February 11, 2024, Montgomery County, Alabama. Individual data points represent daily average for clarity.

efforts. An aquifer test was conducted at the conclusion of the down-hole camera survey, and a rehabilitation process if performed, to reestablish communication between the wellbore and surrounding aquifer to ensure that water-level data from the well accurately represents site groundwater conditions and to derive aquifer hydraulic properties.

ACCOMPLISHED PROJECT WORK

DOWN-HOLE CAMERA SURVEY

A downhole camera survey of well MTG-6 was conducted by the GSA-GAP personnel on May 10, 2022, using a Strahl Borehole Dual Inspection camera. The Strahl unit incorporates both downhole and rotating sideview cameras equipped with ample halogen light for maximum exposure and image capture at depth. The unit features a 10-inch diameter viewing screen with a display ratio of 4:3, which is optimally suited for downhole applications. It is mounted on a field vehicle equipped with an elevated camper and a sliding bed for ease of mounting and camera insertion and a motorized winch. The survey was designed to traverse the entire 80-foot depth of the well if possible.

Results from the survey revealed that the well is equipped with a 4-inch screen set from 64.33 feet to a total depth of 80 feet. Observations of continuous video from the test indicate that the casing is in good condition with only minor rust and white-colored scaling along its inner surface (table 2). The static water level was encountered at 34.26 feet; water was cloudy. Images collected from the screened interval (figs. 5, 6) reveal that the screen is unobstructed with no observable material. Detached scale and rust derived from the casing has collected at the bottom of the well but do not appear to restrict water flow from the aquifer to the well bore.

Results from the down-hole camera indicated that there are no outstanding issues with the MTG-6 well casing and that the well screen is unobstructed by debris or scaling. As a result, no rehabilitation of the well was required under the current project.

Table 2.—Observations from a down-hole camera survey, well MTG-6, GSAL111889, Montgomery County, AL, on May 10, 2022.

Depth (ft bgs*)		**Observations**
From	**To**	
2.45	20.00	Light rust and scale with minor pitting of casing
20.00	20.00	Joint #1
20.00	24.59	Joint compound or grout on casing
24.59	34.26	Light rust and scale reduced on casing. Minor mud streaking on casing
34.26	34.26	Static water level; water appears cloudy
34.26	38.59	Light rust and scale; casing appears to be in excellent condition
38.59	41.77	Rust and scale on casing greatly reduced
41.77	41.77	Joint #2
41.77	45.00	White scaling
45.00	64.33	White scaling continues
64.33	64.33	Top of screen; minor rust particles
64.33	77.90	Minor rust accumulation
	80.00	Bottom of hole

* feet below ground surface

AQUIFER TEST

In the fall 2023, GSA-GAP issued a Request For Proposals from licensed professional well drilling companies to perform a continuous aquifer pump and recovery test on MTG-6 in support of the current project. Weldon-Hay Drilling Services was awarded the contract to be completed with the following objectives:

- The well will be pumped to perform a continuous aquifer test until water levels in the well have stabilized, or for 6 hour, whichever comes first. The test will be conducted as outlined in standards described in ASTM D4043-17 “Standard Guide for Selection of Aquifer Test Method in Determining Hydraulic Properties by Well Techniques” (ASTM, 2017).
- Record accurate elapsed time/water level measurements throughout the test. Readings will be taken every 2 minutes for the first hour, every 5 minutes for the next hour, every 10 minutes for the next 2 hours, every 30 minutes for the remainder of the test if necessary.

