New Hampshire Geological Survey
New Hampshire Department of Environmental Services
National Ground-Water Monitoring Network Project
(Cooperative Grant Agreement No. G22AC00123)
7/15/2022 – 7/14/2024
Final Report

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Attn: Jason Fine

By

Michael W. Howley, P.G., Senior Geoscientist
Principal Investigator
New Hampshire Geological Survey
29 Hazen Drive, PO Box 95
Concord, New Hampshire 03302-0095
(603) 271-2876
Michael.W.Howley@des.nh.gov

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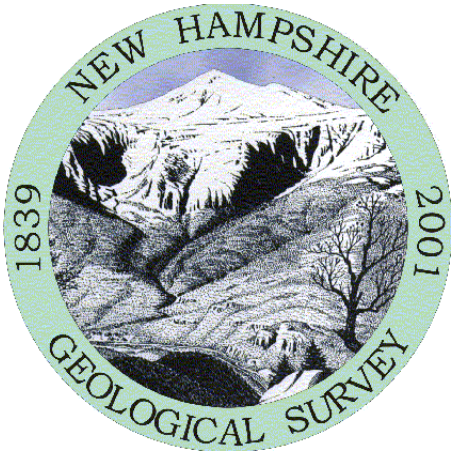

Introduction

The New Hampshire Geological Survey (NHGS), a unit within the New Hampshire Department of Environmental Services (NHDES), has been involved with the National Ground-Water Monitoring Network (NGWMN) since becoming a new data provider in 2016. NHGS's involvement with NGWMN has been as an initial data provider, standing up web services, performing evaluation and maintenance of the network wells to ensure compliance with the network criteria for inclusion, implementing procedures for data handling and quality control, replacing existing network wells, installing network expansion wells, and identifying data gaps. This document is meant to fulfill our obligation of a final report for our 2022 grant, Cooperative Grant Agreement No. G22AC00123, effective dates 07/15/2022 to 07/14/2024.

All groundwater level monitoring wells monitored by NHGS provide groundwater level data to the NGWMN and are part of New Hampshire's Groundwater Level Monitoring Network ("the network"). In addition to contributing daily and monthly groundwater level measurements to the NGWMN, the network is also utilized to evaluate the effects of meteorological drought on groundwater conditions within the State of New Hampshire. The network serves as a critical resource to both NHDES' internal and statewide Drought Management Teams. In addition, these data are crucial to instream flow evaluations and to evaluate the effects of longer-term climate change trends.

On a monthly basis, NHGS staff and volunteers collect data from the current 39 network wells, the locations of which are shown in Figure 1. Thirty-one (31) of the 39 network wells are equipped with transducers and data loggers which record hourly water level and temperature measurements. The monthly data collection at each site includes a monthly hand measurement at all wells and manual download of data from 4 wells equipped with data loggers where cellular service is not available. Twenty-seven (27) wells equipped with data loggers have cellular modems that transmit data daily to State of New Hampshire managed servers. Following data collection and quality control procedures, the data are loaded into a database management system. Once finalized, these data are then shared to the internet via web services and, in cooperation with USGS, are made publicly accessible through the NGWMN portal. NHGS prepares a monthly report of groundwater conditions across the network and provides the data along with hydrographs and statistical tables of monthly frequency analysis to stakeholders involved with drought management.

In our 2022 proposal, NHGS proposed the following tasks:

Objective 2, Part A:

- NHGS proposed to continue to collect, QC, database, and make groundwater level measurements available through our web services to support the continued flow of groundwater data to the NGWMN from the wells monitored by NHGS.

Objective 3:

- NHGS proposed to fill gaps in information at one existing NGWMN site, NHGS:NWWB-01, by conducting borehole video logging to determine well construction details. NHGS proposed to subsequently update NGWMN metadata with the construction details determined by the borehole video logging.

Objective 4:

- NHGS proposed to replace the corroded surface casing at one existing NGWMN site, NHGS:BBW-53.
- NHGS proposed to conduct maintenance pumping of 14 overburden wells currently in the NGWMN to assess and maintain their connection to the aquifer.

