Activities of the Hydrogeology Program, 2009

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Introduction

In 2009, the Nova Scotia Department of Natural Resources (DNR) Hydrogeology Program focused on the development of regional scale groundwater budgets and the characterization of Nova Scotia's major groundwater regions. Hydrogeologist Gavin Kennedy and Groundwater Resources Technician Danielle Finlayson-Bourque constitute the staff of DNR's Hydrogeology Program. The program also provided advice to government and private sector clients, continued its efforts towards the organization, compilation and mapping of provincial groundwater data, and supported provincial groundwater research and groundwater management initiatives, such as the Nova Scotia Groundwater Observation Well Network.

Program Highlights

Groundwater Observation Well Network

The Nova Scotia Groundwater Observation Well Network (Nova Scotia Environment, 2009) is a key source of information on background groundwater chemistry and groundwater levels in the province. A list of priority sites for the conversion of existing drilled water supply wells that are no longer in use at provincial parks into dedicated observation wells was developed during 2008. Priorities were assigned based on various criteria, including the condition of the drilled well and whether the watershed currently hosts an active observation well. The sites in Table 1 were recommended for incorporation into the observation well network in 2009.

A well contractor was hired to conduct a video inspection of the wells in Table 1 (excepting Lewis Lake) to record well construction details, and in some cases to retrofit the well to accommodate monitoring equipment. With the addition of these five observation wells, there are a total of 35 active provincial observation wells.

Where the well was accessible and had not previously been tested, DNR conducted short-term pumping tests and water quality sampling of the observation wells. In addition, DNR conducted pumping tests at three existing observation wells. The observation well at Musquodoboit Harbour was re-tested because the results of the short-term test reported in 2008 were considered anomalous. The 2009 pumping test results are summarized in Table 2.

Updates to Groundwater Databases

The Hydrogeology Program continued its efforts to organize provincial groundwater information into a centralized spatial database. Routine revision of groundwater databases, such as the Pumping Test Database (Nova Scotia Environment, 2009b), Well Logs Database (Nova Scotia Environment, 2009c) and Inorganic Groundwater Chemistry Database (Nova Scotia Department of Natural Resources, 2009) was carried out. In addition, quality assurance and quality control measures were implemented to improve the reliability of these datasets.

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Table 1: Observation wells added at provincial parks in 2009.

Station Name	Station Number	Well Number	Primary Watershed	Groundwater Region / Hydrostratigraphic Unit
Lewis Lake	079	690090	East/Indian River	Plutonic/Granite HU
Arisaig	080	770542	French	Sedimentary/Arisaig HU
Coldbrook	081	Not available	Gaspereau	Sedimentary/Wolfville HU
Long Point	082	Not available	River Inhabitants	Sedimentary/Mabou HU
Tatamagouche	083	Not available	River John	Sedimentary/Pictou HU

Table 2: Summary of 2009 pumping tests by DNR.

Location	Test Type	Duration (mins)	Average Pumping Rate (m^3/d)	Static Water Level (mbgs)[2]	Well Transmissivity (m^2/d)	Hydraulic Conductivity (m/d)	Specific Capacity (m^2/d)	Long-Term Yield (Q_{20})[1] (m^3/d)
Arisaig (Station 080)	Step test	192	0.3 to 7.2	4.94	3.0×10^{-3}	3.75×10^{-5}	0.17	0.14
Coldbrook (Station 081)	Step test	240	19.0 to 27.6	14.70	1.3×10^{0}	3.45×10^{-2}	2.89	36.17
Long Point (Station 082)	Step test	222	16.4 to 29.4	1.60	2.8×10^{0}	1.12×10^{-1}	3.55	15.23
Sheet Harbour (Station 056)	Constant rate	180	9.5	-0.42	1.9×10^{-1}	3.22×10^{-3}	0.58	4.22
Kelley River (Station 073)	Step test	247	18.1 to 37.2	1.67	10.6×10^{0}	8.22×10^{-1}	20.46	49.56
Musquodoboit Harbour (Station 078)	Constant rate	162	6.9	2.69	1.1×10^{-2}	1.47×10^{-4}	0.15	0.31

1. The Q_{20} refers to the potential long-term (20 year) safe yield. Due to the short duration and low pumping rate of the tests, the Q_{20} estimates provided in the table are not considered reliable.
2. mbgs = metres below ground surface

Groundwater Data Availability

An enhanced georeferenced version of Nova Scotia Environment's Well Logs Database (2009c) was made available as a GIS download on the Mineral Resources Branch web site (http://www.gov.ns.ca/natr/meb/download/dp430.asp).