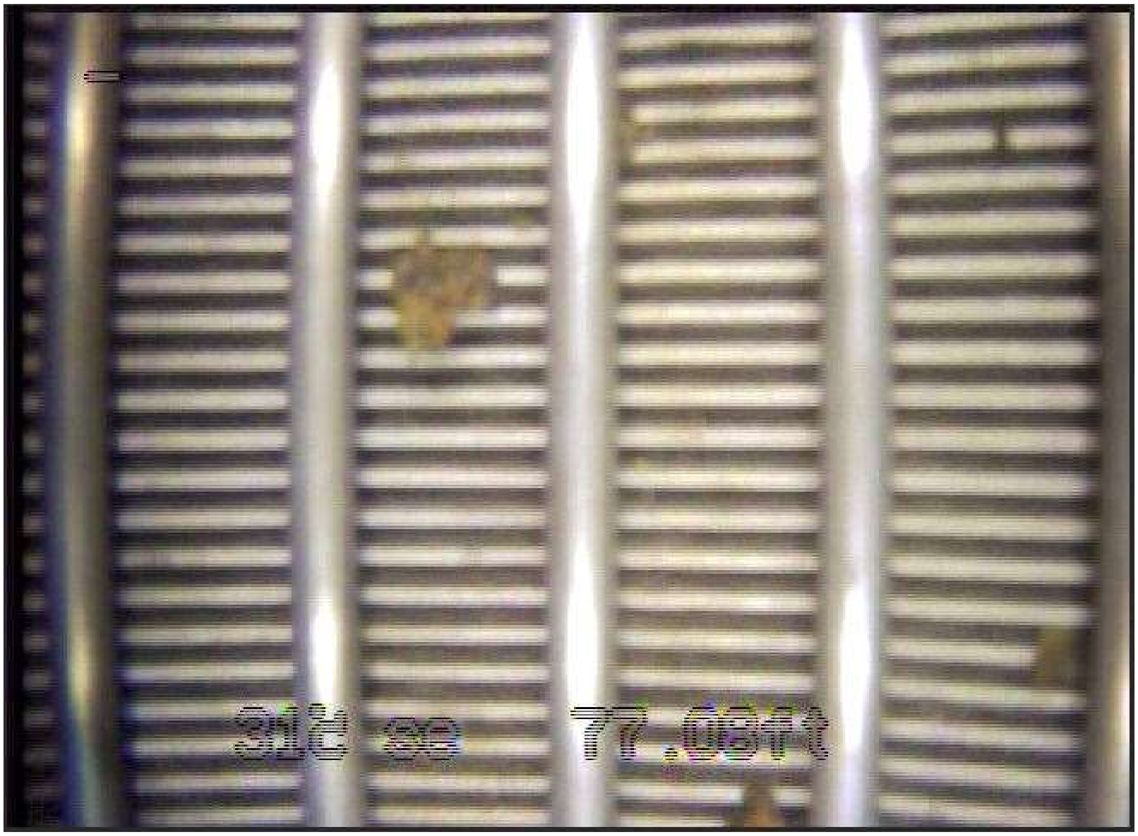


Figure 5. Lateral view of screens in well MTG-6, GSAL111889, Montgomery County, Alabama, at 77.08 feet as shown by down-hole camera survey. Note orange scale material from casing above attached to unobstructed screen. Image from down-hole camera video survey collected by a Strahl Borehole Dual Inspection camera on May 10, 2022.

- Record elapsed time and recovery water level measurements following the same schedule until the water level in the well returns to static condition.

A static water level of 37.73 feet below top of casing was measured both manually and with an OTT EcoLog 500 electronic transducer by GSA-GAP personnel upon arrival at the site on November 30, 2023. A Goulds 5 H.P. submersible pump with an intake set at 65 feet below ground surface (fig. 7) was installed in the well. An orifice was used to regulate discharge (figs. 8, 9). An initial pump test was attempted at 60 gallons per minute (gpm). The water level immediately dropped 21.61 feet when the pump was started and a decision was made by GSA-GAP and Weldon-Hay personnel that the rate was too high and that a lower pumping rate would result in a sustainable discharge. Discharge was terminated and the water level recovered to 38.34 feet in six minutes elapsed time. The well was then discharged for 63 minutes at 13.88 gpm (1.86 cubic feet

