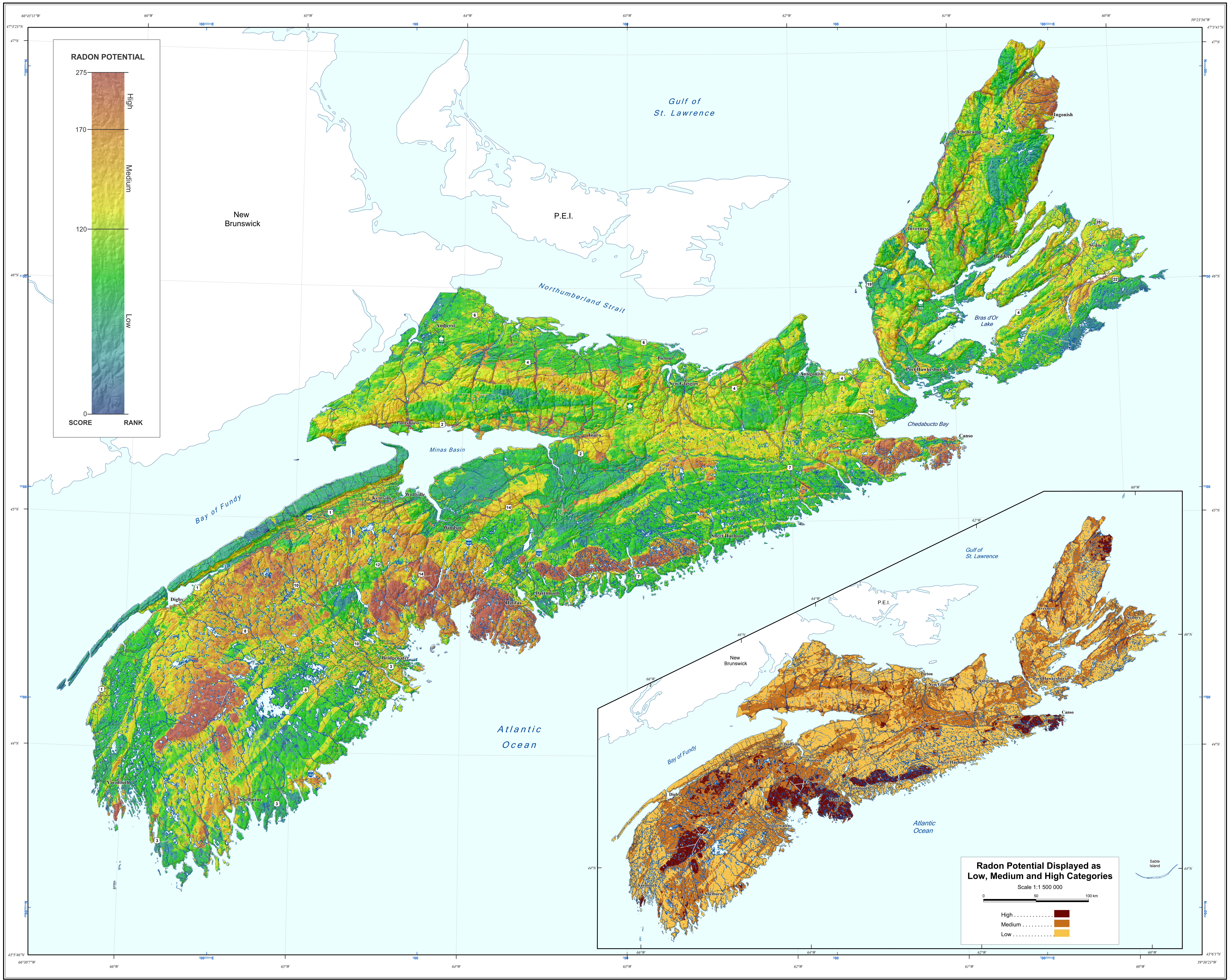


The Radon in Indoor Air Problem

Radon (Rn) is a naturally occurring, colourless and odourless gas that is radioactive and known to cause lung cancer. In fact, Rn is the second leading cause of lung cancer after smoking and the leading cause of the disease among non-smokers (World Health Organization, 2009). Radon is generated naturally from the radioactive decay of uranium. Both elements are found in varying amounts in all the soils and rocks throughout the province (Goodwin et al., 2009, 2010a). Since Rn is a gas, it is easily transported in the natural environment and transfers readily into air and water. In the outdoor environment, Rn emanating from the earth is very quickly diluted in the air to very low (background) concentrations (Goodwin et al., 2010b) that are well below the level of 200 Bq/m^3 that is deemed a health risk by Health Canada (Health Canada, 2008). Although a gas, Rn is very heavy, heavier than lead, in fact, and in the enclosed spaces of an indoor environment (homes and buildings) Rn can concentrate in low-lying areas like the basement or lowest levels of the home. Radon in indoor air can sometimes reach high enough levels to be a health risk and exceed the 200 Bq/m^3 Health Canada guideline.

Health Canada has established a protocol for Rn testing of homes (Health Canada, 2008). The protocol states that a home exceeding the 200 Bq/m^3 guideline, but below 600 Bq/m^3, should be remediated to below the guideline level within two years. Homes with a Rn level greater than 600 Bq/m^3 should be remediated to below the guideline within one year. There is an abundance of information available regarding Rn testing of homes and the remediation of homes that are found to exceed the Health Canada guideline. Readers may begin their search with the Nova Scotia Environment (www.gov.ns.ca/nse/radon/) and Health Canada (www.hc-sc.gc.ca/ewh-semt/radiation/radon/index-eng.php) websites.

The Nova Scotia Department of Health and Wellness recommends that all homeowners in the province test their homes for Rn. Many Rn studies carried out globally have shown conclusively that, although the percentage of homes exceeding established Rn guidelines can vary from area to area, there are no areas completely devoid of homes with high Rn. No matter where you live, the only way you will know for sure whether or not your home has high Rn is to complete a proper Rn test (Health Canada, 2008). Since there are regions where there are a higher percentage of Rn guideline exceedences, a map such as this showing the distribution of these regions is useful in determining priority areas for testing and for assisting with building code guidelines.

