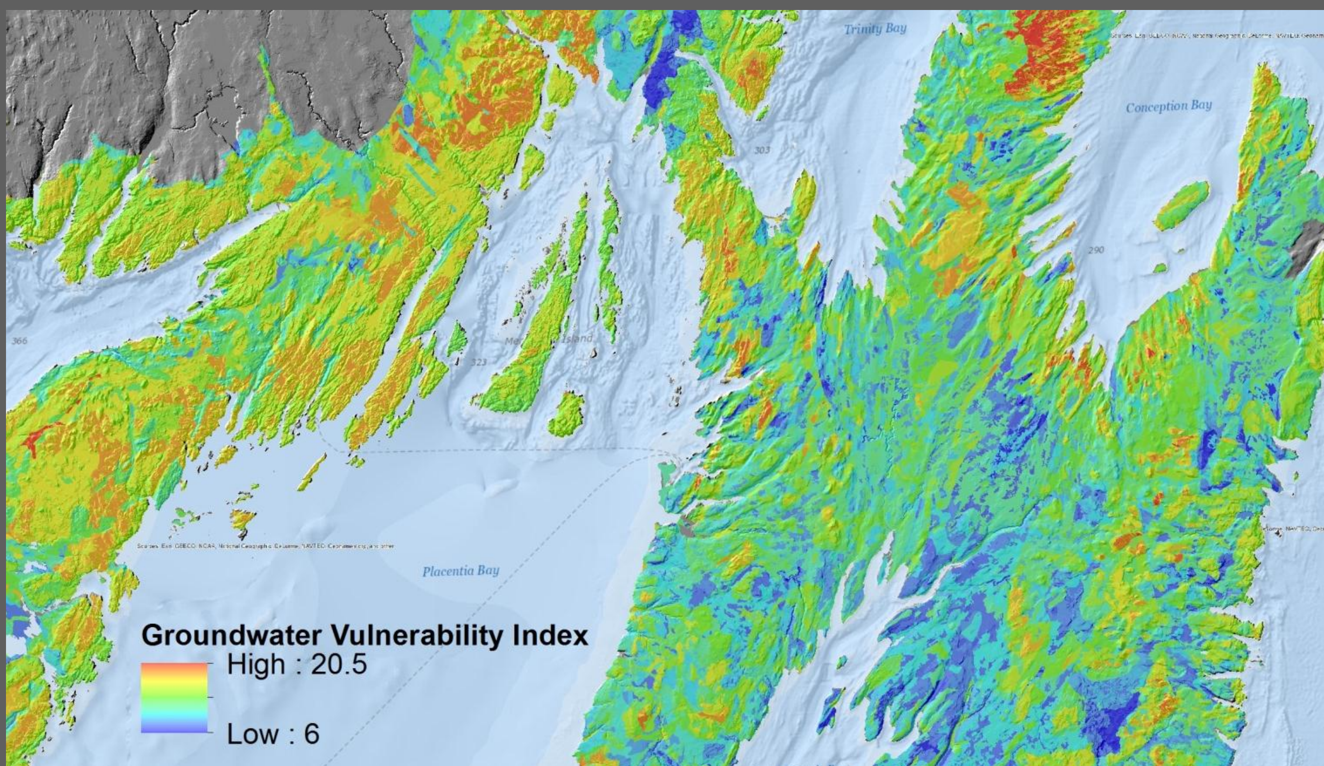
Groundwater Vulnerability Mapping Eastern Newfoundland

Executive Summary



123102.00 ● Executive Summary ● March 2014

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Prepared for:

Water Resources Management Division
Department of Environment and Conservation
Government of Newfoundland and Labrador

Prepared by:

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		March 2014	C. Walker
Executive Summary	T. Hennigar	February 2014	C. Walker
Draft Report	M. Bishop	February 2014	C. Walker
Issue or Revision	***Reviewed By:***	***Date***	***Issued By:***

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EXECUTIVE SUMMARY

CBCL Limited (CBCL) was retained by the Water Resources Management Division of the Department of Environment and Conservation (ENVC) to complete a Groundwater Vulnerability Study for Eastern Newfoundland. Groundwater is an essential resource for the island portion of the province where approximately 29% of people rely on groundwater as a source of potable water. ENVC has recognized the value of Newfoundland's groundwater resources and has initiated this study to serve as a planning tool to provide a basis for protection of groundwater resources.