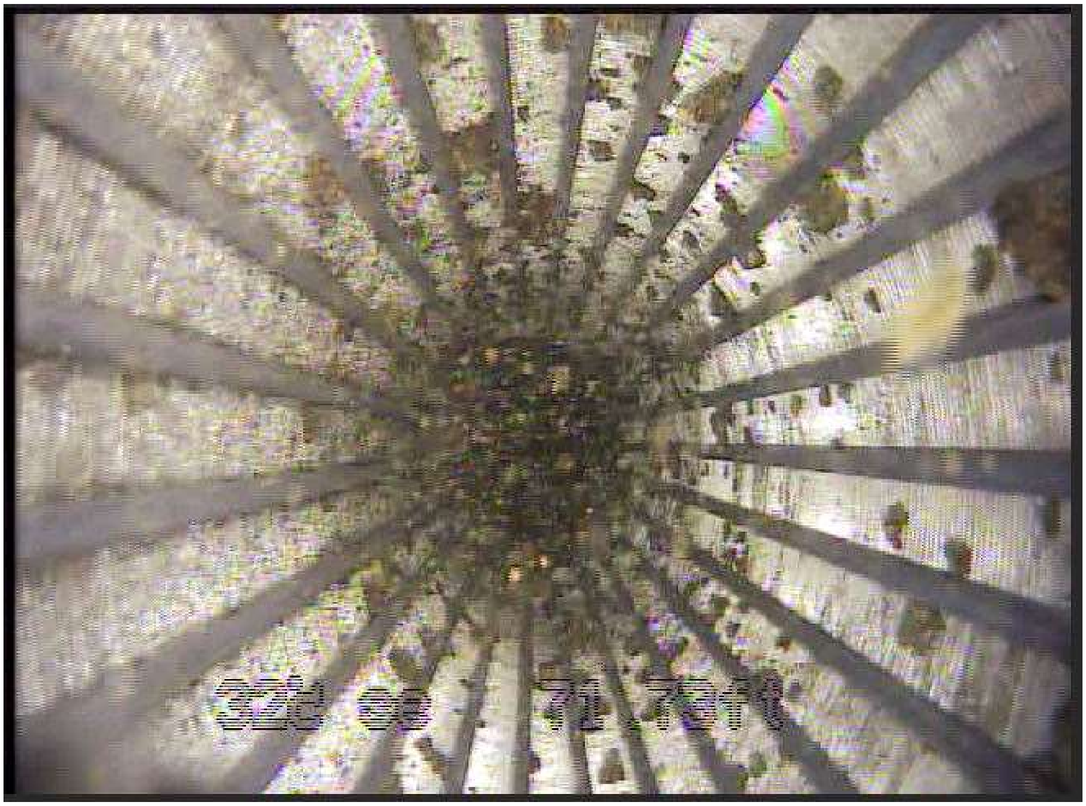


Figure 6. Down-hole view of screens in well MTG-6, GSAL111889, Montgomery County, Alabama, at 71.73 feet as shown by down-hole camera survey. Note orange scale material derived from casing above attached to screen and in water column. Image from down-hole camera video survey collected by a Strahl Borehole Dual Inspection camera on May 10, 2022.

measurement stabilized within 0.02 feet of the previous reading. Discharge was terminated at 64 minutes resulting in a total drawdown of 11.45 feet and a calculated specific capacity of 1.21 gpm per feet drawdown. Recovery to 38.54 feet occurred within 28 minutes of pump shut off. Data from the test was analyzed using AQTESOLV Pro version 4.50.002 using the Cooper-Jacob solution method (Cooper and Jacob, 1946). The solution method assumes that the well is fully penetrating in a confined aquifer and neglects wellbore storage, but is often used for wells in unconfined aquifers (Kruseman and deRidder, 1990). Early drawdown versus time data display a linear arrangement prior to stabilizing at approximately 11.4 feet of drawdown (fig. 10). Analysis of the pump test data indicates the Ripley aquifer at this location has transmissivity (T) equal to 0.1554 square feet per minute and storativity (S) of 0.002149. Hydraulic conductivity (K) was calculated to be 0.00373 feet per minute and specific storage (S_s) to be 5.158e^{-5} per foot (table 3).

Figure 7.—Submersible pump installation in well MTG-6, GSAL111889, Montgomery County, Alabama, prior to aquifer test conducted on November 12, 2023.

A second pumping test was conducted on the same day after the static water level had recovered to 38.54 feet. The second test was conducted using a discharge rate of 14.09 gpm (1.88 cubic feet per minute). Early drawdown versus time data display a linear trend, albeit with a steeper slope than the initial test, and stabilized at approximately 11 feet of drawdown after approximately 30 minutes (fig. 11), and a specific capacity of 1.28 gpm per foot drawdown. Discharge was terminated at 56 minutes, and the water level recovered to 37.73 feet after 16 minutes. The data were analyzed using the Cooper-Jacob solution method resulting in T equal to 0.06593 square feet per minute, S = 0.1978, K = 0.00159 feet per minute, and $S_s = 4.771e^{-3}$ per foot (table 3).

Figure 8.—Orifice installation at well MTG-6, GSAL111889, Montgomery County, Alabama, prior to aquifer test conducted on November 12, 2023.

Figure 9.—Final orifice assembly and discharge pipe at well MTG-6, GSAL111889, Montgomery County, Alabama, prior to aquifer test conducted on November 12, 2023.

