Information Gap Filling and Continuing Operations for the Maine Groundwater Level Monitoring Network, 2018-2021

Final Technical Report for NGWMN Award Number G18AC00079:
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Introduction

The Maine Groundwater Monitoring Network was created by the Maine Geological Survey (MGS) in 2017 by a selection of 32 wells at 22 unique site locations that are monitored by the Maine Department of Environmental Protection (MEDEP). This selection was made specifically for inclusion in the National Groundwater Monitoring Network (NGWMN), and the work was performed under a US Geological Survey (USGS) cooperative agreement that began on September 1, 2016 (Award Number G16AC00077). The wells were selected based on their geographic distribution around the state, distance from existing USGS wells, long records of greater than ten years, and representation of Maine's principal aquifers. Further objectives in monitoring long-term groundwater wells include improving access to groundwater level information that represents background conditions unaffected by anthropogenic activities and providing information about long-term changes to groundwater due to climate change.

In 2018, MGS was awarded funding from the USGS to continue our ongoing work with the NGWMN, by maintaining and improving Maine's contribution to the network (Award Number G18AC00079). Project tasks included maintaining the current network infrastructure, adding new wells to the network, and performing field work to gather and fill gaps in information about current network wells and sites. The project included two of the five objectives supported in the Program Announcement document: Objective 3, to fill gaps in information at NGWMN sites, and Objective 2, to support persistent data services from existing data providers.

This project was originally proposed to last from September 1, 2018 through August 31, 2020; however, due to complications to field work from the COVID-19 pandemic, the end date was extended to February 28, 2021. This report serves as the Final Technical Report to the USGS for this completed project, describing the work that was performed and the results that were obtained.

Description of work

Overall, the project was very successful. In Year 1, we visited all of the original 22 unique site locations in our network and measured and surveyed 29 wells with an RTK GPS system. In Year 2, we returned to 12 of these wells to take down-hole videos of the well casings, screens, and bores. As a result of the project, most informational gaps that existed at the beginning of the project were eliminated. In addition, 5 wells were removed from our network and 1 new replacement well was added. During the project, we found original lithologic logs for 2 wells, and created new lithologic logs for another 2 wells based on the down-hole well bore videos. As part of our support and maintenance work, we diagnosed and repaired a server address issue that was preventing the NGWMN portal from finding our web services and we kept up-to-date the list of sites and attributes in the well registry and MGS databases, among several other accomplishments.

Objective 3: Information gap filling

The information gap filling objective involved three tasks, a GPS survey, a physical measurement and observation task, and a down-hole camera inspection. Table 1 summarizes the work tasks that were completed at each individual well.

Table 1. Summary of work completed by well site number.

SiteNo	Well Removed	New Well Added	Survey and Measurement	Video
39412			X	
39413			X	
39414			X	
39415			X	
39870			X	X
39939			X	X
39954			X	X
39965			X	X
40005			X	X
40412			X	
40460			X	X
40496			X	X
40568	X			
40775			X	X
40966	X			
40967	X			
40973	X			
41155	X		X	
41176			X	X
41259			X	
41260			X	
41675			X	
41901			X	X
42037			X	
42147			X	X
48169			X	
52215			X	X
66131			X	
66132			X	
66134			X	
66408			X	
66409			X	
100408		X	X	

GPS survey of ground surface and measuring point

At the 29 wells indicated in Table 1, we used a survey-grade global navigation satellite system (GNSS) to survey the water-level measuring point on the top of the well casing, collecting latitude, longitude, and elevation in the NAD83(2011) (horizontal) and NAVD88 (vertical) datums. The GNSS equipment consisted of a Leica GS14 smart GPS antenna mounted on a leveling rod or tripod and a Leica CS15 field controller (Leica Geosystems AG) (Figure 1).

Figure 1. The GNSS antenna collecting GPS data and RTK correction information, mounted on a tripod over the measuring point of well number 40460 in Milo, Maine.

At 26 of the 29 surveyed wells, cellular data connections were available and the GNSS system was able to use real-time kinematic (RTK) correction using base station information from the Continuously Operating Reference Station (CORS) network maintained by the Maine Department of Transportation. The RTK corrections allowed us to collect precise locations with an average accuracy of 2 cm horizontally and 4 cm vertically. Three of the 29 surveyed wells were outside the reach of a cellular data connection. At these locations, we performed a static occupation of the site with the GNSS system, collecting dual-frequency GPS carrier phase observables that were later uploaded to the NOAA Online Positioning User Service (OPUS) for post-processing correction. At 2 wells (41176 and 100408), the OPUS correction was successful, resulting in average accuracy of 10 cm horizontally and 6 cm vertically. At well 40412, heavy tree-cover in a small stream valley made the GPS data too noisy to correct with OPUS. At this location, the uncorrected GPS accuracy was 2.1 m horizontally and 2.9 m vertically.