Objective 5:

- NHGS proposed to drill a replacement overburden well for one existing NGWMN site (Nashua, NHGS:NAW-218) and to drill one bedrock well at a network expansion site to fill a geographic gap in the NGWMN in Keene, New Hampshire.
- NHGS proposed to obtain the required metadata for the newly drilled wells, calculate initial well hydraulic conductivity for each replacement well, upload the metadata to the NGWMN portal, and purchase and install a continuous monitoring data logger in the NGWMN expansion site well in Keene.

Objective 2, Part A: Data and Web Service Management

NHGS continues to collect, curate and store groundwater level data from our network of monitoring wells. The current (October 2024) NHGS well network that provides data to the NGWMN Portal can be seen in Figure 1. These data are then exposed to the public through our web services and through a GIS web mapping application which displays the statistical analysis of the most recent groundwater level data. Over the last year, we have been engaged with USGS to ensure our web services are operating and providing data to the NGWMN network. Specifically, over the last year NHGS has worked with NGWMN data managers to redesign and reconfigure web services to maintain data flows that have been interrupted by changing security requirements for web services that serve water levels, and sunsetting of software NHGS previously used to support web services that serve well location, lithology, and construction details. These data flow issues have been resolved, and 100% of recent data retrieval requests from USGS NGWMN are successful as of October 17, 2024. NHGS also continues to work with the USGS New England Water Science Center to display up-to-date data from NHGS-monitored NGWMN groundwater wells on the Groundwater Levels in New England website. Inclusion of the NHGS NGWMN data alongside other USGS monitored sites in New Hampshire and elsewhere in New England has benefitted both the internal NHDES and statewide stakeholders and federal partners at the National Weather Service and U.S. Drought Monitor map authors.

Objective 3: Network Data Gap Filling

Under Objective 3, NHGS proposed to conduct borehole video logging in NHGS:NWWB-01 to determine well construction details, specifically the length of the steel casing in this bedrock well. Borehole video logging was conducted on September 19, 2023. The steel casing was determined to extend to a depth of 23.6 feet below ground surface. Following the completion of borehole video logging, NHGS updated NGWMN metadata in the Monitoring Location Registry and in the construction details that are exposed to NGWMN through NHGS' Web Services.

Objective 4: Network Well Maintenance Activities

NHGS proposed to replace the protective well casing that is part of well BBW-53. The replacement well casing was purchased in late September 2023 and was installed on May 2, 2024. The elevation of the new measurement point was updated in the NHGS database and

NGWMN registry. Photo 1 below shows the protective surface casing of NHGS:BBW-53 both before and after replacement.

Figure 1. Photos of the protective surface casing of BBW-53 before (left) and after (right) replacement of the surface protective casing.

NHGS proposed to conduct maintenance pumping in 14 existing NGWMN wells, specifically: ADW-14, ADW-15, BBW-53, CBW-34, CVW-02R, DDW-46, EPW-90, GSW-75, LCW-01, LLW-19, NFW-53, NPW-03, NPW-06, and OXW-38. Maintenance pumping was completed in these 14 wells between May 8, 2023 and June 6, 2023. The pumping duration, measured pumping rate, and approximate volume pumped from each well are reported in Table 1. Large amounts of fine sand and silt were removed from CVW-02R, DDW-46, GSW-75, and LCW-01 by the maintenance pumping. Oxidized metal particles were also observed during pumping of LCW-01. Subsequent borehole video logging conducted in LCW-01 showed significant oxidation occurring within the metal well riser, and approximately 2 feet of materials has accumulated within the well screen. Well redevelopment to remove the accumulated materials and sleeving of the well with PVC

was conducted in October 2023. Approximately 5 gallons of silty sand were removed from LCW-01 during redevelopment. Borehole video logging conducted after well redevelopment showed continued infiltration of sediment into the screened portion of LCW-01. We infer that LCW-01 was installed without a sand filter-pack to prevent infiltration of fine materials. Static groundwater levels in LCW-01 before and after well redevelopment are identical, indicating that the lack of sand filter-pack does not impact the continued use of this well for groundwater level monitoring.

Table 1. Maintenance Pumping Rates and Observations.