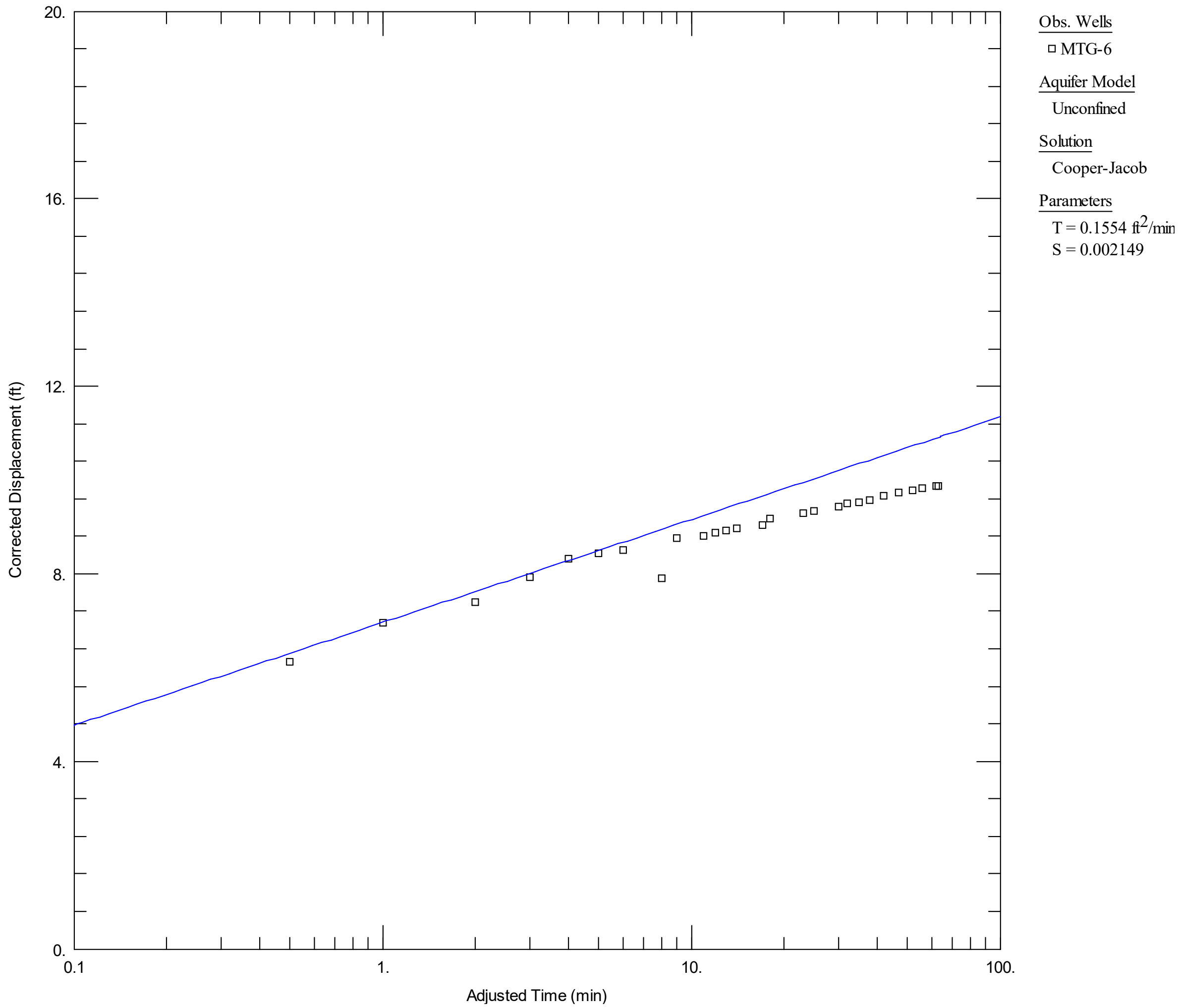


Figure 10.—Elapsed time versus displacement plot from the first aquifer test, well MTG-6, GSAL111889, Montgomery County, Alabama, conducted on November 30, 2023. Squares represent measured water levels and blue line represents Cooper-Jacob solution.

Table 3. Aquifer properties derived from analyses of pumping tests conducted on well MTG-6, GSAL111889, Montgomery County, Alabama, on November 30, 2023.

Pump test number	Transmissivity (square feet per minute)	Storativity	Hydraulic conductivity (feet per minute)	Specific storage
1	0.1554	0.002149	0.00373	$5.158e^{-5}$
2	0.06593	0.1978	0.00159	$4.771e^{-3}$