Derivation of the Map

A GIS-based (Geographic Information System) approach was used to produce this map (O'Reilly et al., 2010). A similar GIS-based approach was used successfully to produce a Rn potential map of the Oslo region of southern Norway (Smethurst et al., 2008) and the Geological Survey of Canada is currently undertaking a similar study for southern Ontario (K. L. Ford, personal communication). Using a GIS model to produce a map of this sort requires coverage of the study area in digital information layers of bedrock geology, surficial/soil geology and airborne gamma-ray spectrometry for eU (equivalent uranium). Coverage of the study area by indoor Rn measurement surveys is also necessary in order to test the validity of the GIS model and to determine exceedence probability percentages. Nova Scotia, more so than any other Canadian province or territory, benefits by having total provincial coverage in all these digital data layers and is, thus, a prime candidate for utilizing this map-making technique. The derivation and running of the GIS model are explained in more detail in O'Reilly et al. (2010). Basically, the GIS model brings together the three digital information layers and integrates the characteristics of each that pertain to its potential for the generation of Rn and for allowing the gas to migrate and accumulate within homes. The airborne gamma-ray spectrometric layer provides an estimate of the U concentration (U is the original source of the Rn) of the surface soils and rocks. The bedrock geology layer shows the distribution of each rock unit throughout the province and provides an estimate of each unit's potential to produce Rn. The surficial geology layer provides an estimate of the permeability of the surface material, a factor deemed very important in allowing Rn to travel through the soil to reach a building's foundation. These three data layers are factored against each other in the running of the GIS model and collectively produce a new layer depicting Rn potential score (Rn Score).

In our model the three data layers were given an equal weighting. Within each data layer, the potential for each unit constituting that layer to produce Rn was subjectively scored from 1 to 100. As such, following the running of the GIS model, a maximum cumulative Rn score of 300 is possible for any particular area. The GIS model produced a range of cumulative Rn scores from a minimum of 25 to a maximum of 275. It should be noted that areas of water cover produce a Rn score of zero, but since there are no homes or dwellings in water, these areas were ignored.

