Hydraulic testing of NGWMN wells by the Iowa Geological Survey

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INTRODUCTION

The National Ground-Water Monitoring Network (NGWMN), which was established to assess long-term water-level and water-quality trends at a national scale, provides a unique opportunity to collect and share date from different states, agencies, and others. The Iowa Geological Survey (IGS) at the University of Iowa joined the NGWMN in 2017 to cover a gap in the network's Midwest coverage. The IGS contributes 40 wells, completed in the Cambrian-Ordovician (USGS national code S300CAMORD), Cretaceous (N300lLCRTCS), Mississippian (N500MSSPPI), and Silurian-Devonian (N400SLRDVN) aquifers, where quarterly static water level measurements are made to the NGWMN.

Many of the IGS wells are decades old and lack documentation of when (or if) water was last purged or if hydraulic tests were ever conducted. Through U.S. Geological Survey (USGS) Award #G18AC00077, the IGS received funding to pump water and conduct hydraulic tests on seven (7) selected NGWMN sites. This report describes the work performed and results obtained under this award.

WELL SELECTION

The IGS received funding to pump water and conduct hydraulic tests on seven (7) selected NGWMN sites. When the proposal for funding was submitted to the USGS, the IGS had not finished its selection of wells for inclusion into the NGWMN. Therefore, specific NGWMN sites for hydraulic testing could not be provided at that time. By the start of this award, the IGS had finished its NGWMN site selection. Nine (9) wells at seven (7) locations were selected for pumping and hydraulic testing (figure 1). Appendix A contains more detailed information on the wells, including their NGWMN IDs.

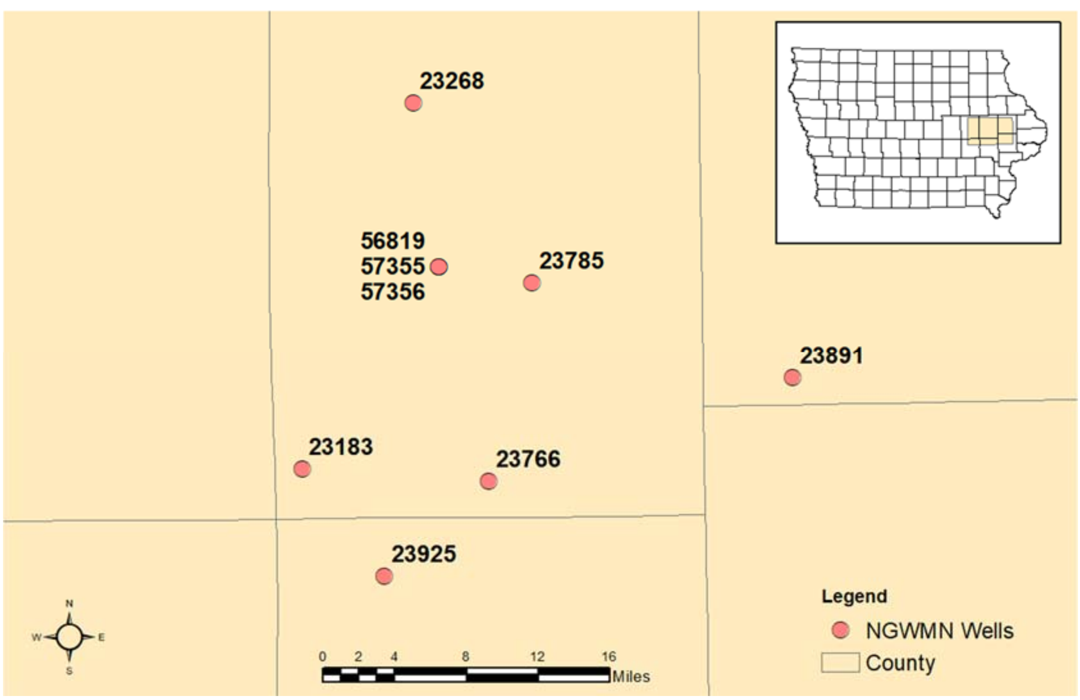


Figure 1. Location of wells selected for pumping and hydraulic testing.

Well caps on six of the selected wells hindered access into the wells and were modified to allow access. Figure 2 shows an example of a well cap before and after modification. The top of the cap was removed using a reciprocating saw with a metal cutting blade. A new measuring point was established on the new top. A locking well cap was installed to secure the well. The cap was then covered with a PVC cap to prevent precipitation accumulating on the top of the well.

