

An Overview of Hydrogeology Program Activities for April 2018 to March 2019

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Introduction

The Hydrogeology Program is one of nine program areas within the Geological Survey Division of the Nova Scotia Department of Energy and Mines. Over the past year the Hydrogeology Program continued to focus on broadening the province's understanding of the distribution of various naturally occurring contaminants in private well water, such as arsenic, uranium, and manganese. The Hydrogeology Program also investigated the distribution of corrosive groundwater in Nova Scotia, which is associated with leaching of metals, such as lead, from plumbing materials. About 40% of Nova Scotians use private wells for their water supply (Kennedy and Polegato, 2017), and these supplies are not regulated or monitored by the province for water quality. Therefore, exposure to well water contaminants poses a significant challenge for public health protection. Another key activity of the program in 2018-2019 was the development and field testing of a low-cost meter for monitoring water levels in shallow wells.

Staff of the Geological Survey Division and Nova Scotia Environment worked collaboratively on many of the projects described herein. Collaborative work with external organizations included providing data and technical support to various B.Sc. and M.Sc. student projects. Geological Survey Division activities related to geohazard research are reported in the Geohazard Program report (Drage and Kennedy, this volume, p. 13-16).

Program Highlights

Groundwater Data Management and Access

Updates to Groundwater Databases

Activities related to the management of provincial groundwater information in 2018-2019 included routine updating of groundwater databases, such as the Well Logs Database (Nova Scotia Department

of Energy and Mines, 2018a) and the Pumping Test Database (Nova Scotia Department of Energy and Mines, 2018b).

Web Services and Client Applications

A new client application for the relative risk of corrosive groundwater in drilled water wells was launched in 2019 and can be accessed at https://fletcher.novascotia.ca/DNRViewer/index.html?viewer=Drilled_Corrosive_Groundwater_NS.Relative_Corrosivity_of_Groundwater_in_Drilled_Water_Wells. Owners of drilled wells can enter their civic address and find out if their well is located in a relative low-, medium-, or high-risk zone for corrosive groundwater. The development of the risk zones is discussed in the following section. Where there is a higher potential for corrosive groundwater, there is a higher likelihood of concentrations of lead in well water exceeding acceptable levels. Because well water testing is the only way to find out whether lead is present, it is recommended that private well owners regularly test their water no matter where they live.

Another new client application was produced by Nova Scotia Environment and the Geological Survey Division in collaboration with students from Nova Scotia Community College. A groundwater level timeline map was created using groundwater level data from the Nova Scotia Groundwater Observation Well Network (Nova Scotia Environment, 2019). The map provides a visual representation of historical groundwater level data in Nova Scotia by comparing monthly groundwater levels to the historical averages at each observation well for the period between 2012 and 2017 (Leahy and Lloyd, 2018). The application can be accessed at <http://www.arcgis.com/apps/webappviewer/index.html?id=0074d282ec244efb889fab65b8d4bc22>.

The Nova Scotia Groundwater Atlas, which can be accessed at <https://fletcher.novascotia.ca/DNRViewer/?viewer=Groundwater>, was updated in July of 2018. The Potential Impact of Drought to Private Wells application was updated monthly

during the summer of 2018, and can be accessed at <https://fletcher.novascotia.ca/DNRViewer/?viewer=DroughtIndex>.

Groundwater Research and Mapping

Uranium in Well Water

Uranium is a naturally occurring contaminant in Nova Scotia groundwater and is associated with kidney damage at levels above the Health Canada (2017) maximum acceptable concentration (MAC) of 20 µg/L. A project was initiated in 2017 to review available research related to uranium in Nova Scotia well water, to develop our understanding of the hydrogeological controls of uranium in well water, and to produce a revised risk map to communicate risk to private well users. The overall objective of the project is to protect the health of Nova Scotians from exposure to uranium in well water by promoting the importance of water testing and appropriate treatment.

Activities of Geological Survey Division staff in 2018-19 included the publication of an Open File Report (Kennedy and Drage, 2018b) that reviews available research related to uranium occurrence in well water in Nova Scotia. A second report, investigating the association of uranium with various hydrogeologic criteria, and a new risk map and web mapping application, are planned for 2019-2020.

Potential Corrosivity of Groundwater

Lead in private well drinking water in Nova Scotia has been associated with corrosive groundwater that leaches lead and other metals from plumbing materials (e.g. Maessen et al., 1985; Sweeney et al., 2017). Waterborne lead is associated with various adverse human health effects, including neurological impacts, increased blood pressure and kidney damage, and is a probable human carcinogen (Health Canada, 2019). Health Canada recently lowered the maximum acceptable concentration of lead in drinking water from 10 µg/L to 5 µg/L (Health Canada, 2019). Although public drinking water systems in Nova Scotia are risk-managed for lead exposure, private well water supplies are not regulated; therefore, additional efforts to communicate risks are needed.