As a result of this surveying work, information gaps related to spatial location, elevation, location accuracy, survey method, and vertical datums were eliminated for all wells in our current network, and the quality of our location and elevation information was greatly improved.

Measurement of physical well dimensions and observations

At the 29 wells we visited in Year 1, we also recorded physical observations and measurements of the wells and their environment. We measured the height of the measuring point (surveyed in Task 1) above the ground surface, the diameter of the well casing, the depth to water using an electric water level measuring tape, and the depth to the bottom of the well using a weighted fiberglass tape measure. We recorded the casing material, a description of the measuring point, and other dimensional notes and observations about the well. We also recorded observations about site and well access and the condition of the well, and took photographs of the well and immediate environment.

As a result of this task, information gaps related to the casing material, casing diameter, casing stickup (difference between measuring point and ground surface elevations), and well depth were eliminated for all wells in our current network. We also gathered general information about access and conditions at the sites and wells that will help us with ongoing work with the network.

Down-hole camera inspection

In Year 2, we visited 12 of the wells that had been visited in Year 1 to record color digital videos of the well casings, screens, bores, and bottoms. The video system consisted of a submersible GeoVISION Nano Camera (Alleghany Instruments, Inc.) suspended on a graduated cable with a digital depth encoder (Figure 2). For this task, we prioritized wells that lacked information about the casing or screened interval, and bedrock wells where lithologic logs were unavailable, followed by wells for which the screen material and size were unknown.

Among the 12 wells that were visited were all the wells in our network where the casing and screen intervals were unknown, and all bedrock wells that were missing lithology information. At each well, we set up the camera so that the lens was positioned three feet below the monitoring point, zeroed the depth counter, then began recording video while lowering the camera slowly to the bottom of the well. At interesting or ambiguous locations, the camera could be raised and lowered repeatedly to get better views of the casing, screen, or bore. The videos were saved as mp4 digital video files, and the depth encoder printed the camera depth in feet at the corner of the videos, so that the depth of observed features was recorded. By taking notes in the field and watching the recorded videos later in the office, we were able to use this system to record the depths of casings, screens, and lithologic features, and to observe the screen material and size.

As a result of this task, information gaps related to casings and screens were eliminated for all wells in our current network; however, we were not able to observe the lithology for all the wells that were missing lithologic logs. While we did visit and take videos at all 7 of the bedrock wells that were missing logs, only two of them turned out to have uncased intervals where the well bore could be observed. For these two wells (40005 and 42147), the camera inspection allowed us to create detailed logs with descriptions of rock type, color, texture, and fractures that were observable on the walls of the well bore. For 2 additional wells, we were able to locate original lithologic logs during the project period (see below under the Support and Maintenance Objective).

Figure 2. (*Left*) The video camera system set up at well 40496 in Greenbush, Maine. (*Right*) The depth encoder and cable positioned over the measuring point at the top of the well casing. The camera is inside the casing, with the lens three feet below the measuring point.

Objective 2: Support and maintenance of persistent data services

Goals of the support and maintenance objective included keeping the list of sites in the well registry and our database current, classifying and entering information for new sites, routine updates to site information in our existing network of sites, maintaining our database and database connections to EGAD, and maintaining our web services and updating them as needed.

Well removals and replacements

During site visits related to the gap filling objective, we made discoveries that caused us to remove 5 of the original wells from our network (Table 2) and replace 1 of them with a new, nearby well in the same aquifer (Table 3). The 5 removed wells were turned off in the NGWMN Well Registry in June 2020, and the new well was added in December 2020.

At one industrial site in Westbrook, Maine, there were 3 network wells (40966, 40967, and 40973) that had been recently made inaccessible due to site changes at the active paper mill, and we could not reach the wells to even confirm if they still existed. No suitable replacement wells were available at this site because of continuing concerns about access.

In Dexter, Maine, we were able to survey and measure well 41155, but the casing was found to be damaged at the ground surface and contaminated with an oily substance at the water surface. As a result, we ended monitoring here and removed the well from the network. No suitable replacement well was available at this site.