Figure 2. A well cap on an IGS network well before (left) and after (right) modification.

WELL PUMPING

Water was purged from the wells in the fall 2018. Eight (8) of the nine (9) sites were pumped using a 3" submersible pump. Water was purged from these sites until either the water's specific conductance readings stabilized or three well volumes of water had been removed. The remaining site, NGWMN ID 57356, was pumped using a 1½" Grundfos Redi-Flo submersible pump. This particular well is only 40 feet deep and has been pumped dry using the Redi-Flo in the past. This well was once again pumped dry. The water level was allowed to recover for thirty (30) minutes and the well was again pumped dry. The water level was allowed to recover again for thirty minutes and the well was again pumped dry.

Pumping varied from well to well. Some wells pumped clear water for the entire pumping cycle. Other wells pumped initially pumped rusty colored water and the water slowly cleared (figure 3). Two wells, NGWMN IDs 23183 and 23268, pumped rusty colored water at two intervals. An initial wave of rusty water was observed and eventually cleared with pumping. A second wave of rusty water then came and cleared with continued pumping. The amount of drawdown observed in each well was variable. Some wells had no drawdown. One well had approximately 30' of drawdown before the water level stabilized.

Figure 3. Comparison of water at beginning (top) and end (bottom) of well pumping.

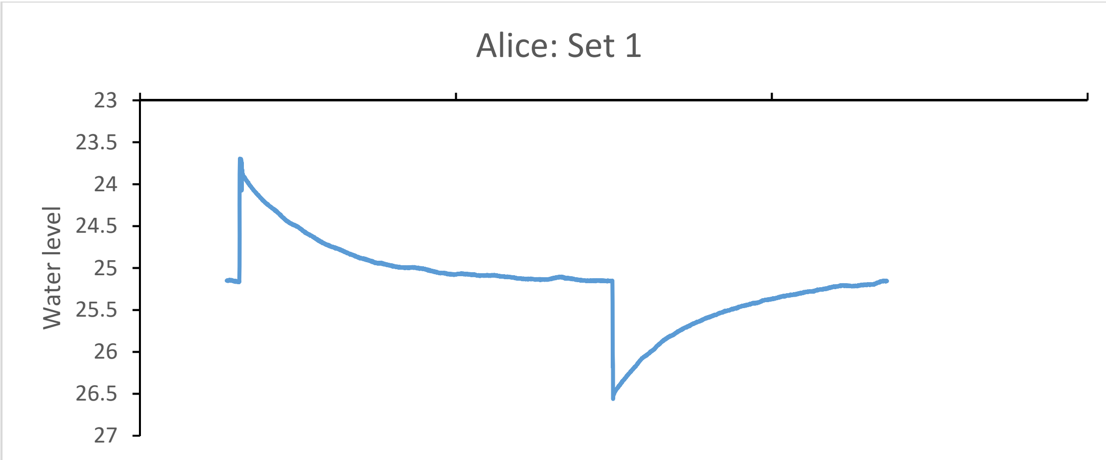
Pumping identified a problem at the Plum Creek (NGWMN ID 23925) site. The initial water level was measured at approximately 62 feet below the well's measurement reference point. The pump was placed at approximately 100 feet below the surface. Within minutes of activating the pump, the pump started to pump air. The pump was subsequently lowered to approximately 130 feet below the surface, which is the maximum depth the IGS pump can be lowered. Again, the pump started to pump air within minutes of turning on the pump. The pump was removed. An e-line was lowered into the well so that we could monitor the water level recovery. The e-line went slack (without sounding) at approximately 130 feet. The interpretation of this is an obstruction at approximately 130 below the surface is preventing water from flowing into the well. Further investigation is needed to determine the cause of the obstruction and to see if the well can be rehabilitated.

HYDRAULIC TESTING

Mechanical slug tests were conducted at eight (8) of the nine wells. The Plum Creek site, which is believed not to be in connection with the aquifer based on pumping results, was the only site where a slug test was not conducted. The slug tests followed procedures established in the USGS' groundwater technical procedure document (GWPD) 17 (Cunningham and Schalk, 2011). A 4 inch diameter, 4 foot long slug was used in wells with 5 or 6 inch diameter casings. A 2½ inch diameter, 3½ foot long slug was used in wells with 4 inch diameter casings. A minimum of four slug tests were conducted at each site (two slug in and two slug out tests). Additional slug in or slug out tests were conducted at sites if any of the original tests seemed anomalous.

