



The BC Radon Data Repository (BCRDR): Developing a provincially integrated database

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Introduction

Radon (^{222}Rn) is a colorless, odorless, and tasteless gas derived from the breakdown of uranium found in rock and soil. Through permeable features within building foundations and the geologic structures beneath, radon can accumulate to problematic levels within confined indoor spaces. Radon further decays and emits alpha particles, which damage the DNA structures of cells when inhaled. Pooled epidemiologic studies suggest that long-term exposure to indoor radon is the second leading cause of lung cancer globally and the leading cause among non-smokers, with a synergistic effect between the two (1). In Canada, it is estimated that 16% of lung cancer mortality is attributed to radon (2).

Radon is relatively easy to measure with widely available devices and clear measurement protocols (3). In British Columbia (BC), indoor radon measurements have been conducted in bulk by government agencies, private companies, industry professionals, non-government organizations, and research groups. Although each individual dataset provides useful information about radon in BC, most are limited in their number of observations and geographic coverage.

Our early work collated some of these indoor radon data from a handful of sources to map regional concentrations (4), conduct ecological health analyses (5, 6), and model exposure vulnerability with other environmental data sources (7). These efforts demonstrated that integrating radon datasets from different sources can yield information that is beyond the scope of any individual dataset. As such, we identified the need for the BC Radon Data Repository (BCRDR), which integrates indoor radon concentrations and related data from multiple datasets into a single location. All data are cleaned and compiled using standardized methods, so they can be integrated and compared for different analyses. The overall objective of the BCRDR is to facilitate better understanding of radon and its health effects in BC, in turn supporting health protection and policy initiatives. This report summarizes the first year of the BCRDR operations, and the data collected during this time.

Methods

Establishing data sharing agreements

A data sharing agreement was created with consultation with the BC Centre for Disease Control (BCCDC) Privacy Officer and Provincial Health Service Authority legal counsel ([Appendix C](#)). The overarching aim of the agreement was to frame the BCCDC as stewards of an integrated database. Beyond finer details, this was achieved with the following core principles:

- Data providers continue to own their data, while the BCCDC is a steward of the integrated BCRDR dataset, using it only as outlined in the data sharing agreement. If a data provider wishes to no longer participate, their data will be removed from the integrated dataset, destroyed or returned.
- The BCCDC will hold BCRDR data in a secure, limited access folder system on its servers with the data security practices standard to the BCCDC for all potentially sensitive public health data.
- The BCCDC will only use BCRDR data for health protection research and mapping work with internal individual access only granted to authorized analysts.

- BCRDR data will not be used to re-identify buildings tested and will not be linked with any other data on a person-level. As such, the BCRDR holds no person-level identifiers.
- External parties can request access to the data through a standard application process at the BCCDC. Data will only be released for approved research and mapping work and the contents of the released data will be limited to what is required to satisfy the request.
- All publications or distributed materials using BCRDR data will only show de-identified or summary level information and must be reviewed by BCRDR data stewards for compliance.

With the data agreement established, we reached out to all parties who have formerly shared data with the BCCDC and all other known and potential radon data holders in the province.

Integrating and anonymizing data

All data management and analysis was done in the R statistical computing environment (9). All original data files were cleaned and standardized for integration into the BCRDR ([Appendix B: Table 1](#)). Any personal identifiers were stripped. Measurement location is a minimum requirement for inclusion in the BCRDR. All quasi-identifying spatial information (i.e., street address or 6-digit postal code) were anonymized with a systematic random jitter, as described below.

Address strings were geocoded using the BC Government's Physical Address Batch Geocoder (10). Only coordinates derived from address strings that were matched to a building or unit within its property boundary were kept. Observations with address strings that did not meet this criterion were geocoded using their 6-digit postal code, if present. Postal codes were geocoded using Statistics Canada's 2018 Postal Code Conversion File (11). The single link indicator (SLI) included in the file was used to estimate the location of the 6-digit postal code.

All coordinates derived from address strings and 6-digit postal codes were assigned the population density of the underlying 2016 census dissemination block. If the dissemination block was unpopulated, the dissemination area population density was used instead. A systematic random jitter was then applied to all coordinates, where the new coordinate was within 2-5 times the square root of the inverse population density in any direction. Simply put, observations in sparsely populated areas were jittered further from their original locations and observations in densely populated areas were jittered relatively closer to their original locations. The address string, 6-digit postal code, and original coordinates were then stripped from the data.

The random systematic jitter was limited to land areas and the community health service area underlying the original coordinate. Jittered coordinates were not generated for original coordinates that: (i) fell in an unpopulated dissemination block or area; (ii) could be jittered more than 500 m; or (iii) fell outside a 1 km buffer of the provincial ecumene (i.e., inhabited land area). Instead, these observations were assigned the larger geographic areas – forward sortation area (FSA) and the four BC health geographies – they fell within. Simply put, BCRDR observations with point geographies are limited to those that can be anonymized while still retaining spatial reliability. More detailed data management steps are described in [Appendix A](#).

Mapping the integrated data

To summarize the provincial distribution of integrated indoor radon data, we mapped median concentrations (given its typical log-normal distribution) and risk categories at the local health area

(LHA) level. The risk categories were defined as “high radon” if at least 5% of observations were 600 Bq/m³ or more, “moderate radon” if at least 5% of observations were 200 Bq/m³ or more, and “low radon” otherwise. A risk category was not assigned in LHAs with less than 20 observations. This categorization is consistent with our previous mapping work with the exception of categorizing risk in low sample size regions given the increased data availability in the present analysis (4, 5).

Observations from non-residential buildings were excluded here. Building type was considered unknown if not explicitly indicated in the source data; however, the providers of said data did note that most of their measurements could be assumed to occur in residential settings. So, observations with unknown building type were assumed to be residential and were retained in this analysis.

When a building had more than one measurement, only one value was included. If a building had indication of both pre- and post-mitigation measurements taken, the pre-mitigation measurement was used. Beyond this, one value was included given the following hierarchical consideration of test floor ([Appendix B: Table 1](#)).