The online interactive groundwater map service and portal for government groundwater information, launched in August 2008, was again revised in June 2009 (http://gis4.natr.gov.ns.ca/website/nsgroundwater/). New layers on the interactive groundwater map include municipal wells, groundwater quality data, government test holes, arsenic risk mapping and surficial geology mapping (1:500 000 scale). Web links to detailed well construction reports have also been added to the data tables. A web site user guide was developed and can be accessed from the interactive map web page.

The Hydrogeology Program continued its collaboration with (NSE) and federal partners on the development of a national water well mapping

and analysis system. The initiative is being led by Natural Resources Canada and will result in the publication of a national scale interactive water well map (http://sst.rncan.gc.ca/gm-ces/proj2/a2_e.php). The project is still in progress with an expected fall 2010 public release date.

Hydrogeologic Characterization of Nova Scotia's Groundwater Regions

Nova Scotia's bedrock aquifers were previously broadly divided into five bedrock groundwater regions based on existing mapping of the dominant bedrock types (Kennedy and Drage, 2008). Similarly, surficial aquifers were divided into five surficial groundwater regions based on dominant sediment types from 1:500 000 mapping by Stea *et al*., 1992 (Fig. 1). Hydrogeologic characterization of the five bedrock and five surficial groundwater regions was carried out by classifying over 70,000 water well records, over 900 pumping test records and over 1000 inorganic groundwater chemistry records into the major groundwater regions, and conducting statistical analyses for various hydrogeologic properties. The statistical summaries provide a general guide to expected hydrogeologic properties, and the mapping and associated databases developed during this work provide a useful framework for more detailed assessment activities. This work was presented at the annual meeting of the Canadian National Chapter of the International Association of Hydrogeologists in September 2009 (Kennedy and Drage, 2009).

Evaluation of Groundwater Stress in HRM Service Request Areas

The extension of municipal water services to replace individual well supplies has been requested (~15 requests) in a number of areas of the Halifax Regional Municipality (HRM) that are experiencing well water supply issues. To identify priority areas for the extension of central water servicing, HRM requested assistance from the DNR Hydrogeology Program to develop a framework for evaluating relative potential groundwater stress in these areas. Groundwater stress is generally defined as the ratio of groundwater demand to renewable supply. A general methodology was developed for HRM that relies on existing databases to evaluate potential groundwater stress in areas where the extension of municipal water services has been requested.

Estimation of Regional Groundwater Budgets in Nova Scotia

Planning for the Nova Scotia Water Strategy, due in 2010, highlighted the need to develop preliminary regional groundwater budgets to answer fundamental questions about groundwater use and availability and to prioritize assessment activities. A key objective of the Hydrogeology Program therefore was to generate preliminary estimates of groundwater availability and groundwater use throughout the province.

Regional groundwater budgets were estimated for 44 major groundwatersheds across Nova Scotia. Groundwatershed boundaries were assumed to correspond to primary surface watershed boundaries, since groundwater flow systems are relatively shallow in Nova Scotia (i.e. most groundwater flow occurs in the upper 150 m) and, therefore, they are likely to be controlled by the hydraulic boundaries associated with primary watersheds. Nova Scotia's geology does not lend itself to simple determination of large regional aquifer flow systems, and currently, there is no evidence of large scale groundwater flow between primary watersheds.

Groundwater availability was estimated using a GIS processing model with precipitation and bedrock groundwater recharge ratio inputs derived from available climate and streamflow data. Recharge ratios are calculated as mean annual baseflow divided by mean annual precipitation. The approach used was similar to the approach developed during the pilot Annapolis Valley Groundwater Use Survey (CBCL, 2009). Municipal wells, and residential and non-