Groundwater vulnerability is a measure of the likelihood for contaminants to enter an aquifer, and the rate at which they travel and disperse along a groundwater flow path. Groundwater vulnerability is determined by the physical environment, and some definitions are extended to include the influence of land use on the likelihood of contaminant release. For the purposes of this report, "aquifer vulnerability" is used to describe the physical factors controlling the pathways of contaminants entering and travelling through aquifers, and "land use-vulnerability" incorporates the influence of land uses on the likelihood of contaminant release.

Aquifer vulnerability is determined primarily by the ease and speed with which contaminants move from sources at the ground surface through soil and bedrock. The thickness and permeability of material at the ground surface influence how easily contaminants can move between the ground surface and sub-surface flow zones (primarily downward flow). Horizontal flow and spreading of contaminants that have reached the groundwater is controlled by properties of the aquifer. Factors that affect vertical and horizontal flow can be subdivided to provide a way of mapping aquifer vulnerability. Methods to determine aquifer vulnerability have been the subject of study and application in other jurisdictions for over forty years.

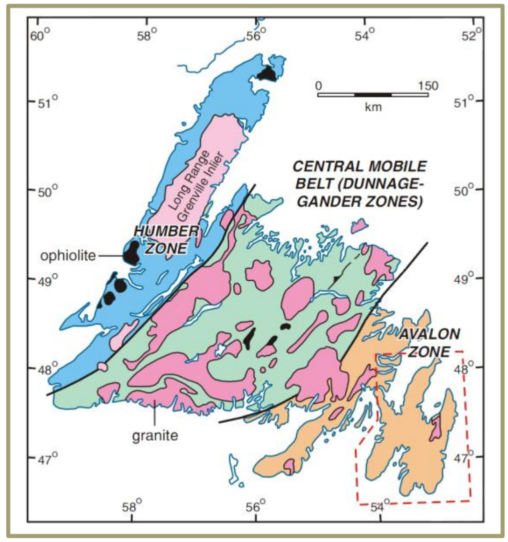
Hydraulic conductivity is a measure of how easily groundwater may flow through an aquifer or other geologic unit.

ENVC has subdivided the Island of Newfoundland into three study areas, corresponding to principal tectonic divisions. Table A provides a summary of these study areas. This study is concerned with the Eastern Newfoundland Study Area.

Table A: Tectonic Zones of Newfoundland

Tectonic Zone	Hydrogeological Study Area
Avalon	Eastern Newfoundland
Dunnage-Gander (Central Mobile Belt)	Central Newfoundland
Humber	Western Newfoundland

Inset 'A' shows the principal tectonic divisions of Newfoundland. The study area comprises the Burin, Bonavista and Avalon Peninsulas, and has been defined for the purposes of this study using geologic contacts to define its western boundary. The western boundary extends from Fortune Bay in the south to Bonavista Bay in the north, and follows the eastern edge of the Devonian and Carboniferous granite intrusion shown on provincial mapping.



Inset A: Tectonic Zones of Newfoundland (from: King, A.F., 1988)

Aquifer vulnerability mapping was completed in three stages, subdivided into Tasks 1, 2 and 3. Detailed methodologies and results for each Task are described in three separate technical reports. The first task entailed collation, formatting, and trimming of data from the province and topographic survey of Canada to the Eastern Newfoundland study area. The second task provided a hydrogeological analysis of the data, including a review and summary of existing studies on the hydrogeology of Eastern Newfoundland. Existing hydrogeological studies were used in planning and design of groundwater vulnerability mapping. The third task described a methodology to adapt the information collected as part of Tasks 1 and 2 to a "DRASTIC"-style analysis of aquifer vulnerability[1], and presented a series of groundwater vulnerability maps.

DRASTIC was developed by the US Environmental Protection Agency as a way of calculating a single vulnerability index for a given location. The index is calculated using the seven DRASTIC parameters shown at right. The values of each parameter are determined by examining mapping of physical data such as geology and topographic mapping. A typical aquifer vulnerability map contains shaded ranges of the DRASTIC index to show areas of high, moderate, and low vulnerability. Vulnerability indices can be used in planning work to identify and prioritize focus areas where groundwater may be at risk and further, detailed investigations are required.