- 1) If all measurements were taken on unknown floors, select one at random.
- 2) If measurements were taken on an unknown floor and main or upper floors, select one at random.
- 3) If measurements were taken on an unknown floor and lowest floor, crawl space, or basement, use one value from the lowest floor, crawl space or basement measurement in this order.
- 4) Otherwise, use one value with the following hierarchy: lowest floor, crawl space, basement, main floor, and then upper floor.

Comparison groups for mapping

Among the current BCRDR data sources, only the Health Canada surveys used a random sampling approach. The Cross-Canada Survey (CCS) of Radon Concentrations in Homes conducted cluster random sampling at the health service delivery area (HSDA) level (12) and the Radon and Thoron Data from Canadian Homes survey conducted a similar approach at the census metropolitan area (CMA) level (13). Data from other sources were collected on a volunteer basis, primarily for business or community service purposes. As such, BCRDR data holdings not included in the CCS (non-CCS) were compared with the CCS survey data at the HSDA level to investigate how selection bias impacts the aggregate results. The same non-residential and unique building measurement exclusions were done for this comparative analysis. The Radon and Thoron survey did not yield enough results for province-wide comparisons as it only sampled from four CMAs. This data subset was included in the non-CCS subset.

Results

Repository description

To date, the BC Radon Data Repository includes data from fourteen contributors ([Appendix B: Table 2](#)), summing to 14,063 unique observations from 8,512 known unique buildings ([Appendix B: Table 3](#)). If all observations that could not have a unique building inferred from their FSA or postal code were assumed to be from unique buildings, the current holdings would include data from 11,976 unique buildings.

The source data indicated that 5,346 (38%) measurements were from residential buildings and 1,383 (9.8%) were from non-residential settings such as schools or commercial spaces. Of the 14,063

observations, 8,730 (62.1%) were assigned to anonymized point coordinates. Of the remaining, 3,516 had FSA as the smallest spatial unit and 1,817 had LHA as the smallest. There were 8,678 (61.7%) observations with known start and end dates, and 8,044 of these had a duration of at least 90 days, which is Health Canada's recommended minimum length of time for an indoor radon measurement (3). Most occurred in the winter months, with 6,017 (69.3%) observations beginning sometime between November and February. Most of BCRDR data holdings, 11,425 (81.2%) observations, were measured using some form of alpha track detector.

Map of findings

After non-residential and multi-measurement exclusions, 10,783 observations were mapped to BC local health areas ([Appendix B: Table 4, Figures 1-3](#)). Of the 89 provincial LHAs, 68 had at least 20 observations to assign a radon risk category. The LHAs with small sample sizes were generally in remote areas or in the provincial Lower Mainland or Island where radon concentrations are typically lower. Thirteen LHAs were categorized as high radon areas, and twelve of these were in the Interior Health region. Large sample sizes in high radon areas were driven mostly by two data providers. The Donna Schmidt Lung Cancer Prevention Society contributed 2,464 (41.2%) observations and the BC Lung Association contributed 2,113 (35.3%).

The observed elevated radon in the provincial Interior are consistent with our previous analyses (4, 5, 7) and the CCS ([Appendix B: Table 5, Figure 4](#)). Median concentrations at the HSDA level were almost always higher among the non-CCS subset [n = 9,169] compared with the CCS data [n = 1,817]. However, these differences are mostly small. Three of sixteen HSDAs had an elevated risk category in the non-CCS subset: Central Vancouver Island, Thompson Cariboo Shuswap, and Northern Interior. Although the Kootenay Boundary region is characterized as high radon in both subsets, sample sizes and concentrations were notably higher among the non-CCS subset. It is reasonable to expect that a largely volunteer sampled dataset would find larger concentration values than a randomly sampled dataset.

Discussion

The data sharing process

The BCRDR has cast a wide net to invite sharing of relevant datasets. We did not receive replies from nine potential data providers – eight industry groups and one government agency. Three potential data providers declined participation citing their organization's privacy policy or consent forms at the time of data collection not allowing for data sharing. One potential provider declined participation without providing a reason. We did not engage in any data entry or ask data providers or potential participants to do the same. One industry professional noted interest in participation, but declined due to all relevant records being paper-based. Data sharing conversations began with ten potential providers that were lost to follow up – six industry groups, three government agencies, and one non-government organization. These conversations could be reignited when appropriate. Communication records were kept and could assist in these efforts. Participation was completely voluntary and no compensation, material or otherwise, was provided. It can be safely assumed that participation was a low priority for organizations that did not immediately see the utility of the BCRDR for their objectives. Moreover, several parties cited shifting demands and limited resources due to the COVID-19 pandemic, preventing or delaying participation.

The current BCRDR includes thirteen external contributors ([Table 2](#)). No data providers or potential providers raised concerns or requested revisions to the data sharing agreement. All finalized agreements cover data collected into the future. This is particularly useful for providers that collect indoor radon data on an ongoing basis, notably the BC Lung Association, the Donna Schmidt Lung Cancer Prevention Society, the Evict Radon program, the Take Action on Radon program and the various industry professionals. Routine data transfers were not discussed; integration will occur on an ad hoc basis.

Considerations for next steps

As this was a data integration initiative, we are not able to comment on the quality of the source data or its collection. The current integrated BCRDR holdings do not include any contextual building information as this was fairly limited in the source data. These include variables such as building construction year, foundation type, and presence of mitigation system, among others. Moreover, the current repository holdings do not have exact testing dates or test floor for a large percentage of observations.

Even so, the current repository holdings have almost three times as many observations than the data we have collated previously on an ad hoc basis. There are 8,730 observations available with anonymized point geographies with a max spatial error of 500 m to their original geocoded location. This is often critical for exposure vulnerability mapping in order to associate exposure estimates with a range of geospatial data types. One potential future use can be to explore smaller scale spatial distributions of indoor radon concentrations. For example, the BCRDR currently holds 1,621 point observations for the Prince George City – Central community health service area (CHSA) [2016 census population = 41,431] and 1,315 point observations for the Castlegar CHSA [2016 census population = 13,710]. Larger sample sizes at smaller geographies can also potentially improve the validity of ecological health analyses if the health data is available at this smaller scale as well.