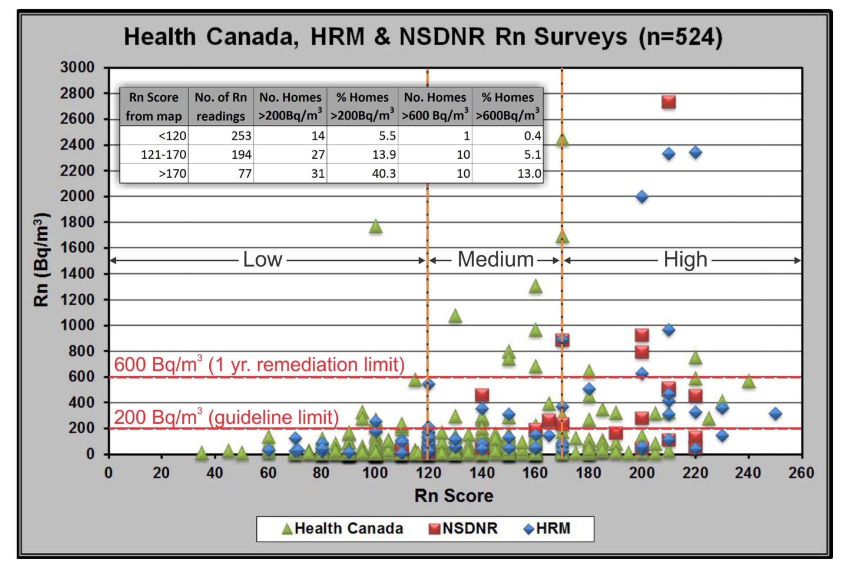
Interpretation of the Map Patterns

The Rn potential scores generated by this GIS model are presented here as two maps. The larger scale, multi-coloured map shows the Rn scores scaled progressively from low (circa 25; blue to blue-green) to the highest values (circa 275; reddish brown). This map will allow for a detailed examination of the Rn potential for particular areas should readers so desire. The second, smaller scale, three-colour map shows Rn potential scores separated into three categories based on their Rn producing capacity: low, medium and high. The low category encompasses Rn potential scores that are less than 120; the medium category encompasses Rn potential scores between 121-170; and the high category encompasses Rn potential scores greater than 170. The rationale explaining selection of these category breaks and a comparison of indoor Rn measurements versus their corresponding Rn potential score from the map is given below.

The Rn score patterns were tested against three datasets of indoor Rn measurements from 524 homes. Two of these datasets were provided by Health Canada: one consists of a 2011 province-wide survey (Health Canada, 2012) and the other was a survey that focused on the greater Halifax Regional Municipality in 2010 (Chen et al., 2011). A third dataset was a survey carried out by the Nova Scotia Department of Natural Resources (the location of the homes tested in these surveys will not be presented here due to a confidentiality agreement with Health Canada). These three surveys had rigid design controls and utilized unbiased sample selection criteria so they are suitable to use for comparison against the derived Rn potential score patterns from the GIS model. The authors also had access to data from other indoor air Rn surveys, such as Jackson (1990), and the results of a five year (2008-2012) provincial government program of Rn testing of all government-owned and -operated facilities (data contained within Department of Infrastructure Renewal Buildings Management Database). These latter two databases, although numbering in the thousands of Rn measurements, did not meet the rigid selection controls required for our statistical comparison and were not used to determine the probability estimates explained below.

Indoor Rn measurements from the Health Canada and NSDNR surveys, compared with their corresponding Rn potential scores from the map, are presented as an XY plot in Figure 1. This plot shows an obvious trend toward increasing incidence of homes with elevated Rn (Y axis) corresponding to the higher Rn potential scores from the map (X axis). In addition, the inset table on Figure 1 summarizes these data according to the low, medium and high category designations utilized on the three-colour Rn potential map. The figure shows the limit boundaries for each of the three Rn potential categories as well as the 200 Bq/m^3 Health Canada Rn in indoor air guideline and the 600 Bq/m^3 Health Canada one year remediation action level. This comparison shows that within the low Rn potential category (Rn score <120) 5.5% of the homes exceed the Health Canada 200 Bq/m^3 guideline, but only 0.4% exceed the 600 Bq/m^3 one year remediation action level. Within the medium Rn potential category (Rn score 121-170) the number of exceedences of the Health Canada 200 Bq/m^3 guideline rises sharply to 13.9% and the number of homes exceeding the one year remediation action level also begins to rise sharply (5.1%). In the high Rn potential category (Rn score >171) there is a very marked increase in the number of homes exceeding the Health Canada 200 Bq/m^3 guideline (40.3%) and also the one year remediation action level (13%).