Water levels during the slug tests were collected using a pressure transducer with a built-in data logger (In-Situ Level TROLL 700). The data collection interval varied from 0.25 to one (1) second depending on the anticipated response of the aquifer to the slug's introduction and removal. Data from the slug tests was processed in Microsoft Excel and analyzed using the AquiferTest 7.0 software (Waterloo Hydrogeologic). Two separate test methods were used to analyze the slug tests and determine hydraulic conductivity (K): Hvorslev (1951) and Bulter et al. (2003). The Hvorslev method was used in wells where the water level response to the introduction/removal of the slug had minimal oscillations. The Butler method was used in wells where the water level response to the introduction/removal of the slug produced significant oscillations. A comparison of non-oscillatory and oscillatory response is shown is figure 4.

Slug test results are presented in Table 1. Hydraulic conductivities varied considerably between wells with average K ranging from 0.2 to 967 feet/day. Unfortunately, no previous estimates of hydraulic conductivity exists to compare the current results. The current results will be used as the baseline to compare future hydraulic conductivities against.



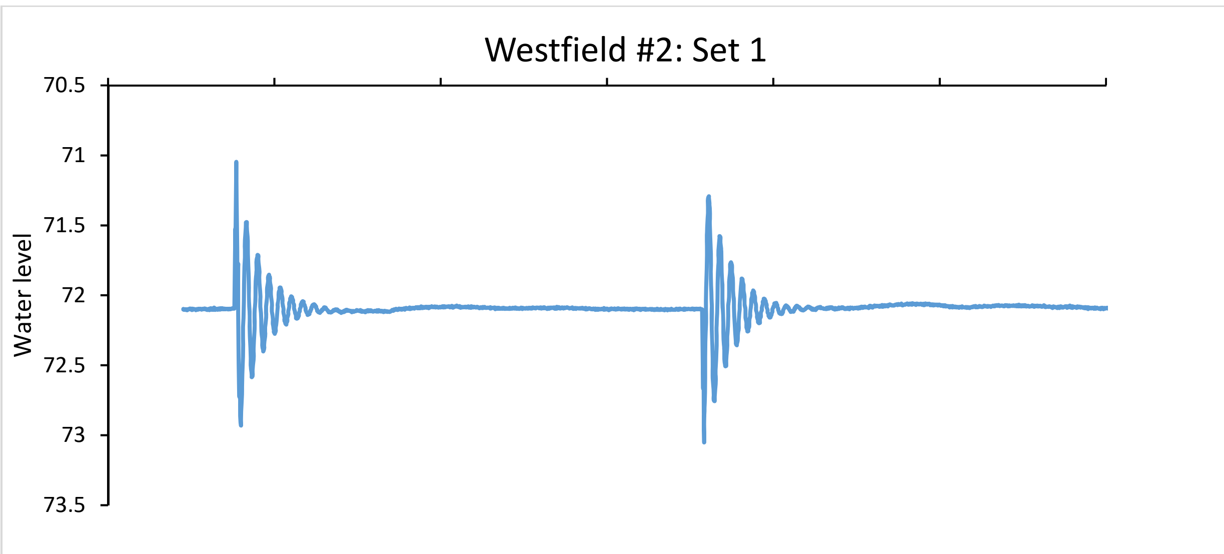


Figure 4. Water level response to introduction/removal of slug: non-oscillatory (top) and oscillatory (bottom).

The slug tests were conducted in wells located in bedrock aquifers where much of the formations permeability/water movement often comes from small zones within the formation containing fractures and/or voids (e.g. secondary openings). Wells with lower K suggests minimal hydraulic connection to fractures and/or voids within the bedrock; whereas, wells with higher K suggests connection to an area of the bedrock with secondary openings. For example, the highest K measured, 987 ft/day, was at Westfield #2, NGWMN ID 57355, (table 1). Westfield #2 is a Devonian well with an open borehole from 138 feet to 200 feet. Prior to Westfield #2's construction, a flowmeter log (available at https://www.iihr.uiowa.edu/igs/geosam/uploads/2016/05/75336_56819_FlowmeterLog.jpg) was generated for a test well located with 10 ft. of the well. Based on this log, significant flow occurs in a zone between 160 and 200 feet below the ground surface. The depth of this productive water zone corresponds with portion of the aquifer measured by Westfield #2 slug test, which indicates a hydraulic connection to secondary openings within that portion of the aquifer and supports the high K measured by the slug test

Table 1. Results from slug tests conducted on the NGWMN wells.