NGWMN Site ID	Well Depth	Date Pumped	Pumping Duration (minutes)	Pumping Rate (GPM)	Volume Pumped (gallons)	Change in Total Depth (feet)	Observations
NHGS:ADW-14	79.5	2023-05-16	40	0.3	12	-	
NHGS:ADW-15	18.0	2023-05-16	15	0.8	12	0.2	
NHGS:BBW-53	23.0	2023-06-06	20	0.8	16	0.2	
NHGS:CBW-34	106.6	2023-05-08	40	0.3	12	-	
NHGS:CVW-02R	60.0	2023-06-06	30	0.4	12	1.4	Sand and silt removed
NHGS:DDW-46	47.5	2023-06-06	20	0.5	10	0.5	Sand and silt removed
NHGS:EPW-90	37.8	2023-06-06	25	0.6	15	0.2	
NHGS:GSW-75	68.0	2023-06-06	35	0.4	14	0.8	Sand and silt removed
NHGS:LCW-01	30.0	2023-05-08	40	0.6	24	0.3	Sand, silt, and rust removed.
NHGS:LLW-19	42.0	2023-05-08	25	0.6	15	0.2	
NHGS:NFW-53	60.0	2023-05-16	25	0.4	10	0.2	
NHGS:NPW-03	56.4	2023-06-06	30	0.5	15	0.1	
NHGS:NPW-06	19.3	2023-06-06	20	0.8	16	0.2	
NHGS:OXW-38	114.7	2023-05-16	40	0.3	12	-	

Objective 5: Well Drilling

NHGS proposed to drill 2 wells in this grant proposal. One well was proposed as a replacement overburden well for NAW-218 located in Litchfield, New Hampshire. The second well was proposed as a NGWMN expansion site located in Keene, New Hampshire to fill a geographic gap in the NGWMN. During the two-year performance period NGWMN grant G22AC00123, NHGS has:

- Finalized the locations for the two wells to be installed.
- Negotiated access agreements on two State of New Hampshire-owned properties.
- Solicited bids and selected drilling contractors to perform the well installation.
- Entered into contracts with the selected drilling contractors.
- Completed installation of replacement well NHGS:LMW-36 and expansion well NHGS:KEWB-01.
- Collected initial site metadata including well construction details, GPS position, and other required site metadata of the new wells
- Uploaded site metadata to the NGWMN Monitoring Location Registry for the two network expansion sites
- Purchased and installed continuous monitoring data loggers in both wells

Both wells are now serving groundwater levels to the NGWMN through our water level web services. Groundwater pressure transducers and data loggers ("loggers") to support continuous water-level data collection were purchased and installed in KEWB-01 and LMW-36 using funding provided by G22AC00123 in April 2024. The loggers are transmitting water level data to NHGS' servers daily by cellular telemetry. Entries have been created for both wells in the NGWMN location registry. Construction details, stratigraphic/lithologic information, and screen information for both wells has been made available through NHGS' web services.

NHGS:LMW-36

LMW-36 was installed on November 22, 2023 to a depth of 30 feet below ground surface into the "Sand and gravel aquifers (glaciated regions)". The well was drilled using hollow stem augers and constructed of 2-inch id PVC with 10-feet of screen and 22.4-feet of riser. The riser stick-up above ground surface is 2.40 feet. A locking cap and protective casing were cemented in place at the ground surface. GPS positions and elevations of the well were recorded, and the site metadata was entered into the NGWMN location registry. A cellular enabled data logger was deployed into the new well and daily groundwater level data transmissions were enabled.

Figure 2. Protective surface casings for replacement overburden well LMW-36 (left) in Litchfield, NH and NGWMN expansion well KEWB-01 (right) in Keene, NH,

NHGS:KEWB-01

KEWB-01 was installed on March 11-12, 2024 to a depth of 325 feet below ground surface into the "New England crystalline-rock aquifer". The well was drilled using mud-rotary drilling methods for the overburden and bedrock socket, and air-rotary methods for the bedrock portion of the well. Bedrock depth was found to be 32-feet below ground surface. The bedrock socket was drilled 26-feet into competent bedrock from the bedrock surface at 32-feet to a depth of 58-feet below ground surface. 6-inch diameter steel casing was installed from 2-feet above the ground surface to a depth of 58-feet. The casing was cemented in place and left to cure overnight. Bedrock drilling commenced the following day and continued to a total depth of 325-feet below ground surface. Budgetary constraints prohibited drilling any deeper in this well. Several productive fractures were encountered, and their depths and measured yields were recorded during drilling. A 30-minute air-lift yield test conducted at the conclusion of drilling measured a total yield of 25 gallons/minute. A locking well cap was installed onto the 6-inch steel casing. GPS positions and elevations of the well were recorded, and the site metadata

was entered into the NGWMN location registry. A cellular enabled data logger was deployed into the new well and daily groundwater level data transmissions were enabled.