A project was initiated in 2018 to investigate spatial patterns of the potential corrosivity of

groundwater and lead in well water compared to Nova Scotia's major aquifer types. The project's goal was to produce a map to communicate to private well users the relative risk of having potentially corrosive well water, and hence the relative risk of having elevated levels of lead and other metals (e.g., copper) in their drinking water. In 2018-2019 the Hydrogeology Program published an Open File Report on the corrosivity of groundwater in Nova Scotia and its association with lead in private well water (Kennedy, 2019), and produced a risk map application indicating the relative risk of corrosive groundwater in private drilled wells.

Manganese in Well Water

Manganese is a naturally occurring chemical that is commonly found in Nova Scotia well water. The existing Health Canada guideline for manganese in drinking water is an aesthetic objective of 50 µg/L. However, a health-based maximum acceptable concentration of 120 µg/L (Health Canada, personal communication) has been proposed based on emerging epidemiological evidence (Health Canada, 2016). Manganese commonly occurs in Nova Scotia well water and it is estimated that approximately 30% of the province's private water wells will have manganese levels above the proposed Health Canada health-based guideline. A revised aesthetic objective of 20 µg/L has also been proposed by Health Canada (Health Canada, 2016). It is estimated that over 50% of the province's private water wells may exceed the proposed aesthetic objective.

A project was initiated in 2018 under the Hydrogeology Program to develop our understanding of the hydrogeological controls of manganese in well water, which will be used to develop a risk map for private well users. The aim of the project is to protect the health of Nova Scotians from exposure to manganese in well water by promoting water testing and appropriate treatment.

In 2018-2019, program activities focused on the preparation of a manganese in well water chemistry dataset. Future work will focus on the spatial correlation between manganese in well water and hydrogeologic criteria, and the potential development of a risk map and web application.

Profiling Contaminants in Nova Scotia Drinking Water

A joint project with researchers from the Nova Scotia Health Authority was initiated in 2019 to develop comprehensive exposure maps for various contaminants by combining well water sample data from the Geological Survey Division and Atlantic Path, a long-term cohort study of chronic disease in Atlantic Canada. Contaminant-specific maps will be produced at two levels of geography (community areas and a 5 km square grid) considered to be relevant to address public health concerns (e.g., see Saint-Jacques et al., 2016; Saint-Jacques et al., 2017). These exposure maps will thereafter be used to support knowledge transfer projects and environmental health research.

One of the most important predictors of private well owners testing and treating their water is risk knowledge. This project aims to improve the understanding of the spatial distribution of naturally occurring groundwater contaminants, which will be used to develop appropriate communication materials that aim to raise awareness and promote private well water testing and treatment. An improved understanding of the spatial distribution of the contaminants will also enable the province to focus its risk mitigation efforts on areas where there is the greatest potential exposure to groundwater contaminants. Further, it will provide more comprehensive environmental exposure data to examine the association between the spatial distribution of environmental risk factors and health risk, particularly cancer.

Shallow Aquifer Water Level Monitoring

The need for a real-time monitoring network for shallow aquifers was highlighted during a drought in Nova Scotia in 2016. The drought was particularly severe in southwestern Nova Scotia where the driest summer in 137 years was recorded. This area of the province relies more heavily on shallow dug wells for private water supplies, and over 1,000 wells went dry in the summer of 2016 (Kennedy et al., 2017). During the drought, there was a need to track aquifer levels so that emergency management staff could plan appropriate management responses and the public and media could be kept informed about the drought impacts. Although Nova Scotia has a provincial groundwater observation well network, it monitors deeper drilled wells and is not equipped for real-time reporting. Therefore, a low-cost real-

time water level meter for dug wells was developed and pilot tested in 2017.

The newly developed water level meters are permanently installed in dug wells and use an ultrasonic sensor to measure water levels. The meters are custom-built and cost approximately \$200 each to build. The water level data are transmitted daily via WiFi and are immediately available for viewing and download. The water level data collected during the 2017 pilot test compared well with data from pressure transducers and manual measurements (Drage and Kennedy, 2018). In 2018, the network was expanded to 10 monitoring sites across Nova Scotia. The network relies on private well owners to volunteer their dug wells for meter installation, and to provide access to their WiFi network to transmit the daily water levels. The monitoring site locations are shown on the *Potential Impact of Drought to Private Wells* map (<https://fletcher.novascotia.ca/DNRViewer/?viewer=DroughtIndex>), which also provides access to the real-time water level results.

Example results from one of the dug wells in the network are shown in Figure 1. These results show a typical seasonal water level pattern that appears in many of the dug wells in the network. As shown in Figure 1, spring water levels are relatively high until July, when they begin to decline, which continues throughout the summer until fall precipitation causes a rapid rise in October. Water levels then remain high for the fall and early winter, until cold winter conditions reduce recharge to the aquifer, causing water levels to decline again in January. The maximum water level range from summer to fall in this well was 3.7 m.