Location (NGWMN ID)	Hydraulic Conductivity (feet/day)		Method
	Average	Range	
Alice (23268)	0.2	0.2 to 0.2	Horslev
Ely NW (23766)	48	42 to 59	Horslev
Marion (23785)	50	44 to 55	Butler
Stockpile (23183)	1.6	0.7 to 2.2	Horslev
Westfield #1 (56819)	262	131 to 514	Butler
Westfield #2 (57355)	987	841 to 1,160	Butler
Westfield #3 (57356)	11	10 to 13	Horslev
White Oak (23891)	1.5	0.9 to 2.0	Horslev

The raw data and analysis results of the slug tests have been entered into IGS Pump Test (https://www.iihr.uiowa.edu/igs/pump-test/) to allow public access. Entries into IGS Pump Test are screened randomly to ensure data standards are maintained.

WEBSERVICE AND DATABASES

The IGS did not encounter any problems with its web services transferring data to the NGWMN data portal in this contract period.

At the present, no changes in databases or web services are expected that would impact future integration of web services with the NGWMN data portal.

SUMMARY

The IGS has achieved all of the project goals. Specifically, we pumped water from nine (9) NGWMN wells located at seven (7) sites to ensure the wells were still in connection with the aquifer. Mechanical slug tests were conducted at eight (8) of the nine wells to establish baseline hydraulic conductivity for future comparison. The raw data and analysis results of the slug tests have been entered into IGS Pump Test for public access.

References

Butler Jr, J. J., Garnett, E. J., and Healey, J. M., 2003, Analysis of Slug Tests in Formations of High Hydraulic Conductivity, Groundwater, 41(5), 620-631.

Cunningham, W.L., and Schalk, C.W., comps., 2011, Groundwater Technical Procedures of the U.S. Geological Survey: U.S. Geological Survey Techniques and Methods 1–A1, 151 p.

Hvorslev, M. J., 1951, Time Lag and Soil Permeability in Ground-Water Observations, Vicksburg, MS: U.S. Army Waterways Experiment Station.

APPENDIX A

DETAILED WELL INFORMATION

NGWMN ID	Name	County	Latitude	Longitude	Accuracy	Drill Date	Well Depth	Aquifer
23183	Stockpile	Linn	41.901831	-91.802555	GPS +/- 10 m.	8/8/1972	569	Silurian/Devonian
23268	Alice	Linn	42.197431	-91.676045	GPS +/- 10 m.	7/11/1973	435	Silurian/Devonian
23766	Ely NW	Linn	41.889658	-91.600499	GPS +/- 10 m.	5/12/1976	401	Silurian
23785	Marion	Linn	42.050092	-91.549517	GPS +/- 10 m.	6/2/1976	481	Silurian
23891	White Oak Cr.	Jones	41.96909	-91.26849	GPS +/- 10 m.	6/24/1976	517	Silurian
23925	Plum Cr.	Johnson	41.814384	-91.714701	GPS +/- 10 m.	7/27/1976	535	Silurian/Devonian
56819	Westfield #1	Linn	42.06398	-91.6509	GPS +/- 10 m.	1/15/2003	445	Silurian
57355	Westfield #2	Linn	42.06401	-91.65086	GPS +/- 10 m.	2/10/2003	200	Devonian
57356	Westfield #3	Linn	42.063995	-91.65088	GPS +/- 10 m.	1/21/2003	40	Devonian

NGWMN ID	Name	HLINK
23183	Stockpile	https://www.iihr.uiowa.edu/igs/geosam/well/23183/general-information
23268	Alice	https://www.iihr.uiowa.edu/igs/geosam/well/23268/general-information
23766	Ely NW	https://www.iihr.uiowa.edu/igs/geosam/well/23766/general-information
23785	Marion	https://www.iihr.uiowa.edu/igs/geosam/well/23785/general-information
23891	White Oak Cr.	https://www.iihr.uiowa.edu/igs/geosam/well/23891/general-information
23925	Plum Cr.	https://www.iihr.uiowa.edu/igs/geosam/well/23925/general-information
56819	Westfield #1	https://www.iihr.uiowa.edu/igs/geosam/well/56819/general-information
57355	Westfield #2	https://www.iihr.uiowa.edu/igs/geosam/well/57355/general-information
57356	Westfield #3	https://www.iihr.uiowa.edu/igs/geosam/well/57356/general-information