D	**D**epth to Aquifer
R	**R**echarge
A	**A**quifer Media
S	**S**oil Media
T	**T**opography (slope)
I	**I**mpact of Vadose Zone
C	Hydraulic **C**onductivity

DRASTIC has been tested and modified in international jurisdictions and across North America. The current study followed on work by the US Geological Survey (USGS) to incorporate GIS methods to collect, overlay, and display data[2]. The present methodology for groundwater vulnerability mapping of

[1] Aller, L., Bennett, T., Lehr, J.H., Petty, R.J., and Hackett, G., 1987. Drastic: A Standardized System for Evaluating Ground Water Pollution Potential using Hydrogeologic Settings. EPA/600/2-87/035. United States Environmental Protection Agency.

[2] USGS, 1999. Improvements to the DRASTIC Ground-Water Vulnerability Mapping Method. National Water-Quality Assessment Program-NAWQA. 6 p

Eastern Newfoundland was adapted to the data available for the study area, but is not directly comparable to mapping completed for US jurisdictions.

Data and mapping collated as part of Task 1 included creation of a digital elevation model and slope analysis, agricultural soils mapping, surficial and bedrock geology mapping, mapping and analysis of drilled well and pumping test data, and a preliminary delineation of watersheds and watershed groupings. All data were entered into an ArcGIS geodatabase together with topographic mapping and other base data layers available from web portals or provided directly by the province. The geodatabase served as a platform for collection and organization of all subsequent data layers generated as part of this study. Maps produced throughout the study were collated into an Atlas of Groundwater Vulnerability Maps for the Eastern Newfoundland Study Area. Map series 'A' provides base data mapping.