In Princeton, Maine, we were informed by the site custodian that the well that had been in our network there (40568) had been recently abandoned and completely removed, and environmental monitoring moved to several newer wells installed in 2011 and 2012. Using information from recent monitoring reports and our observations at the site, we selected one of these new wells (100408) to serve as a replacement in our network. Information about well 100408 was gathered from paper records held by the landowner (a hydrogeologic investigation report, monitoring reports, and drilling logs) and our field work described above, then entered into the NGWMN Well Registry and our internal database. The water level record was analyzed, and the well classified into the “background” subnetwork and the “trend” monitoring category using guidance from the NGWMN Framework Document and Tip Sheets.

Table 2. Wells removed from the network during the project period.

SiteNo	Latitude	Longitude	Depth	National Aquifer	Replacement SiteNo	Reason for removal
40568	45.169268	-67.472746	35.3	Sand and gravel aquifers (glaciated regions)	100408	well abandoned and removed; replace with 100408
40966	-67.472746	-70.346249	36.5	Other aquifers (marine deposits)		no longer measured: no access
40967	43.686291	-70.346638	36.0	Sand and gravel aquifers (glaciated regions)		no longer measured: no access
40973	43.686893	-70.346694	15.0	Sand and gravel aquifers (glaciated regions)		no longer measured: no access
41155	45.022676	-69.270112	9.8	New England crystalline-rock aquifers		no longer measured: well contaminated

Table 3. New replacement wells added to the network during the project period.

SiteNo	Latitude	Longitude	Depth	National Aquifer	Replaced SiteNo
100408	45.1743272	-67.4729535	20.0	Sand and gravel aquifers (glaciated regions)	40568

Updates to information at existing sites

In April 2019, we found a missing drilling log for well number 40775 after discussions with a new staff member at the MEDEP. The lithology for this bedrock well had been previously unknown, so we updated the lithology in our database. This find was lucky, because this bedrock well was one of those that was found to be completely cased when we took a down-hole video in 2020.

In June 2020, we updated the NGWMN registry and our database to change the monitoring category for wells 39939, 66131, 66132, 66134, 66408, and 66409. These wells were moved from the “trend” category to the “surveillance” category due to a low frequency of measurement in recent years. These wells are located at long-term MEDEP remediation sites and have had their required measurement frequency reduced by agreement with the landowners.

Internal database modifications

Throughout the project, several changes in the MGS database had to be made to accommodate new and updated site information collected for the gap filling objective. We sent updated information to project managers at MEDEP, but we also wanted to store values in preferred formats and with appropriate precision for the NGWMN and to make them easier to edit at MGS. As a result, we moved several fields from the MEDEP database to the MGS database as a primary storage location for serving to the NGWMN. These fields were DecLatVa, DecLongVa, HorzDatum, HorzMethod, HorzAccuracy, and WellDepth. We increased field width for the character fields HorzDatum, HorzMethod, AltDatumCd, and AltMethod to accommodate longer entries. We also increased the precision on the numeric latitude and longitude fields DecLatVa and DecLongVa to store 7 digits after the decimal place, to match the precision of our newly surveyed locations (precision equivalent to approximately 1 cm).

Problems encountered serving data

In June 2020, it came to our attention that the NGWMN Portal was not able to access our web services, and many of the wells that we were serving to the Portal appeared there without recent water level data updates. After a series of troubleshooting steps and discussions between MGS staff and technical staff at the USGS Water Mission Area, we discovered that the NGWMN Portal was trying to reach our web services with a misconfigured REST URL. After the Portal updated its URLs to our web services on July 16, the service was restored, and up-to-date data appeared in the Portal.

Updates to web services

There were no updates to our web services during the project period. During discussions with USGS technical staff in June and July 2020, described above, we investigated moving our web services host from an ArcServer installation to ArcGIS Online, but it was determined that the data format returned (JSON or GeoJSON) was not consumable by the NGWMN Portal, and serving data in the required format (XML) could not be easily accomplished with ArcGIS Online. At this time, web services remain on the original ArcServer host.

Future changes to web services

We do not anticipate any changes in the near future to our databases or web services that would impact integration with the NGWMN Portal.

Conclusion

Maine's NGWMN Project (Award Number G18AC00079) conducted September 1, 2018 to February 28, 2021 was very successful. Project tasks that were completed included field work to fill information gaps at 29 network wells, the removal of 5 problematic wells from the network, the addition of 1 new replacement well, and maintenance of network infrastructure including internal databases, web services, and the Well Registry. As a result of this project, most preexisting informational gaps have been eliminated, well information has increased in quality, well locations and elevations have been surveyed with high accuracy, and the network functionality and utility has continued to improve.