The overarching goal of the BCRDR is to facilitate understanding of radon exposures in BC and their health effects. Here we presented the underlying framework to integrate data from unique sources and data security practices that allow for flexible analyses while still protecting the privacy of the source data participants. This can be used for reference in other jurisdictions where indoor radon data are also held by many different potential providers.

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Conflicts of Interest

The authors have no conflicts of interest to declare.

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Appendix A: Data Management Details

In the 2016 census, 14,629 of the province's 52,850 dissemination blocks were unpopulated. An address string or postal code coordinate could fall within these because: (i) the dissemination block did not include any residences, but included non-residential buildings that were tested for radon, such as a school; and (b) the geocoded coordinate did not represent the true location of the actual building tested, but rather the centroid of a postal delivery area, for example. Of the 14,629 unpopulated dissemination blocks, only 450 were in unpopulated dissemination areas. Using any larger census geography would be an unreliable indicator of population density for the jittering method used.

Measurements in sparsely populated areas require a large jitter to achieve anonymity, leading to spatially unreliable data. Capping the maximum possible jitter to 500 m retains point geography data that can still be reliably used to create clusters, overlay to other raster grids, or roll up to other geographies. These are observations that fall in a dissemination block (or area if the block is unpopulated) with a population density of less than 100 persons/km².

Some rural postal codes coordinates are central to a very large delivery area. Inherently, these points have too much spatial error to be reliably used as points. Geocoded coordinates that fall outside of a 1 km buffer of the provincial ecumene (i.e., inhabited land area) are removed. The provincial ecumene used considers census, geographic, and land use data (14). The 1 km buffer was chosen as it covers most within-city inhabitable areas such as city parks.

Some source data were limited to FSA as their smallest spatial unit. In these cases, FSAs were linked to the BC health geographies that they have at least 99% population weighted area overlap with. Population statistics from 2016 census dissemination blocks were used, where dissemination block centroids were within spatial joined to FSA health geography intersecting polygons.

Some source data had explicit indication of multiple measurements within one building (e.g., a measurement done pre- and post-mitigation). When not available, measurements with matching geocoded address string coordinates were considered as measurements within the same building. For observations with FSA or postal code as their most resolved spatial unit, a measurement with an entirely unique FSA or postal code within its source data was considered a unique building. Same building measurements were assigned the same jittered coordinates.

Appendix B: Tables and Figures

Table 1 – List and description of variables included in the BC Radon Data Repository.

Variable	Description
Start date	Start date of the test.
End date	End date of the test.
Start year	Start year of the test.
Building ID	Unique building identifier to indicate multiple measurements in the same building. When not explicitly stated in the source data, observations with matching geocoded address string coordinates were considered as observations within the same building. For observations with FSA or postal code as their most resolved spatial unit, an observation with an entirely unique FSA or postal code within its source data was considered a unique building. Same building measurements were assigned the same jittered coordinates.
Building type	A derived indicator of the building type. Variable categories limited to Residential, Non-Residential, and Unknown. Schools, daycares, commercial buildings, and health care facilities were defined as non-residential buildings. The building type was set to unknown when the source data was not able to indicate the building type of each observation despite acknowledgement that most its observations are in residential buildings.
Test floor	A derived indicator of the floor that the test occurred on. Variable categories limited to Crawl Space, Basement, Main Floor, Upper Floor, Lowest Floor, and Unknown. The ground level or first floor of a building was defined as a main floor. Any floor above the main floor was defined as an upper floor. If the specific floor was not indicated but it was explicitly stated that the test occurred on the building's lowest floor, the test floor was defined as the lowest floor.
Average radon concentration	The radon concentration in Becquerel per cubic metre rounded to the nearest whole number. If the measured concentration was below the device's minimum detection limit, the concentration value was set to the minimum detection limit divided by the square root of two.
Below device detection limit indicator	Indicator if the average radon concentration value was below the measurement device's minimum detection limit. Variable categories limited to Below Detection Limit and Not Relevant.
Testing device	Radon measurement device used.
Test occurrence indicator	Indicator of when the test occurred with respect to radon building mitigation. Variable categories limited to Pre-Mitigation, Post-Mitigation, and Unknown.
Jittered longitude	Jittered longitude coordinate of the building in the NAD 83 BC Albers projection (EPSG 3005).
Jittered latitude	Jittered latitude coordinate of the building in the NAD 83 BC Albers projection (EPSG 3005).

Postal code indicator	Indicator if the jittered coordinates were derived from a rural postal code (i.e., second postal code value = 0). Variable categories limited to Rural, Urban, and Not Relevant. This indicator is not relevant for observations without jittered coordinates or coordinates derived from address strings.
Forward sortation area	The forward sortation area the building resides within.
Community health service area	The community health service.
Local health area	The local health area.
Health service delivery area	The health service delivery area.
Health Authority	The health authority.

Table 2 – List and description of current contributors to the BC Radon Data Repository. Number of observations is after the cleaning and integration process.