A review and analysis of hydrogeological data (Task 2) indicated that well yields (and by extension the expected range for hydraulic conductivity and contaminant mobility) are poorly correlated with rock type. DRASTIC-type analysis depends directly on bedrock geology mapping, indicating a need for a way to draw meaningful data from bedrock geology mapping. A geospatial and statistical analysis of well yield data provided a means of grouping bedrock polygons according to the apparent yield in each region. A similar analysis provided a way of assessing the depth to bedrock throughout the study area. An analysis of baseflow and groundwater recharge indicated that existing data are insufficient to include a recharge parameter in groundwater vulnerability mapping. Results of the hydrogeological analysis are provided in Map series 'A'.

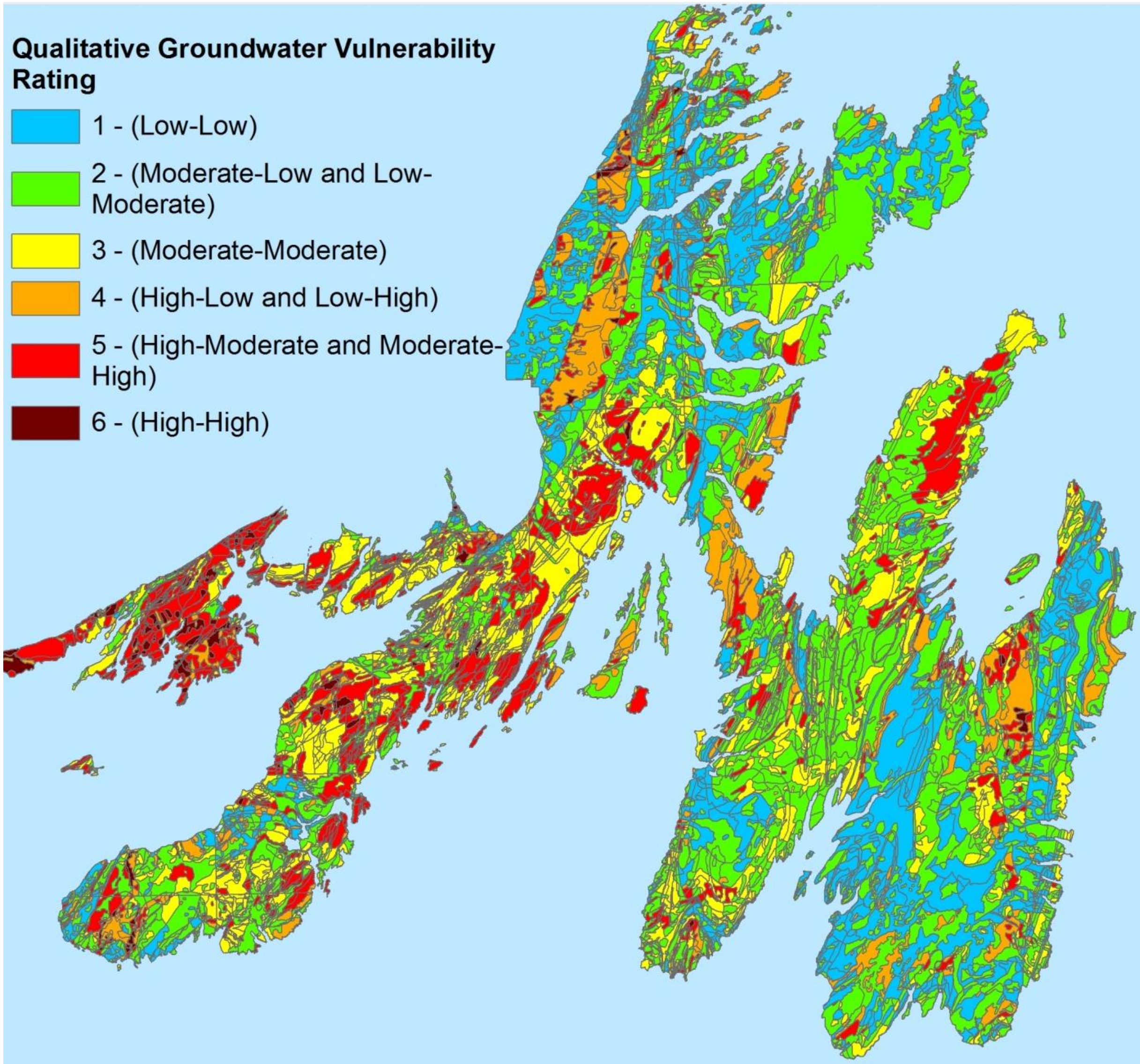
Groundwater vulnerability mapping was completed using a screening-level qualitative approach, followed by more in-depth quantitative calculations. Under qualitative mapping, each part of the study area received an intrinsic rating of Low, Medium, or High based on surficial geology, and an extrinsic rating of Low, Medium, or High based on bedrock geology. Surficial and bedrock geology maps were overlain to provide a combined rating for qualitative groundwater vulnerability. Qualitative mapping is provided in Map series 'B'.