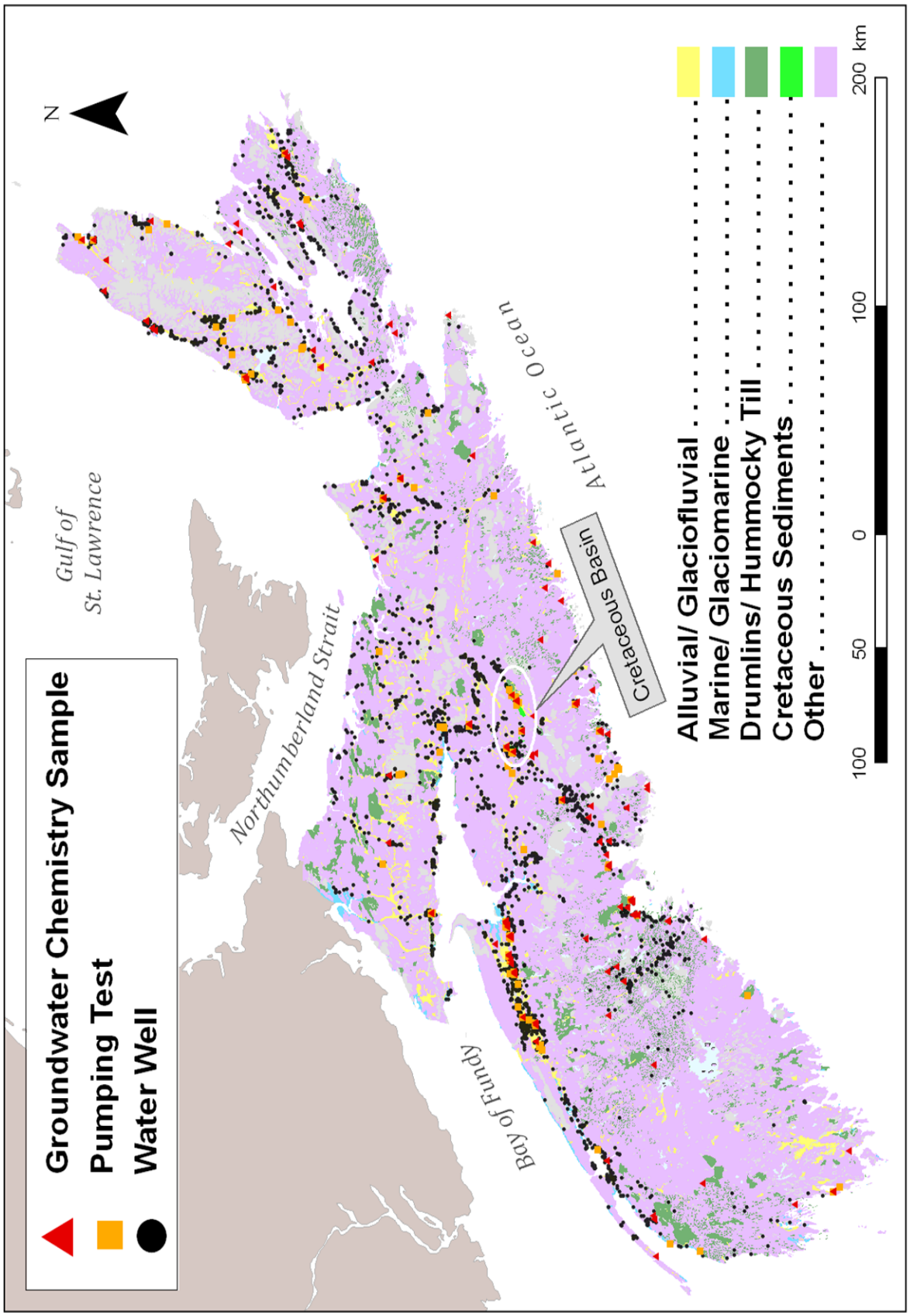

Figure 1. Surficial groundwater regions of Nova Scotia and distribution of groundwater data.

residential unserviced groundwater users were plotted, and total groundwater use in each major groundwatershed was estimated using the best available information. Few flow records could be obtained, and groundwater use estimates often relied on typical water use figures for a given type of user. Consumptive groundwater use, which is the amount of water permanently removed from the groundwater system, was estimated for each primary watershed by multiplying total use by a consumption coefficient for each user type. Consumption coefficients were compiled from literature sources as reported in the Annapolis Valley Groundwater Use Study (CBCL, 2009).

The study found that groundwater usage in Nova Scotia from bedrock aquifers appears to be sustainable on a regional scale, with groundwater use ranging from 0.1 to 12% of available groundwater. Table 3 lists the major components of the groundwater budget for each of the 44 groundwatersheds considered in the study. The limitations of the approach used to generate the budget estimates include a high level of uncertainty with respect to groundwater use, the exclusion of surficial aquifers, the assumption of steady-state use and recharge (e.g. transient period of high use and low recharge not considered), and poorly defined groundwater flow boundaries.