Contributor	Description
Andrea Klingbeil	A C-NRPP certified measurement professional working through AmeriSpec Inspection Services, a franchise home inspection company. Data from ongoing measurement services.
BC Lung Association	A respiratory health community engagement and advocacy organization. Data from their RadonAware program, own ongoing sales of radon measurement devices, and ongoing lending from the North Shore library program.
BC Centre for Disease Control	A provincial public health agency. Data from previous surveys of homes, schools, daycares, and health care facilities.
Donna Schmidt Lung Cancer Prevention Society	A charity that donates radon measurement devices primarily in the provincial Interior. Data from ongoing donations.
Energy Advise	A company providing radon protection services through a C-NRPP certified measurement and mitigation professional. Data from ongoing measurement services.
Evict Radon	A research program out of the University of Calgary. Data from ongoing citizen science work.
Health Canada	A department of the Government of Canada. Data from the Cross-Canada Survey of Radon Concentrations in Homes and Radon and Thoron Data from Canadian Homes survey.
Interior Health Authority	One of five BC regional health authorities. Data from daycares tested in the region.
Little Bear Engineering	A company providing radon protection services through a C-NRPP certified measurement and mitigation professional. Data from ongoing measurement services.
Northern Health Authority	One of five BC regional health authorities. Data from radon measurement tests sold or provided to residents of the Northern Health region.
Peter Chataway	The sole proprietor of a building design business. Data from testing done as a non-profit aside.
Radon Protect Nelson	A company providing radon protection services through a C-NRPP certified measurement and mitigation professional. Data from ongoing measurement services.
Sterling IAQ Consultants	A company that provided radon measurement services through a C-NRPP certified measurement professional at the time of data sharing. Data from ongoing measurement services.
Take Action on Radon	A national advocacy and community engagement program that provides radon measurement devices to communities across Canada through their 100 Radon Test Kit Challenges. Data from this ongoing community work.

Table 3 – High level description of the BC Radon Data Repository.

	Number of observations
Total observations	14,063
Known unique building observations	8,512
Presumed unique building observations	11,976
Testing date availability	
Start and end date	8,678
Start year	10,812
With jittered point geographies	8,730
From rural postal codes	1,349
From urban postal codes	3,843
From address strings	3,538
Without jittered point geographies	5,333
With FSA as the smallest spatial variable	3,516
With LHA as the smallest spatial variable	1,817
Building type	
Residential	5,346
Non-Residential	1,374
Unknown	7,343
Test floor	
Upper floor	106
Main floor	2,465
Basement	3,241
Crawl space	15
Lowest floor	83
Unknown	8,153
Testing Device	
Alpha track detector	11,425
Various short-term testing device	94
Unknown	2,544

Table 4 – BC Radon Data Repository local health area summary statistics.

Health Authority	Local Health Area	Number of observations	Median radon concentration (Bq/m³) [5th, 95th %ile]	Risk Category
FHA	Abbotsford (AB)	222	35 [11, 131]	Low
FHA	Agassiz/Harrison (AH)	5	23 [12, 82]	Not Classified
FHA	Burnaby (BU)	76	16 [11, 48]	Low
FHA	Chilliwack (CW)	36	30 [11, 159]	Low
FHA	Delta (DLT)	47	11 [11, 45]	Low
FHA	Hope (HP)	10	42 [11, 281]	Not Classified
FHA	Langley (LG)	31	18 [11, 84]	Low
FHA	Maple Ridge/Pitt Meadows (MRPM)	36	11 [11, 37]	Low
FHA	Mission (MS)	21	15 [11, 52]	Low
FHA	New Westminster (NW)	12	22 [11, 40]	Not Classified
FHA	South Surrey/White Rock (SSWR)	26	18 [11, 46]	Low
FHA	Surrey (SR)	45	11 [11, 88]	Low
FHA	Tri-Cities (TC)	192	20 [11, 67]	Low
IHA	100 Mile House (1MH)	25	56 [15, 498]	Moderate
IHA	Armstrong/Spallumcheen (AS)	30	133 [39, 337]	Moderate
IHA	Arrow Lakes (AL)	141	155 [22, 662]	High
IHA	Cariboo/Chilcotin (CC)	55	63 [14, 176]	Moderate
IHA	Castlegar (CG)	1,464	192 [41, 869]	High
IHA	Central Okanagan (CO)	565	96 [26, 502]	Moderate
IHA	Cranbrook (CR)	164	48 [15, 227]	Moderate
IHA	Creston (CT)	73	74 [13, 362]	Moderate
IHA	Enderby (END)	17	74 [18, 331]	Not Classified
IHA	Fernie (FER)	80	124 [32, 544]	Moderate
IHA	Golden (GD)	28	87 [12, 328]	Moderate
IHA	Grand Forks (GF)	73	155 [35, 907]	High
IHA	Kamloops (KML)	150	74 [16, 428]	Moderate
IHA	Keremeos (KM)	8	78 [30, 501]	Not Classified
IHA	Kettle Valley (KV)	33	233 [45, 1,088]	High
IHA	Kimberley (KB)	84	116 [23, 414]	Moderate
IHA	Kootenay Lake (KTL)	28	130 [39, 494]	Moderate
IHA	Lillooet (LL)	12	86 [17, 174]	Not Classified

IHA	Merritt (MR)	16	64 [18, 182]	Not Classified
IHA	Nelson (NS)	944	148 [33, 676]	High
IHA	North Thompson (NT)	94	185 [52, 1,210]	High
IHA	Penticton (PTT)	141	78 [25, 651]	High
IHA	Princeton (PCT)	9	163 [48, 263]	Not Classified
IHA	Revelstoke (RS)	219	156 [48, 719]	High
IHA	Salmon Arm (SA)	213	100 [22, 350]	Moderate
IHA	South Cariboo (SRB)	5	55 [13, 244]	Not Classified
IHA	Southern Okanagan (SO)	62	111 [26, 858]	High
IHA	Summerland (SML)	52	144 [43, 648]	High
IHA	Trail (TL)	451	122 [31, 636]	High
IHA	Vernon (VN)	304	126 [30, 527]	Moderate
IHA	Windermere (WM)	42	114 [21, 822]	High
NHA	Burns Lake (BL)	30	31 [11, 123]	Low
NHA	Fort Nelson (FN)	71	63 [11, 220]	Moderate
NHA	Haida Gwaii (HG)	63	11 [4, 44]	Low
NHA	Kitimat (KT)	33	11 [11, 48]	Low
NHA	Nechako (NC)	52	75 [13, 245]	Moderate
NHA	Nisga'a (NA)	1	69 [69, 69]	Not Classified
NHA	Peace River North (PRN)	183	56 [11, 265]	Moderate
NHA	Peace River South (PRS)	136	55 [16, 237]	Moderate
NHA	Prince George (PG)	2,266	111 [18, 631]	High
NHA	Prince Rupert (PR)	42	11 [10, 15]	Low
NHA	Quesnel (QS)	127	57 [15, 186]	Low
NHA	Smithers (SM)	121	30 [11, 197]	Low
NHA	Snow Country (SCT)	9	26 [11, 122]	Not Classified
NHA	Stikine (ST)	26	56 [14, 419]	Moderate
NHA	Telegraph Creek (TGC)	1	290 [290, 290]	Not Classified
NHA	Terrace (TR)	146	58 [11, 316]	Moderate
NHA	Upper Skeena (US)	15	25 [11, 92]	Not Classified
VCH	Bella Coola Valley (BC)	2	120 [35, 206]	Not Classified
VCH	Central Coast (CTC)	0	-	Not Classified
VCH	Howe Sound (HS)	76	22 [11, 127]	Low
VCH	North Vancouver (NV)	107	18 [11, 80]	Low