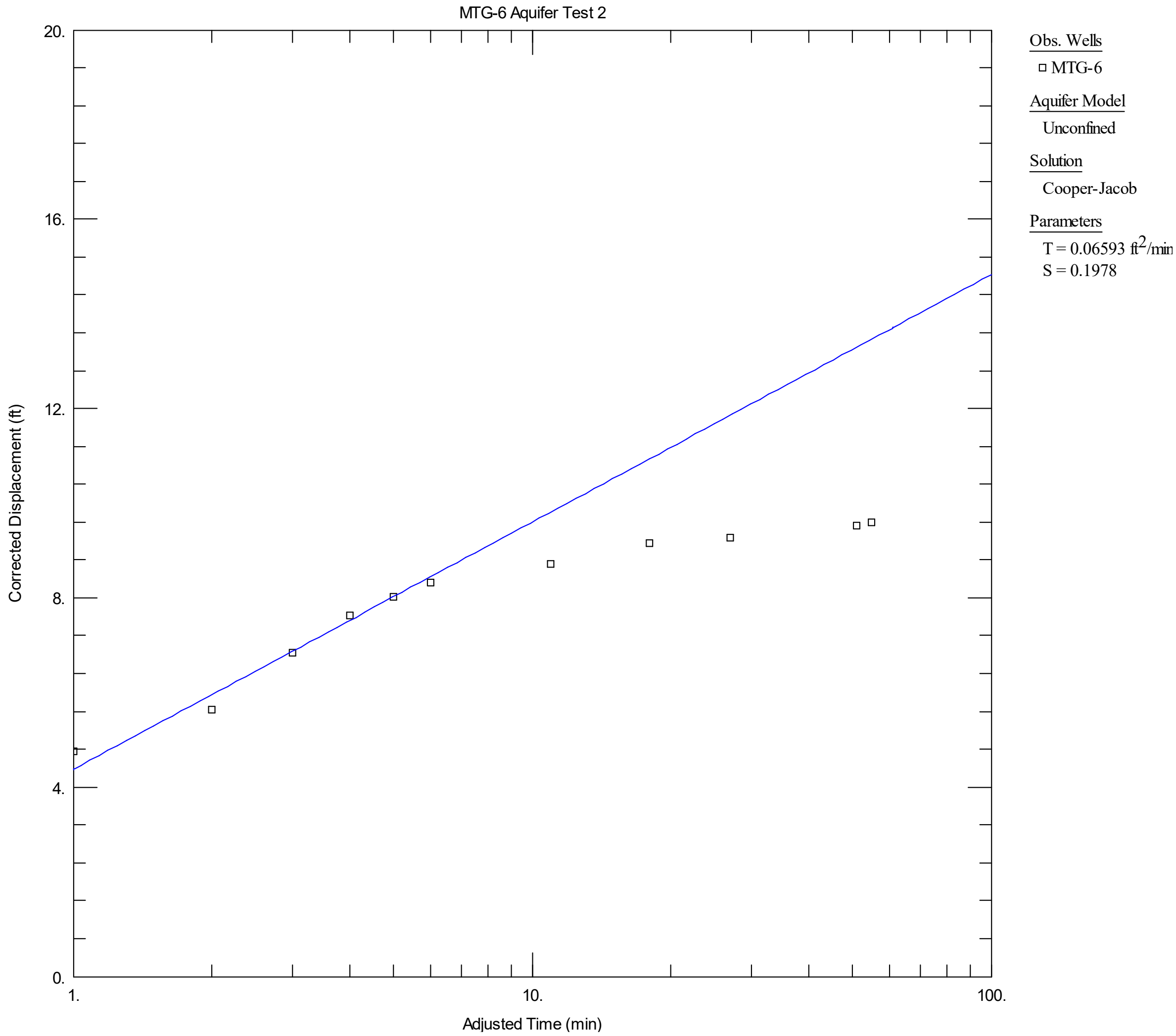


Figure 11.—Elapsed time vs. displacement plot from the second aquifer test, well MTG-6, GSAL111889, Montgomery County, Alabama, conducted on November 30, 2023. Squares represent measured water levels and blue line represents Cooper-Jacob solution.

SUMMARY AND CONCLUSIONS

The GSA began conducting groundwater and surface water investigations in 1898 in cooperation with the U.S. Geological Survey (Johnston, 1933). These evaluations have continued over the succeeding decades and resulted in an extensive collection of published reports on the groundwater and surface water resources of the state. The GSA-GAP operates real-time and periodic monitoring networks in support of these efforts. Data from these networks are used to evaluate natural and anthropogenic stresses that impact the state's groundwater resources. Real-time data collection began in 2010, with the installation of the first equipment in a selection of observation wells originally used for periodic monitoring. The GSA began serving data from 29 real-time network monitoring wells to the NGWMN trend network in 2020 through funding from the USGS. In 2022, 172 periodic wells were added to the NGWMN surveillance network as a result of USGS funding. Additional funding from the USGS in 2023 resulted in an update of web services to the NGWMN and well maintenance on four real-time network wells served to the NGWMN trend network.

Hydrograph analysis from one of the GSA real-time wells, MTG-6 (GSAL111889), served to the NGWMN trend network indicated that water level behavior prior to 2017 was relatively predictable. Post-2017, water level declines in the well were inconsistent compared to water levels measured in other area Ripley aquifer of the Southeastern Coastal Plain aquifer system wells. Well construction details on file at GSA provided no information on the presence or absence of a well screen. As a result, it was unclear if connectivity problems between the well and the aquifer due to fouling of the well bore or screen by sediment or bacteria-derived mineralization may have resulted in the anomalous water level behavior revealed by the hydrograph analysis. A proposal submitted to the USGS for funding to conduct a down-hole camera survey, well rehabilitation, and an aquifer test was approved in 2021 for a two-year project. A one year no-cost extension to 2023 for the project was granted based on difficulties contracting with a registered professional well driller because of scheduling backlogs that arose during the COVID-19 epidemic.