Table 2. Summary of location and construction information for groundwater monitoring wells installed under NGWMN grant G22AC00123.

NGWMN Site ID	Latitude[1]	Longitude[1]	Land-surface altitude[2]	Date drilled	Hole depth	Well depth	Depth to top of screen / open interval	Depth to bottom of screen / open interval
NHGS:LMW-36	42.84472	-71.46636	182.90 ft	2023-11-22	94 ft	30 ft	20 ft	30 ft
NHGS:KEWB-01	42.95529	-72.27157	650.07 ft	2024-03-12	325 ft	325 ft	58 ft	325 ft

[1] Latitude and longitude determined by global positioning system, NAD83.
[2] Land-surface altitude estimated from USGS Connecticut River, NH State Plane LiDAR (2016), NAVD88.

Slug testing was conducted in replacement well NHGS:LMW-36 and expansion well NHGS:KEWB-01 after drilling and development was completed. Subsequent analysis of the slug-testing data was conducted using AQTESOLV v4.5 software. Hydraulic conductivity (K) was determined using the straight-line methods of Bouwer and Rice (1976) for unconfined aquifers from an overdamped slug test. Multiple slug-in (falling head) and slug-out (rising head) tests were conducted in each well. The hydraulic conductivity (K) values determined for each well from the falling head slug tests are presented in Table 3. The screened portion of NHGS:LMW-36 is installed in a glaciofluvial silty sand, sand, and gravel surficial deposit. A mean hydraulic conductivity value of 27.25 feet/day ($9.6x10^{-3}$ cm/sec) was determined from slug testing in this well, which is reasonable value for a silty sand to gravel aquifer. Multiple productive bedrock fracture zones were observed in the open portion of NHGS:KEWB-01 during well installation. The mean hydraulic conductivity determined for this well of 1.03 feet/day ($3.6x10^{-4}$ cm/sec) is in the middle of the range of values expected for a fractured crystalline bedrock aquifer (Freeze and Cherry, 1979, Table 2.2).

Table 3. Hydraulic Conductivity determined from slug tests in replacement well NHGS:LMW-36 and expansion well NHGS:KEWB-01.

Well	Test #	Test Type	Solution	Aquifer Model	Calculated K (feet/day)	Calculated K (cm/sec)
NHGS:KEWB-01	1	Falling Head	Bouwer-Rice	Unconfined	0.9895	$3.5x10^{-4}$
NHGS:KEWB-01	2	Falling Head	Bouwer-Rice	Unconfined	1.064	$3.8x10^{-4}$
NHGS:KEWB-01	3	Falling Head	Bouwer-Rice	Unconfined	1.05	$3.7x10^{-4}$
Mean Hydraulic Conductivity (± std. dev.)					**1.03 (± 0.04)**	**$3.6x10^{-4}$ (± $1.4x10^{-5}$)**
NHGS:LMW-36	1	Falling Head	Bouwer-Rice	Unconfined	28.04	$9.9x10^{-3}$
NHGS:LMW-36	2	Falling Head	Bouwer-Rice	Unconfined	26.21	$9.2x10^{-3}$
NHGS:LMW-36	3	Falling Head	Bouwer-Rice	Unconfined	27.51	$9.7x10^{-3}$
Mean Hydraulic Conductivity (± std. dev.)					**27.25 (± 0.94)**	**$9.6x10^{-3}$ (± $3.3x10^{-4}$)**

References:

Bouwer, H. and R.C. Rice, 1976. A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells, Water Resources Research, vol. 12, no. 3, pp. 423-428.