VCH	Powell River (PWR)	35	22 [11, 116]	Low
VCH	Richmond (RM)	91	11 [9, 22]	Low
VCH	Sunshine Coast (SSC)	28	21 [11, 181]	Moderate
VCH	Vancouver - Centre North (VCN)	4	24 [12, 30]	Not Classified
VCH	Vancouver - City Centre (VCC)	8	11 [0, 25]	Not Classified
VCH	Vancouver - Midtown (VM)	94	11 [11, 31]	Low
VCH	Vancouver - Northeast (VNE)	17	15 [11, 42]	Not Classified
VCH	Vancouver - South (VS)	36	18 [11, 60]	Low
VCH	Vancouver - Westside (VW)	40	18 [11, 44]	Low
VCH	West Vancouver/Bowen Island (WVBI)	26	30 [11, 125]	Low
VIHA	Alberni/Clayoquot (AC)	23	11 [11, 42]	Low
VIHA	Comox Valley (CV)	57	11 [11, 51]	Low
VIHA	Cowichan Valley North (CVN)	16	22 [11, 79]	Not Classified
VIHA	Cowichan Valley South (CVS)	35	21 [11, 301]	Moderate
VIHA	Cowichan Valley West (CVW)	4	30 [12, 110]	Not Classified
VIHA	Greater Campbell River (GCR)	38	11 [11, 28]	Low
VIHA	Greater Nanaimo (GN)	47	18 [11, 61]	Low
VIHA	Greater Victoria (GV)	156	28 [11, 72]	Low
VIHA	Oceanside (OS)	21	26 [11, 157]	Low
VIHA	Saanich Peninsula (SP)	41	24 [11, 115]	Low
VIHA	Southern Gulf Islands (SGI)	52	30 [11, 151]	Low
VIHA	Vancouver Island North (VIN)	31	11 [11, 18]	Low
VIHA	Vancouver Island West (VIW)	1	17 [17, 17]	Not Classified
VIHA	Western Communities (WC)	34	22 [11, 107]	Low

Table 5 – Observations in the Health Canada Cross-Canada Survey (CCS) and compared with non-CCS observations in the BC Radon Data Repository, by health service delivery area summary statistics.

Group	Health Authority	Health Service Delivery Area	Number of observations	Median radon concentration (Bq/m ³) [5th, 95th %ile]	Risk Category
BCRDR	FHA	Fraser East (FE)	194	43 [11, 149]	Low
CCS	FHA	Fraser East (FE)	100	20 [11, 114]	Low
BCRDR	FHA	Fraser North (FN)	210	24 [11, 67]	Low
CCS	FHA	Fraser North (FN)	108	11 [11, 26]	Low
BCRDR	FHA	Fraser South (FS)	79	18 [11, 85]	Low
CCS	FHA	Fraser South (FS)	70	11 [11, 34]	Low
BCRDR	IHA	East Kootenay (EK)	529	96 [18, 509]	Moderate
CCS	IHA	East Kootenay (EK)	102	84 [11, 395]	Moderate
BCRDR	IHA	Kootenay Boundary (KB)	3,029	166 [37, 796]	High
CCS	IHA	Kootenay Boundary (KB)	106	96 [16, 716]	High
BCRDR	IHA	Okanagan (OK)	1,074	104 [30, 570]	Moderate
CCS	IHA	Okanagan (OK)	114	90 [18, 459]	Moderate
BCRDR	IHA	Thompson Cariboo Shuswap (TCS)	678	116 [30, 623]	High
CCS	IHA	Thompson Cariboo Shuswap (TCS)	112	44 [11, 232]	Moderate
BCRDR	NHA	Northeast (NE)	184	52 [22, 265]	Moderate
CCS	NHA	Northeast (NE)	206	64 [11, 239]	Moderate
BCRDR	NHA	Northern Interior (NI)	2,299	107 [18, 618]	High
CCS	NHA	Northern Interior (NI)	176	56 [11, 401]	Moderate
BCRDR	NHA	Northwest (NW)	222	35 [7, 277]	Moderate
CCS	NHA	Northwest (NW)	235	18 [11, 203]	Moderate
BCRDR	VCH	North Shore/Coast Garibaldi (NSCG)	196	26 [11, 104]	Low
CCS	VCH	North Shore/Coast Garibaldi (NSCG)	81	11 [11, 124]	Low
BCRDR	VCH	Richmond (RICH)	37	11 [7, 24]	Low
CCS	VCH	Richmond (RICH)	54	11 [11, 13]	Low
BCRDR	VCH	Vancouver (VAN)	116	18 [11, 49]	Low
CCS	VCH	Vancouver (VAN)	83	11 [11, 22]	Low
BCRDR	VIHA	Central Vancouver Island (CVI)	38	30 [11, 220]	Moderate
CCS	VIHA	Central Vancouver Island (CVI)	108	13 [11, 88]	Low
BCRDR	VIHA	North Vancouver Island (NVI)	20	16 [10, 55]	Low
CCS	VIHA	North Vancouver Island (NVI)	107	11 [11, 32]	Low
BCRDR	VIHA	South Vancouver Island (SVI)	264	30 [11, 104]	Low
CCS	VIHA	South Vancouver Island (SVI)	55	16 [11, 73]	Low