Results from the down-hole camera survey in May 2022 revealed that the well is equipped with a 4-inch screen set from 64.33 feet to a total depth of 80 feet. Details on the screen had previously been unavailable. No significant issues with the MTG-6 well casing or screen were noted in the survey, and as a result, no rehabilitation of the well was required. Two aquifer tests were performed by Weldon-Hay Drilling Services in November 2023. Both tests consisted of discharging the well until the water level stabilized and measuring water level decline versus time on a set schedule. During the first test, the well was discharged for 63 minutes at a constant rate of 13.88 gpm until the water level stabilized with 0.02 feet at 11.45 feet of drawdown. Recovery to 38.54 feet, 0.2 feet from the initial water level, occurred within 28 minutes of pump shut off. The second test used a discharge rate of 14.09 gpm, with a starting water level of 38.54 feet. Water level decline stabilized at approximately 11 feet of drawdown after approximately 30 minutes, and discharge was terminated at 56 minutes. The water level recovered to within 0.46 feet of the beginning static level after 16 minutes. A Cooper-Jacob solution method was used to analyze the elapsed time and drawdown data. Analyses of datasets from the tests revealed linear early time relationships between elapsed time and drawdown. The discharge rate used in the first test may not have been as efficient as the rate used in the second test to stabilize the water level at a later time, resulting in an elapsed time versus drawdown plot with an atypical type curve. Aquifer properties derived from analyses of the two tests are shown in table 3.

The calculated specific capacities are similar for the two tests, 1.21 and 1.28 gpm per foot drawdown, respectively, and the shape of the curves on the elapsed time versus drawdown plots appear to indicate no outside influences on water flowing to the well. Based on the work completed during this project, it is concluded that the construction of well MTG-6 (GSAL111889) included a previously undocumented screen set from 64.33 feet below ground level to the total depth of 80 feet. The casing is in serviceable condition and the screens are unobstructed and groundwater flow from the aquifer to the well bore is unobstructed, and the well requires no remediation. Two aquifer tests conducted on the well revealed similar hydraulic properties and results from the tests suggest that the groundwater flow to the well is not influenced by additional sources. Based on these results, the MTG-6 well is performing as needed for use as a monitoring well in the GSA-GAP real-time network and the NGWMN trend network.

REFERENCES CITED

Advisory Committee on Water Information: Subcommittee on Ground Water, 2013, A national framework for ground-water monitoring in the United States: https://acwi.gov/sogw/ngwmn framework_report_july2013.pdf , accessed November 1, 2020, 168 p.

Arnold, A. C., 2020, Establishing Alabama as a data provider to the U.S. Geological Survey National Groundwater Monitoring Network: Alabama Geological Survey Open-File Report 2011, 28 p.

Arnold, A. C., 2022, Alabama surveillance wells for the U.S. Geological Survey National Groundwater Monitoring Network: Alabama Geological Survey Open-File Report 2209, 34 p.

Arnold, A. C., 2023, Alabama well and data maintenance for the U.S. Geological Survey National Groundwater Monitoring Network final report: Alabama Geological Survey Open-File Report 2301, 20 p.

ASTM Standard D4043, 2017, Standard guide for the selection of aquifer test method in determining hydraulic properties by well techniques: West Conshohocken, Pennsylvania, ASTM International, 2003, DOI: 10.1520/D4043-17.

Cooper, H. H., and Jacob, C. E., 1946, A generalized graphical method for evaluating formation constants and summarizing well field history: American Geophysical Union, v. 27, p. 526-534.

Geological Survey of Alabama, 2018, Assessment of groundwater resources in Alabama, 2010-2016: Alabama Geological Survey Bulletin 186, 426 p.

Johnston, W. D., Jr., 1933, Ground water in the Paleozoic rocks of northern Alabama: Alabama Geological SurveySpecial Report 16, 414 p.

Kruseman, G. P., and deRidder, N. A., 1990, Analysis and evaluation of pumping test data, 2nd edition: Wageningen, The Netherlands, International Institute for Land Reclamation and Improvement, Publication 47, 370 p.

U.S. Geological Survey, 2003, Principal aquifers of the 48 conterminous United States, Hawaii, Puerto Rico, and the U.S. Virgin Islands, https://water.usgs.gov/ogw/aquifer/map.html, accessed October 18, 2017.

APPENDIX —
AQUIFER TEST DATA AND ANALYSIS FOR
WELL MTG-6, GSAL111889, MONTGOMERY COUNTY, ALABAMA

PROJECT INFORMATION

Company: Weldon-Hay
Client: Geological Survey of Alabama
Project: 22-9026
Location: Montgomery County, AL
Test Date: 11/30/23
Test Well: MTG-6

AQUIFER DATA

Saturated Thickness: 41.66 ft
Anisotropy Ratio (Kz/Kr): 1.

PUMPING WELL DATA

No. of pumping wells: 1

Pumping Well No. 1: MTG-6

X Location: 0. ft
Y Location: 0. ft

Casing Radius: 0.5 ft
Well Radius: 0.33 ft

Partially Penetrating Well
Depth to Top of Screen: 25.99 ft
Depth to Bottom of Screen: 41.66 ft

No. of pumping periods: 2

Pumping Period Data			
Time (min)	Rate (cu. ft/min)	Time (min)	Rate (cu. ft/min)
0.	1.86	64.	0.