Bouwer, H., 1989. The Bouwer and Rice slug test--an update, Ground Water, vol. 27, no. 3, pp. 304-309.

Freeze, R.A., and J.A. Cherry, 1979. GROUND-WATER. Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 604 pp.

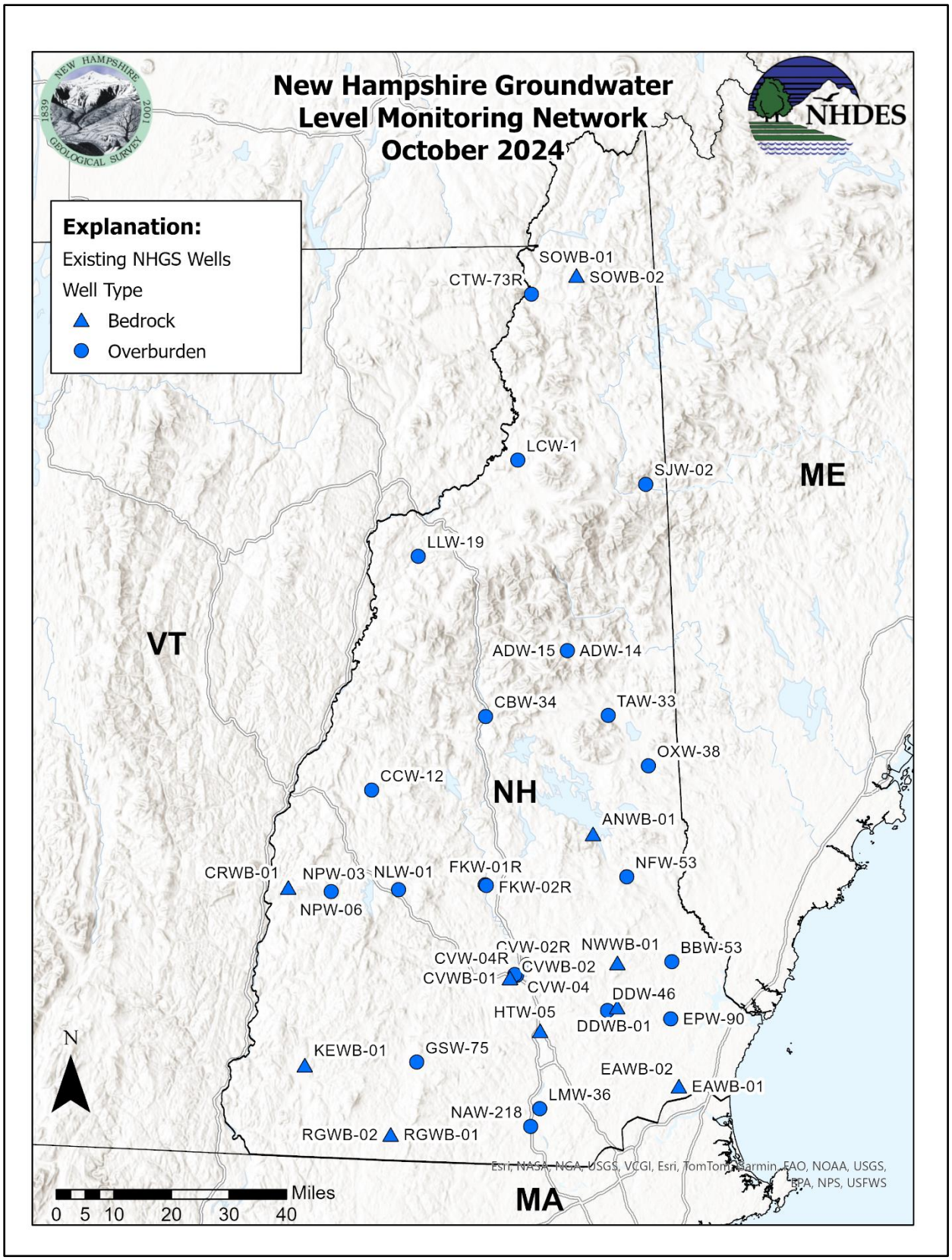

Figure 3. Map indicating the locations of existing NHGS wells contributing data to the NGWMN as of October 2024.