Residential BC Radon Data Repository Holdings in the Northern Health Region

n = 3,322

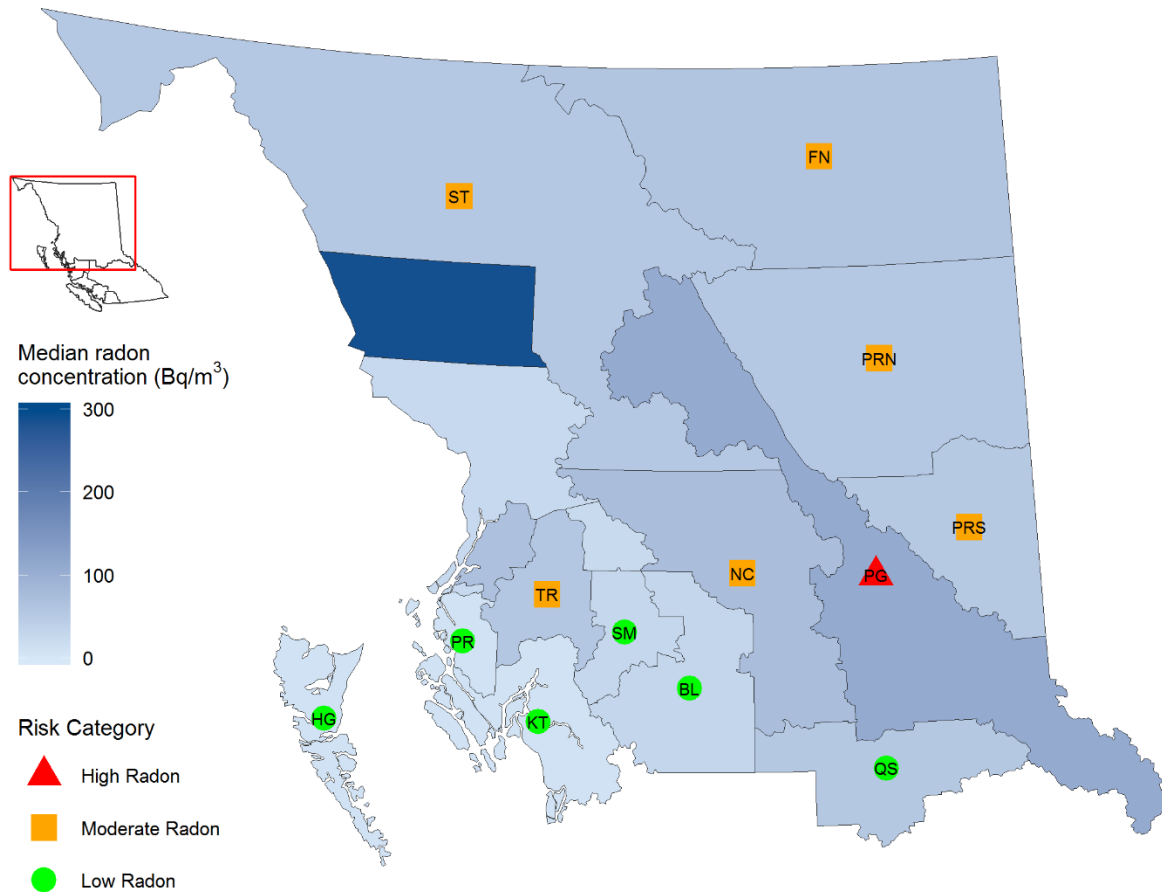


Figure 1 – Local health area map of median radon concentrations and risk categories in the Northern Health region. Measurements from non-residential buildings were excluded and a single measurement was taken from each building in the lowest floor if indicated. Risk categories were not assigned for local health areas with less than 20 measurements. Within each risk symbol are the local health area abbreviations ([Table 4](#)).

Residential BC Radon Data Repository Holdings in the Fraser and Interior Health Regions