OBSERVATION WELL DATA

No. of observation wells: 1

Observation Well No. 1: MTG-6

X Location: 0. ft
Y Location: 0. ft

Radial distance from MTG-6: 0. ft

Partially Penetrating Well
Depth to Top of Screen: 25.99 ft
Depth to Bottom of Screen: 41.66 ft

No. of Observations: 27

Observation Data

Time (min)	Displacement (ft)	Time (min)	Displacement (ft)
0.5	6.66	18.	10.5
1.	7.66	23.	10.66
2.	8.19	25.	10.73
3.	8.88	30.	10.84
4.	9.37	32.	10.93
5.	9.52	35.	10.96
6.	9.63	38.	11.02
8.	8.83	42.	11.16
9.	9.95	47.	11.26
11.	10.	52.	11.33
12.	10.1	56.	11.39
13.	10.16	62.	11.43
14.	10.21	63.	11.45
17.	10.33		

SOLUTION

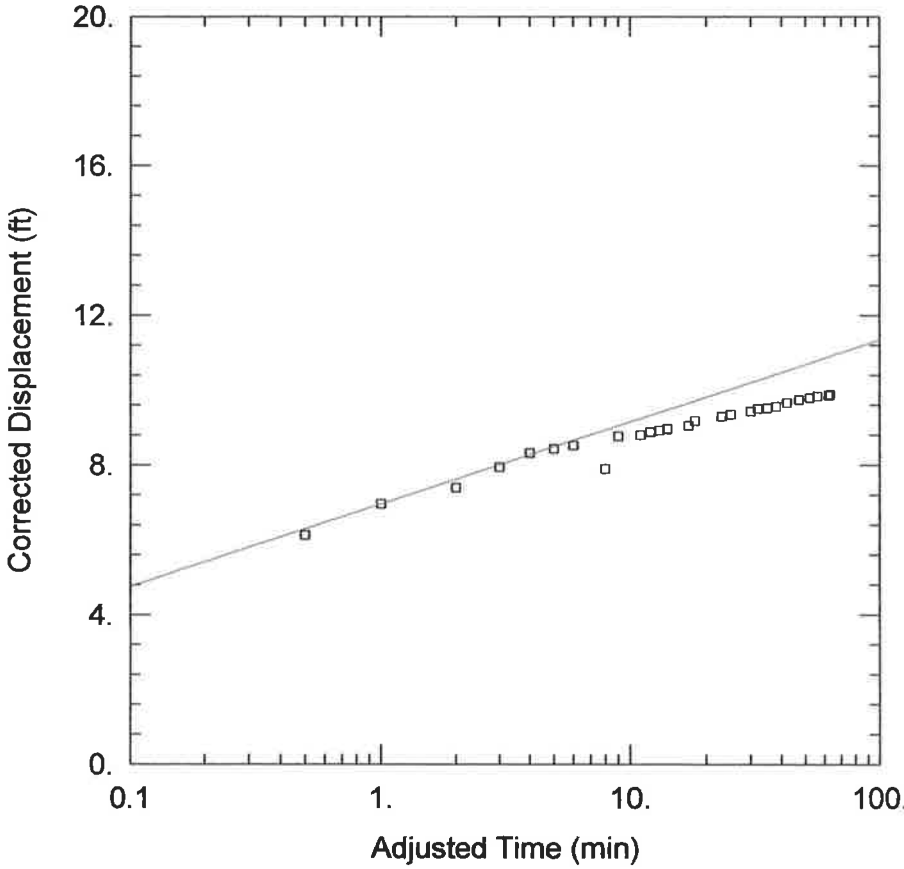
Pumping Test
Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

VISUAL ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	
T	0.1554	ft^2/min
S	0.002149	

K = T/b = 0.00373 ft/min (0.001895 cm/sec)
Ss = S/b = 5.158E-5 1/ft



PROJECT INFORMATION
Company: Weldon-Hay
Client: Geological Survey of Alabama
Project: 22-9026
Location: Montgomery County, AL
Test Well: MTG-6
Test Date: 11/30/23

AQUIFER DATA

Saturated Thickness: 41.66 ft

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
MTG-6	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
□ MTG-6	0	0

SOLUTION

Aquifer Model: Unconfined

Solution Method: Cooper-Jacob

T = 0.1554 ft^2/min

S = 0.002149

Data Set: C:\Users\GGuthrie\OneDrive - ogb.state.al.us\Projects\USGS_Well Rehab\MTG6_test2.aqt

PROJECT INFORMATION

Company: Weldon-Hay
Client: Geological Survey of Alabama
Project: 22-9026
Location: Montgomery County, AL
Test Date: 11/30/23
Test Well: MTG-6

AQUIFER DATA

Saturated Thickness: 41.46 ft
Anisotropy Ratio (Kz/Kr): 1.