Despite the findings with respect to regional groundwater sustainability, groundwater quantity problems are revealed by the increasing numbers of water servicing requests (see previous section) and well modifications to improve yield (e.g. well deepening, well stimulation) reported in the province. Locally, problems may occur where groundwater is used at a faster rate than the capacity of regional bedrock aquifers to transmit groundwater to areas of extraction. Wells intercepting fractured bedrock aquifers can be sensitive to any short-term or small change in water level that causes the dewatering of a groundwater-producing fracture. In coastal areas with large groundwater usage and small groundwatershed area (e.g. shoreline direct watersheds), seawater intrusion can exacerbate sustainability concerns.

Sustainable management of our groundwater resources, therefore, requires water managers to recognize the importance of both regional and local scale management. An appropriate management framework for the scientific knowledge required for sustainable groundwater management is shown in Table 4. The Sackville watershed is identified as a high priority watershed for regional groundwater assessment since it has not previously been the subject of detailed hydrogeological investigation and is experiencing relatively high groundwater stress (Table 3). The spatial database developed during this study will permit the integration of new and more refined datasets and the continuing evaluation of groundwater budgets.

Investigation into Potential Controls on Uranium Concentration in New Municipal Wells in Bridgetown

Groundwater exploration work was initiated by the Town of Bridgetown in 2006 to investigate the potential for a municipal groundwater supply source to replace the existing surface water supply system, which required expensive upgrades due to aging infrastructure and new provincial treatment standards. Total uranium was found to be elevated (maximum of 15 µg/L) but below the Canadian Drinking Water Quality interim maximum acceptable concentration of 20 µg/L in the three open borehole test wells, and appeared to be stable based on the results of a 30 day pumping test. The town decided to pursue a groundwater supply option and converted two of the test wells into partially screened, larger diameter production wells.

During pump testing of new screened production wells in 2007, higher concentrations of uranium (almost two times greater) were detected compared to the open borehole test holes, with a maximum concentration of 27 µg/L recorded in one of the production wells. DNR participated in a multi-organizational study to investigate the increase in uranium in the production wells compared to the test wells.

Since 2007, a series of investigations has been conducted, including additional pumping tests, depth-discrete sampling, a packer test, and aqueous

Table 3. Regional groundwater budgets in Nova Scotia.

Primary Watershed	Primary Watershed Code	Watershed Area (m^2)	Groundwater Availability			Groundwater Use			Groundwater Budget	
			Annual Precipitation (mm/yr)	Recharge Ratio	Annual Recharge to Bedrock Aquifers (m^3/yr)	Residential (unserviced) (m^3/yr)	Municipal and Non-Residential Users (m^3/yr)	Total Use (m^3/yr)	Budget (m^3/yr)[1]	Percent Use of Availability[2]
Gaspereau	1DD	1.32E+09	1155.1	0.18	3.07E+08	2.70E+06	1.60E+07	1.87E+07	1.35E+08	12.1%
Tidnish/ Shinimicas	1DM	4.84E+08	1175.2	0.15	8.91E+07	3.32E+05	3.19E+06	3.52E+06	4.10E+07	7.9%
Tracadie	1DS	5.88E+08	1538.5	0.15	1.21E+08	5.11E+05	3.18E+06	3.69E+06	5.69E+07	6.1%
Salmon/ Debert	1DH	1.17E+09	1202.1	0.16	2.49E+08	2.12E+06	4.64E+06	6.75E+06	1.18E+08	5.4%
Sackville	1EJ	9.62E+08	1508.0	0.12	1.89E+08	3.29E+06	1.76E+06	5.06E+06	8.95E+07	5.4%
Salmon/ Mira	1FJ	2.86E+09	1598.8	0.17	7.46E+08	2.75E+06	1.06E+07	1.34E+07	3.60E+08	3.6%
East/ Middle/ West (Pictou)	1DP	1.19E+09	1232.9	0.16	2.46E+08	1.56E+06	2.84E+06	4.40E+06	1.19E+08	3.6%
Shubenacadie/ Stewiacke	1DG	2.72E+09	1452.2	0.14	5.11E+08	2.95E+06	4.80E+06	7.75E+06	2.48E+08	3.0%
Annapolis	1DC	2.26E+09	1127.3	0.18	5.34E+08	2.33E+06	3.90E+06	6.23E+06	2.61E+08	2.3%
French	1DQ	7.48E+08	1384.3	0.14	1.36E+08	7.15E+05	7.19E+05	1.43E+06	6.68E+07	2.1%
East/ Indian	1EH	7.78E+08	1363.8	0.16	1.74E+08	1.41E+06	3.99E+05	1.81E+06	8.53E+07	2.1%
Gold	1EG	1.07E+09	1523.0	0.14	2.10E+08	1.57E+06	4.72E+05	2.04E+06	1.03E+08	2.0%
Sissiboo/ Bear	1DB	1.44E+09	1377.5	0.21	4.21E+08	9.69E+05	2.91E+06	3.88E+06	2.07E+08	1.8%
Meteghan	1DA	6.20E+08	1295.2	0.22	1.91E+08	8.93E+05	7.81E+05	1.67E+06	9.40E+07	1.8%
South/ West	1DR	9.01E+08	1384.3	0.14	1.73E+08	5.19E+05	9.47E+05	1.47E+06	8.51E+07	1.7%
Musquodoboit	1EK	1.39E+09	1369.9	0.17	3.35E+08	2.29E+06	3.94E+05	2.69E+06	1.65E+08	1.6%
LaHave	1EF	1.69E+09	1523.0	0.14	3.32E+08	1.48E+06	8.69E+05	2.35E+06	1.64E+08	1.4%
River John	1DO	1.09E+09	1232.9	0.15	2.06E+08	1.08E+06	3.15E+05	1.39E+06	1.02E+08	1.4%
Barrington/ Clyde	1EB	1.41E+09	1523.6	0.21	4.13E+08	1.11E+06	1.62E+06	2.73E+06	2.04E+08	1.3%
River Inhabi-tants	1FA	1.20E+09	1298.2	0.21	3.54E+08	4.55E+05	1.79E+06	2.25E+06	1.75E+08	1.3%
Philip/ Wallace	1DN	1.49E+09	1454.5	0.15	2.78E+08	8.72E+05	7.62E+05	1.63E+06	1.38E+08	1.2%
Kelly/ Maccan/ Hebert	1DL	1.29E+09	1175.2	0.17	2.71E+08	3.94E+05	1.19E+06	1.58E+06	1.34E+08	1.2%