n = 6,341

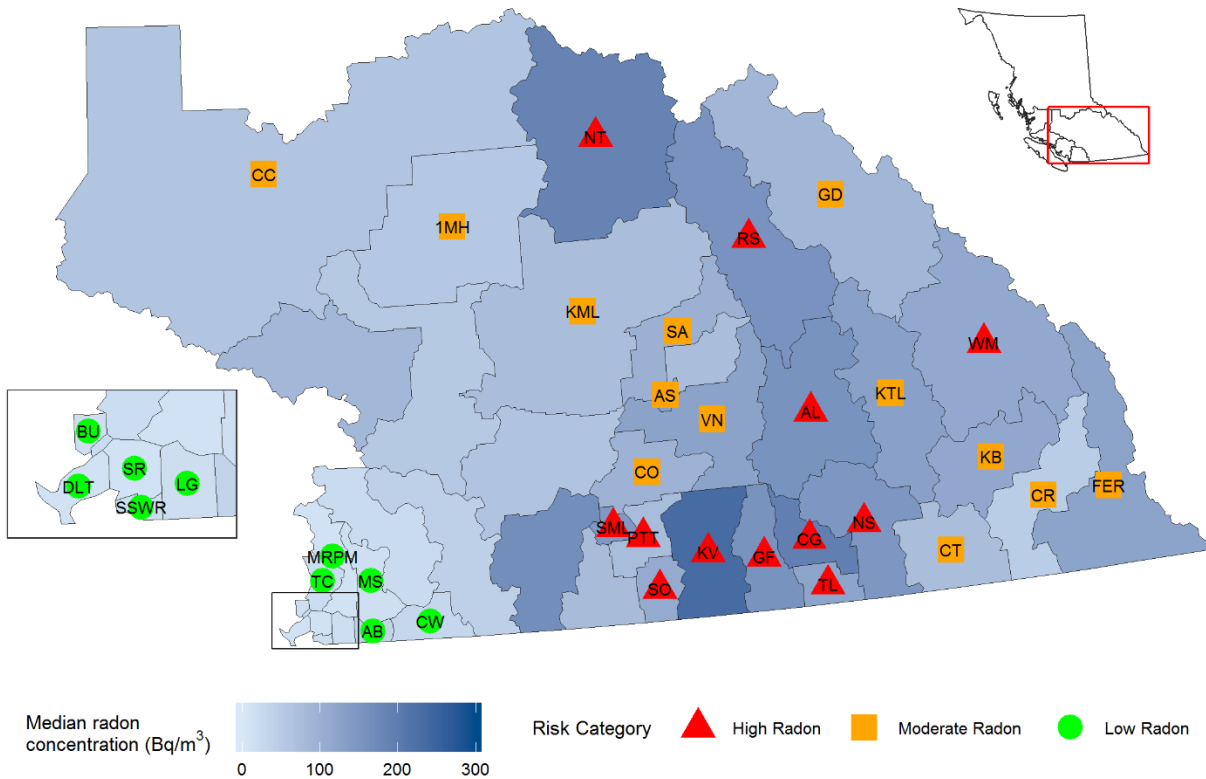


Figure 2 – Local health area map of median radon concentrations and risk categories in the Fraser and Interior Health regions. Measurements from non-residential buildings were excluded and a single measurement was taken from each building, in the lowest floor if indicated. Risk categories were not assigned for local health areas with less than 20 measurements. Within each risk symbol are the local health area abbreviations ([Table 4](#)).

Residential BC Radon Data Repository Holdings in the Vancouver Coastal and Island Health Regions

n = 1,120

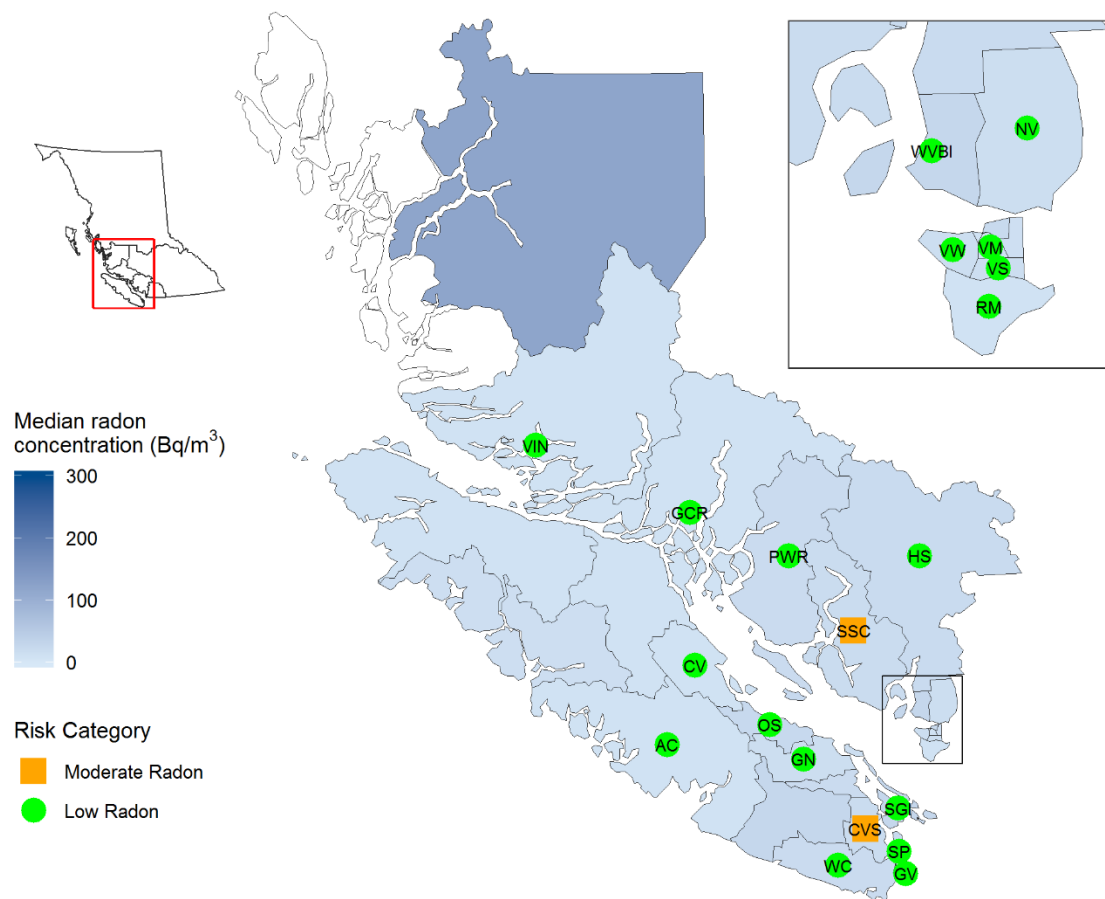
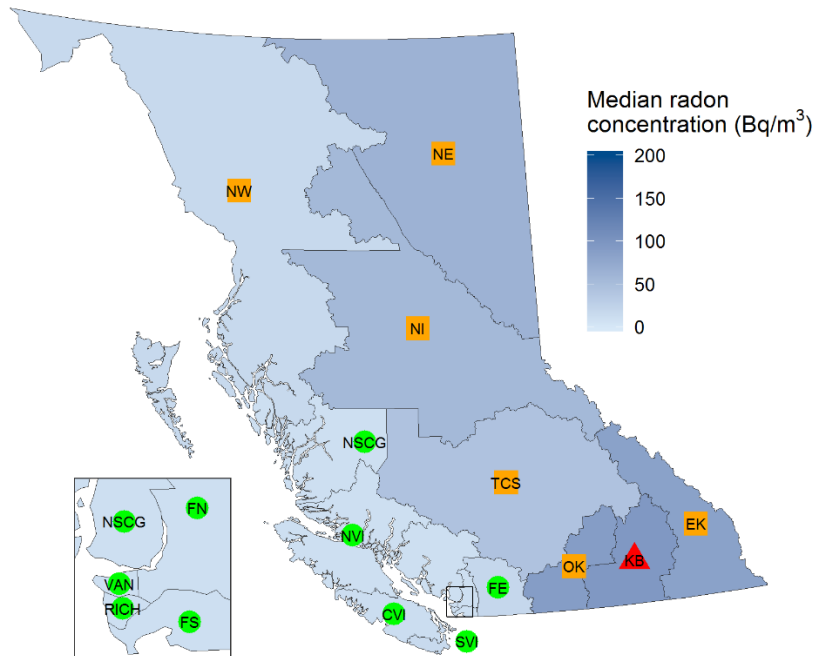


Figure 3 – Local health area map of median radon concentrations and risk categories in the Vancouver Coastal and Island Health regions. Measurements from non-residential buildings were excluded and a single measurement was taken from each building, in the lowest floor if indicated. Risk categories were not assigned for local health areas with less than 20 measurements. Within each risk symbol are the local health area abbreviations ([Table 4](#)).