Intrinsic Vulnerability is a measure of how easily contaminants may enter the subsurface by flowing vertically through surface soils.

Extrinsic Vulnerability is a measure of how easily contaminants may flow and spread horizontally in the subsurface.

Table B: Parameter Weightings for Study Area Screening and DRASTIC Parameters

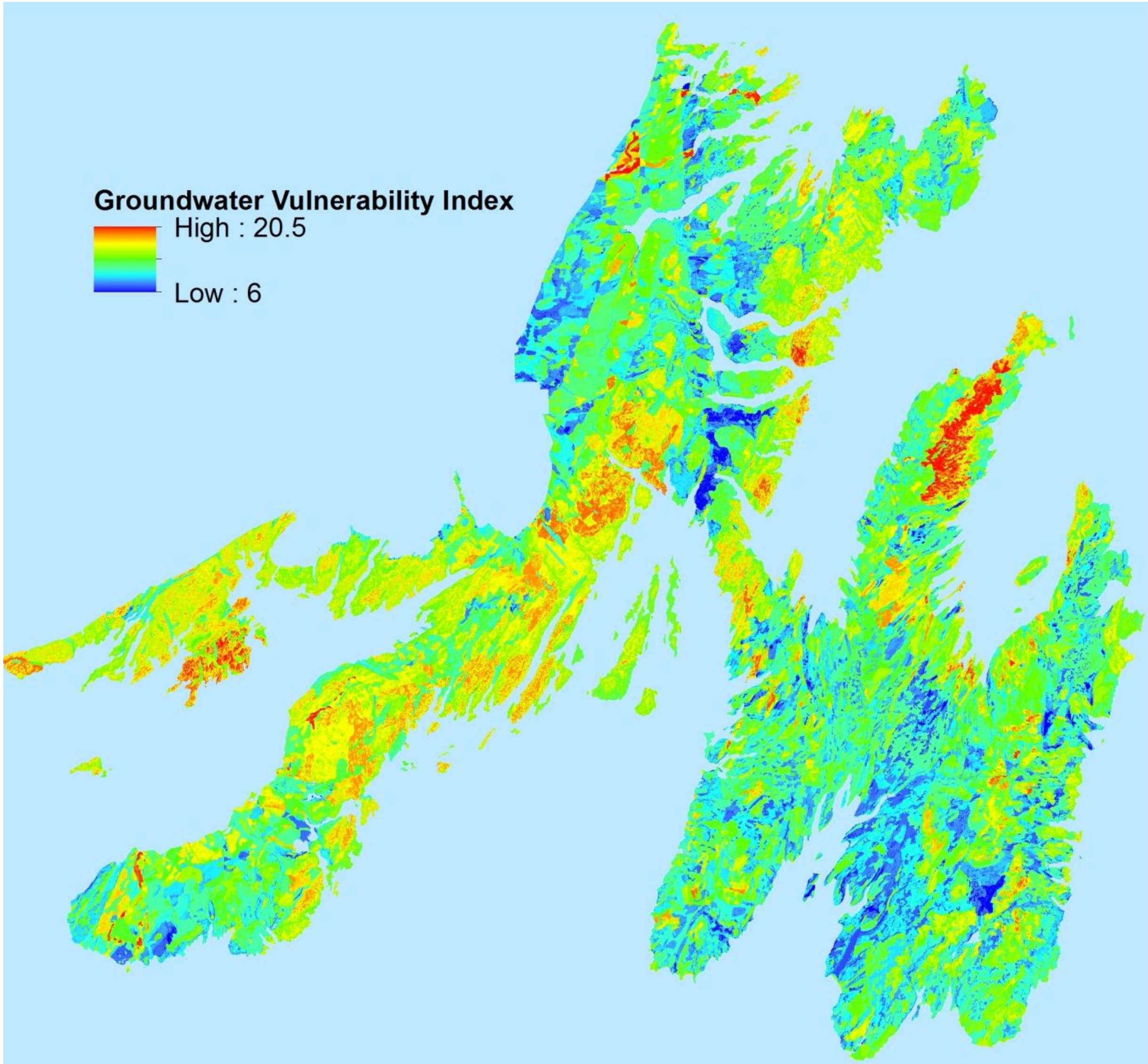
	DRASTIC Parameter	E. NFLD Parameter	Weighting	
D	Depth to Water	Depth to Bedrock	5	22%
R	Recharge	Unavailable	0	
A	Aquifer Media	Bedrock $\bar{Q}$	3	13%
S	Soil Media	Soil Drainage	4	17%
T	Topography	Slope	2	9%
I	Impact of Vadose Zone	Quaternary Geology	6	26%
C	Hydraulic Conductivity of Aquifer	Bedrock $\bar{Q}$	3	13%
Total			**23**	100%



Quantitative mapping for the study area was completed using five input parameters corresponding to the DRASTIC methodology. Table B provides a comparison of parameters used in this study and those developed for the original DRASTIC methodology.

Quantitative mapping is provided in Map series 'C'. The quantitative groundwater vulnerability index was in good agreement with qualitative mapping, while providing more detail and greater variation within smaller study areas. Most parts of the Northeast Avalon Peninsula exhibited low to moderate groundwater vulnerability. Notable exceptions include areas north of Portugal Cove, Conception Harbour-Harbour Main, and inland parts of the East Conception Bay study area.