The authors again want to stress that we agree with the Health Canada and Nova Scotia Department of Health and Wellness recommendation that all homes within the province should be tested for Rn. The data from this study clearly show that there is no region of the province free of homes with Rn exceedences. Conversely, it should also be noted that within all three categories on the map there still are many homes that have an indoor Rn level that is well below the Health Canada guideline. Living within a high Rn potential area is by no means a guarantee that your home will have high Rn. However, the only available option to know for sure is to test your home for Rn and if you find you do have a problem, take the appropriate measures to remediate the situation.



Rn Score from map	No. of Rn readings	No. Homes >200Bq/m^3	% Homes >200Bq/m^3	No. Homes >600 Bq/m^3	% Homes >600Bq/m^3
<120	253	14	5.5	1	0.4
121-170	194	27	13.9	10	5.1
>170	77	31	40.3	10	13.0

Figure 1. Graph comparing Rn potential scores from the map versus indoor Rn measurements of 524 homes across Nova Scotia, collected by Health Canada and NS Department of Natural Resources between 2009 and 2012. Inset provides a summary of the comparison showing the percentage of homes exceeding the 200 Bq/m^3 Health Canada Rn guideline in the low, medium and high Rn potential map categories.

Symbols

- Roads (primary, secondary)
- Roads (unpaved)
- Coastline, rivers, streams
- County boundary
- Lakes/Ocean

Map Notes

GIS databases, cartography and reproduction by Angie Ehler, Brian Fisher and Jeff McKinnon of the Nova Scotia Department of Natural Resources, Geoscience Information Services Section, 2012-2013. The GIS databases and map were developed using ArcGIS® 10.0.

Universal Transverse Mercator Projection (UTM), Zone 20, Central Meridian 63°00' West. North American Datum (NAD) 1983 Canadian Spatial Reference System (CSRS) 98.

Base and digital data derived from the Nova Scotia Topographic Database (NSTDB). Copyright Her Majesty the Queen in Right of the Province of Nova Scotia. The NSTDB is available from Service Nova Scotia and Municipal Relations (SNSMR), Land Information Services Division (LIS), Nova Scotia Geomatics Centre (NSGC), Amherst, Nova Scotia.

Shaded relief image derived from a 25 m Digital Elevation Model of the Province of Nova Scotia, DP ME 56, version 2, 2006. Azimuth of 315°, sun angle of 45° and a vertical exaggeration of 10.

Disclaimer

Acknowledgments

The authors would like to graciously acknowledge the many discussions and collaborations regarding radon and other related radionuclides we have had with several colleagues over the years. A special acknowledgment goes to Ken Ford of the Geological Survey of Canada, with whom we have worked on radiation topics since the early 1980s and who served as peer reviewer of this map. Pat Wall, former Provincial Radiation Health Officer for Nova Scotia, is also thanked for his many insightful discussions and for his efforts in keeping the radon issue front and centre on the provincial agenda. Several other colleagues, such as Dr. Robert Ryan and John Drage of NSDNR and Dr. Anne Marie Ryan of Dalhousie University, also share our interest in the geology of naturally occurring radionuclides and we've crossed paths with them on several occasions. A heartfelt thanks to all.

Nova Scotia Department of Natural Resources
Mineral Resources Branch

Open File Map ME 2013-028

Map Showing the Potential for Radon in Indoor Air in Nova Scotia

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Scale 1:750 000

20 0 20 40 60 80 km

Halifax, Nova Scotia
2013

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† Internal Search Number (ISN) is a unique identifier used in NovaScan - the Nova Scotia Geoscience Maps and Publications Database. The ISN can be used to retrieve a digital version of the listed citation - http://www.gov.ns.ca/natr/meb/default.asp

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Mineral Resources Branch

Open File Map ME 2013-028

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