Table 3. Continued

Kennetcook	1DF	1.01E+09	1054.0	0.15	1.96E+08	7.32E+05	1.41E+05	8.73E+05	9.69E+07	0.9%
Grand	1FH	7.70E+08	1598.8	0.18	2.11E+08	4.37E+05	4.92E+05	9.29E+05	1.05E+08	0.9%
St. Croix River	1DE	1.35E+09	1360.1	0.17	3.19E+08	1.14E+06	2.62E+05	1.40E+06	1.58E+08	0.9%
Herring Cove/ Medway	1EE	2.03E+09	1460.9	0.13	3.99E+08	1.18E+06	4.48E+05	1.62E+06	1.98E+08	0.8%
Tusket	1EA	2.18E+09	1274.1	0.21	6.38E+08	1.65E+06	7.97E+05	2.45E+06	3.17E+08	0.8%
Economy	1DJ	7.80E+08	1454.5	0.16	1.66E+08	4.45E+05	1.21E+05	5.66E+05	8.22E+07	0.7%
Parrsboro	1DK	8.60E+08	1281.6	0.15	1.62E+08	2.42E+05	2.91E+05	5.33E+05	8.04E+07	0.7%
River Denys/ Big	1FG	7.85E+08	1538.5	0.17	1.87E+08	2.79E+05	3.07E+05	5.86E+05	9.31E+07	0.6%
Margaree	1FB	1.37E+09	1500.9	0.22	4.36E+08	4.25E+05	8.52E+05	1.28E+06	2.17E+08	0.6%
Tangier	1EL	1.09E+09	1369.9	0.21	3.33E+08	6.88E+05	1.86E+05	8.74E+05	1.66E+08	0.5%
North/ Baddeck/ Middle	1FF	7.67E+08	1500.9	0.22	2.52E+08	1.31E+05	4.52E+05	5.84E+05	1.25E+08	0.5%
Clam Harbour/ St. Francis	1ER	5.27E+08	1538.5	0.15	1.08E+08	1.88E+05	4.16E+04	2.30E+05	5.38E+07	0.4%
Mersey	1ED	2.99E+09	1517.4	0.14	5.92E+08	6.38E+05	6.00E+05	1.24E+06	2.95E+08	0.4%
Wreck Cove	1FD	1.04E+09	1700.3	0.25	3.84E+08	1.76E+05	5.70E+05	7.45E+05	1.91E+08	0.4%
Roseway/ Sable/ Jordan	1EC	1.43E+09	1523.6	0.17	3.41E+08	3.84E+05	2.60E+05	6.44E+05	1.70E+08	0.4%
Cheticamp	1FC	8.04E+08	1391.1	0.25	2.96E+08	2.12E+05	3.12E+05	5.24E+05	1.47E+08	0.4%
New Harbour/ Salmon	1EQ	1.08E+09	1427.8	0.17	2.58E+08	2.77E+05	1.08E+05	3.85E+05	1.29E+08	0.3%
East/West (Sheet Harbour)	1EM	1.00E+09	1369.9	0.17	2.48E+08	2.08E+05	1.29E+05	3.37E+05	1.24E+08	0.3%
Country Harbour	1EP	5.72E+08	1384.3	0.21	1.72E+08	1.61E+05	6.57E+03	1.68E+05	8.60E+07	0.2%
Liscomb	1EN	1.20E+09	1541.3	0.21	3.69E+08	2.26E+05	1.33E+05	3.59E+05	1.84E+08	0.2%
St. Marys	1EO	1.53E+09	1384.3	0.16	3.38E+08	2.57E+05	5.91E+04	3.16E+05	1.68E+08	0.2%
Indian	1FE	8.46E+08	1639.5	0.25	3.19E+08	1.06E+05	8.76E+03	1.15E+05	1.59E+08	0.1%