PUMPING WELL DATA

No. of pumping wells: 1

Pumping Well No. 1: MTG-6

X Location: 0. ft
Y Location: 0. ft

Casing Radius: 0.5 ft
Well Radius: 0.33 ft

Partially Penetrating Well
Depth to Top of Screen: 25.79 ft
Depth to Bottom of Screen: 41.46 ft

No. of pumping periods: 2

Pumping Period Data			
Time (min)	Rate (cu. ft/min)	Time (min)	Rate (cu. ft/min)
0.	1.88	61.	0.

OBSERVATION WELL DATA

No. of observation wells: 1

Observation Well No. 1: MTG-6

X Location: 0. ft
Y Location: 0. ft

Radial distance from MTG-6: 0. ft

Partially Penetrating Well
Depth to Top of Screen: 25.79 ft
Depth to Bottom of Screen: 41.46 ft

No. of Observations: 11

Observation Data

Time (min)	Displacement (ft)	Time (min)	Displacement (ft)
1.	5.06	11.	9.9
2.	6.09	18.	10.47
3.	7.53	27.	10.65
4.	8.5	51.	10.97
5.	9.	55.	11.06
6.	9.37		

SOLUTION

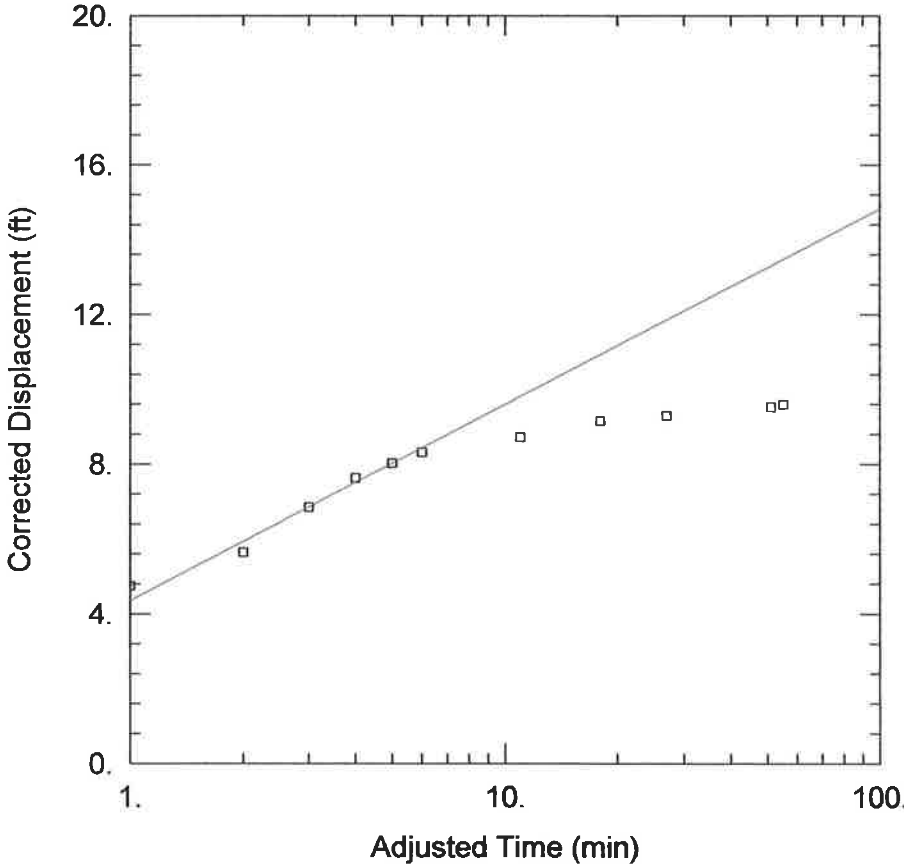
Pumping Test
Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

VISUAL ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	
T	0.06593	ft^2/min
S	0.1978	

K = T/b = 0.00159 ft/min (0.0008078 cm/sec)
Ss = S/b = 0.004771 1/ft



PROJECT INFORMATION

Company: Weldon-Hay
Client: Geological Survey of Alabama
Project: 22-9026
Location: Montgomery County, AL
Test Well: MTG-6
Test Date: 11/30/23

AQUIFER DATA

Saturated Thickness: 41.46 ft

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
MTG-6	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ MTG-6	0	0

SOLUTION

Aquifer Model: Unconfined

Solution Method: Cooper-Jacob

T = 0.06593 ft^2/min

S = 0.1978

GEOLOGICAL SURVEY OF ALABAMA
420 Hackberry Lane
P.O. Box 869999
Tuscaloosa, Alabama 35486-6999
205/349-2852

Berry H. (Nick) Tew, Jr., State Geologist

A list of the printed publications by the Geological Survey of Alabama can be obtained from the Publications Office (205/247-3636) or through our website at http://www.gsa.state.al.us/.

E-mail: publications@gsa.state.al.us