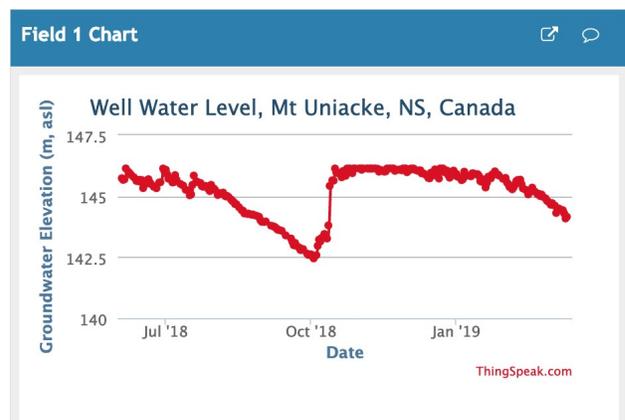


Figure 1. Groundwater level results from a dug well in Mount Uniacke, Nova Scotia.

Groundwater Management

Changes to Health Canada Drinking Water Quality Guidelines

Health Canada has recently reviewed aesthetic and/or health-based limits for several chemical parameters for drinking water quality, such as aluminum, antimony, arsenic, copper, lead, manganese, strontium, and uranium. To assist Nova Scotia Environment (NSE) with evaluation of the potential impact of any proposed changes to the Health Canada drinking water guidelines on private and public water supplies in Nova Scotia, staff of the Geological Survey Division performed analyses of available well water chemistry data compared to the distribution of private well users (Nova Scotia Department of Energy and Mines, 2018c). In addition, Nova Scotia Geological Survey Division staff provided technical support in 2018-2019 to NSE in preparation for changes to the lead in drinking water guideline.

Private Water Supplies Committee

Geological Survey Division staff participated on a Private Water Supplies Committee initiated in October of 2018 and consisting of members from Nova Scotia Environment and the Nova Scotia Department of Health. The committee aims to reduce barriers to testing and treatment of private water supplies and will continue to be active in 2019-2020.

Outreach and Support Activities

Support Activities

Geological Survey Division staff assisted various clients with requests for data and technical advice in 2018-2019. Clients included other government departments, universities, homeowners, municipalities, and groundwater consultants. Support to universities included the provision of data to a Dalhousie M.Sc. project on well water quality issues in Harrietsfield, and to a Dalhousie B.Eng. project on well water quantity issues in southwest Nova Scotia.

Presentations

The Hydrogeology Program delivered the following presentations during 2018-19:

- A lecture on the hydrogeology of Nova Scotia to a first-year hydrogeology class in the Faculty of Engineering at Dalhousie University;
- A conference poster presentation at Resources for Future Generations in Vancouver on a low-cost meter for aquifer drought monitoring in Nova Scotia (Drage and Kennedy, 2018); and
- A presentation to the Nova Scotia Groundwater Association titled *Well Logs Data: From Rig to Regional Assessment*.

Publications

The following publications by the Hydrogeology Program were released in 2018-2019.

Open File Report: Potential Corrosivity of Groundwater in Nova Scotia and its Association with Lead in Private Well Water (Kennedy, 2019), available online at https://novascotia.ca/natr/meb/data/pubs/19ofr02/ofr_me_2019-002.pdf.

Report: An Overview of Hydrogeology Program Activities for April 2017 to March 2018 (Kennedy and Drage, 2018a), available online at https://novascotia.ca/natr/meb/data/pubs/18re01/8_ROA2018Kennedy_hydrology.pdf.

Open File Report: A Review and Summary of Activities Related to Uranium in Nova Scotia Well Water (Kennedy and Drage, 2018b), available online at https://novascotia.ca/natr/meb/data/pubs/18ofr06/ofr_me_2018-006.pdf.

Conference Poster: A Low-Cost Internet of Things Aquifer Drought Monitoring Network in Nova Scotia, Canada: Pilot Program Results (Drage and Kennedy, 2018).

Open File Report: Mapping Historical Groundwater Levels of Nova Scotia: A Conceptual Model (Leahy and Lloyd, 2018), available online at https://novascotia.ca/natr/meb/data/pubs/18ofr07/ofr_me_2018-007.pdf

Journal publication: Development of a leaching procedure to assess the risk of uranium leaching due to construction and demolition waste disposal (Letman et al., 2018), abstract available online at <https://doi.org/10.1016/j.wasman.2018.05.038>

Journal publication: Low-impact development effects on aquifer recharge using coupled surface and groundwater models (Mooers et al., 2018), abstract available online at [https://doi.org/10.1061/\(ASCE\)HE.1943-5584.0001682](https://doi.org/10.1061/(ASCE)HE.1943-5584.0001682)

Research Directions

Private well water quality concerns due to naturally occurring contaminants will remain a significant area of focus for the Hydrogeology Program. The program will therefore continue to advance the province's understanding of the hydrogeological controls on naturally occurring contaminants in private well water and to develop risk communication tools and other interventions to promote appropriate well water testing and treatment. While much of the pilot phase work is complete on the development of a shallow aquifer monitoring network, the Hydrogeology Program will continue to monitor, test and refine the network.

Other high priority activities include the compilation of legacy groundwater data, the improvement of data capture processes, the maintenance of spatial data, and the development of online applications to publish and provide access to these data.

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