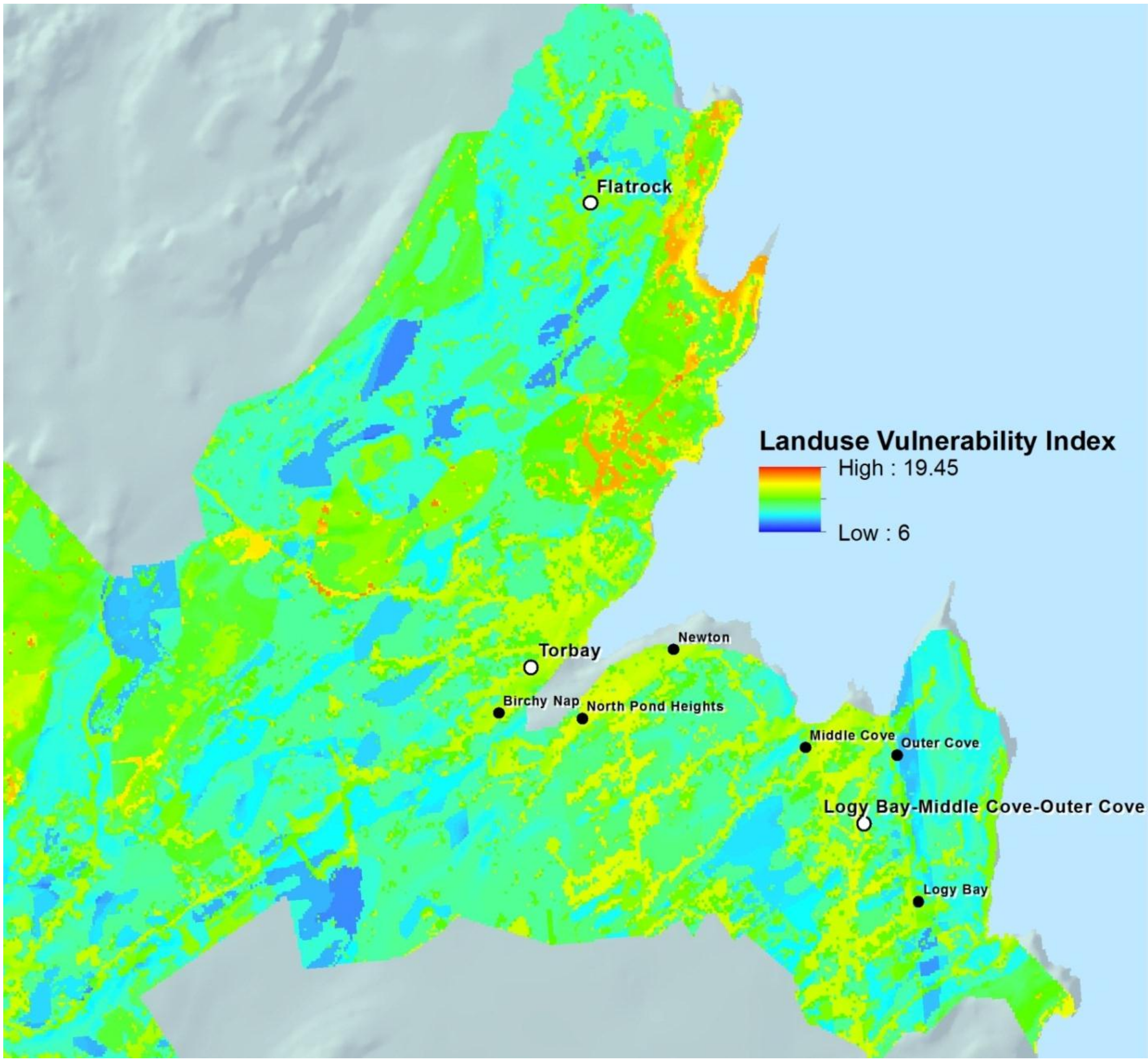
Depth-Normalized Yield ($\bar{Q}$)
The airlift yield for each drilled well record was divided by the well depth to provide a depth-normalized yield, abbreviated as "$\bar{Q}$". $\bar{Q}$ data are reported in units of m^2/day.



The groundwater vulnerability index varied between 6 and 20.5 (higher scores indicated higher vulnerability). The highest vulnerability scores were generally observed in areas where exposed bedrock occurred over units with higher well yields. Detailed groundwater vulnerability maps were plotted, showing 65 public well heads and their potential zones of contribution. The detailed maps may be used to make individual assessments of each well or utility on a case by case basis. Technical reporting for Task 3 provides a more detailed analysis of vulnerability mapping. Public wells that were flagged as being located in sensitive areas include Baine Harbour, Eastport, Sandy Cove, Harbour Main-Chapel's Cove-Lakeview, and Holyrood.

Land-use vulnerability mapping was completed for three detailed study areas: Northeastern Avalon (Flatrock-Torbay-Logy Bay), Witless Bay-Bay Bulls, and East Conception Bay (including Portugal Cove, Paradise, Conception Bay South, and south to Indian Pond). An analysis of remote sensing data allowed for distinction between vegetated, cleared and urban zones in these study areas. The resulting Land Use Index was incorporated into vulnerability mapping to produce a Land Use-Vulnerability Index. The Land Use-Vulnerability Index for urban parts of the Northeast Avalon, Witless Bay-Bay Bulls, and East

Conception Bay study areas generally exceeded 14 to 15. Mapping suggests that the highest Land Use Vulnerabilities (range 17 to 20) are located around Flat Rock Cove, Portugal Cove, Conception Bay South, Manuels, Seal Cove, and Torbay Road near Gallows Cove Pond. Site specific evaluation of land use, individual drilled wells and on-site sewage disposal systems in these areas would be warranted.



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