1. Groundwater budgets were calculated as total groundwater use subtracted from 50% of the estimated annual recharge to bedrock aquifers. The sustainable aquifer yield is assumed to be no greater than 50% of the annual aquifer recharge, unless it can be demonstrated, to the satisfaction of Nova Scotia Environment, that additional withdrawals will not cause unacceptable effects. The 50% unallocated portion is retained to maintain baseflow for surface water bodies.
2. Percent use of availability calculated as total use divided by ½ of the estimated annual recharge to bedrock aquifers, multiplied by 100%.

Table 4. Recommended scientific framework to support sustainable management of Nova Scotia's groundwater resources.

1. Sustainability Indicators	develop and apply valid sustainability indicators that will identify existing and potential problem areas at a scale appropriate to planning decisions
2. Monitoring	expand observation well network and target problem areas for new observation wells, track withdrawals of high capacity groundwater users, monitor changes in recharge
3. Quantitative Assessment	build knowledge of aquifers through systematic regional groundwater assessment studies with an initial focus on priority areas in terms of stress and state of existing knowledge base
4. Groundwater Modelling	build and calibrate numerical models to predict aquifer responses

leachate testing of rock cuttings from the remaining test well. The results of these investigations suggest a redox control on uranium concentration in the wellfield. Greater drawdowns occur where well screens are present, leading to the development of more oxidized conditions which favour the mobilization of uranium. The findings have guided wellfield remedial actions, including the conversion of the remaining test well to a fully screened production well to minimize drawdown while maintaining borehole stability.

Given that Triassic sedimentary aquifers in the Annapolis Valley are widely used as a groundwater source and have been associated with the potential for elevated uranium concentrations, an improved understanding of the controls influencing the mobility of uranium in groundwater could help other water users in the area to address similar concerns.

Seawater Intrusion in Coastal Aquifers

The department participated in the design of a project to assess the susceptibility of coastal aquifers to saltwater intrusion in Nova Scotia. The project is part of the proposed Atlantic Regional Adaptation Collaborative to study the potential effects of climate change, and will provide an estimate of the current distribution of saline groundwater in Nova Scotia's coastal aquifers, an assessment of the origin of this salinity, and an assessment of how climate change may affect the distribution of saline waters in coastal aquifers. In preparation for this project, DNR compiled salinity data and mapping in coastal areas for project partners.

Input to Water Strategy and Policy Documents

The Hydrogeology Program provided technical input to various government policy and strategy documents in preparation, including the Nova Scotia Water Resources Management Strategy, which is expected to be released in 2010.

Research Directions

The Hydrogeology Program will continue its efforts to organize and compile current and historical sources of groundwater information, and publish this information on the interactive groundwater map for public use. Work also continues on the online publication of provincial thematic groundwater maps, such as groundwater chemistry for selected parameters.

Areas of continued research include the compilation and development of groundwater map layers for use by planners as part of the central Antigonish pilot project, and the development of mapping of salinity in coastal areas as part of the proposed Regional Adaptation Collaborative project.

The DNR Hydrogeology Program will work towards refining the hydrogeologic characterization of the province's groundwater regions, characterizing its component hydrostratigraphic units where adequate information is available, and developing more detailed groundwater budgets in high priority areas.

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