Health Canada Cross-Canada Survey

n = 1,817



Homes not included in the Cross-Canada Survey

n = 9,169

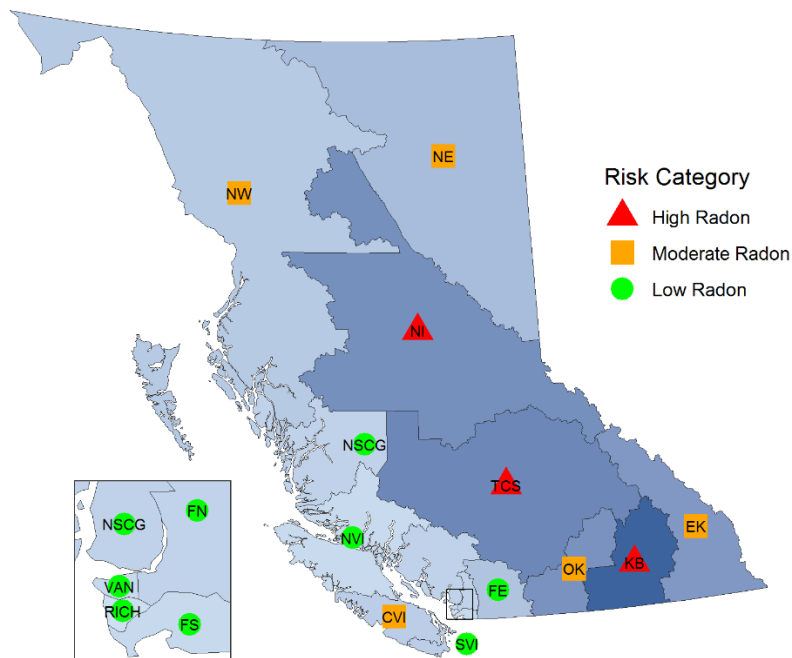


Figure 4 – Health Canada’s Cross-Canada Survey (CCS) and comparison non-CCS BC Radon Data Repository health service delivery area maps. Measurements from non-residential buildings were excluded and a single measurement was taken from each building in the lowest floor if indicated. Within each risk symbol are the health service delivery area abbreviations ([Table 5](#)).

Appendix C: Data Sharing Agreement

DATA SHARING AGREEMENT



British Columbia Radon Data Repository

This Data Sharing Agreement (the “**Agreement**”) is dated for reference March 12, 2020,

BETWEEN:

The British Columbia Centre for Disease Control, a part of the Provincial Health Services Authority, a society established under the *Societies Act* (British Columbia) with offices at 655 West 12th Avenue, Vancouver, BC V5Z 4R4 Canada

(the “**Recipient**”)

AND:

[insert legal name of Provider, describe legal status of Provider] with offices at [insert address of Provider]

(“the “**Provider**”)

(each a “**Party**”, and collectively the “**Parties**”)

BACKGROUND

- A. The Recipient has a mandate in British Columbia to conduct public health surveillance, detection, treatment and prevention, including the provision of direct diagnostic and treatment services for people with diseases of public health importance; and
- B. Environmental Health Services, a division of the Recipient, manages the British Columbia Radon Data Repository (the “**Repository**”), an integrated data set of indoor radon measurements from key stakeholders in British Columbia;
- C. Radon is an environmental carcinogen that is influenced by geographic and built environment factors. Measurement of indoor radon in British Columbia has been done by a variety of organizations; however, public health surveillance has been limited by these datasets remaining mostly separate. To provide a more robust understanding of indoor radon in British Columbia for public health planning, the Repository can merge currently disparate datasets and hold data collected into the future.

- D. As such, the Provider has agreed to deliver to the Recipient a Radon Data Set, described in detail in Appendix A to this Agreement in order to support the Recipient's public health initiatives related to radon and its environmental risks.

THEREFORE in consideration of the mutual premises, covenants and agreements herein, the Parties agree as follows:

1. DEFINITIONS

- 1.1 For the purposes of this Agreement, including the appendices:

"Authorized Person" means a person approved by the Recipient to access the Data and/or the Combined Data;

"BCCDC" means the British Columbia Centre for Disease Control, a program of the Provincial Health Services Authority;

"CDR" means the Central Data Repository, a secure, limited access folder system controlled by the BCCDC, and which houses all datasets retained by the BCCDC which contain Personal Information and/or Personal Identity Information.

"Combined Data" means the combined data sets disclosed by all data providers to the Recipient which once combined will comprise of the data in the Repository;

"Data" means all elements of the Radon Data Set described in Appendix A to this Agreement, for inclusion in the Repository;

"Effective Date" means the date on which this Agreement has been signed by both Parties;

"FIPPA" means the *Freedom of Information and Protection of Privacy Act*, R.S.B.C. 1996, c.165, as amended from time to time;

"Personal Identity Information" means "personal identity information" as defined in FIPPA;

"Personal Information" means "personal information" as defined in FIPPA;

- 1.2 In this Agreement, where applicable, a reference to the singular includes a reference to the plural and vice versa.

2. TERM

- 2.1 The Term of this Agreement shall commence on the Effective Date and will continue for five (5) years unless terminated earlier in accordance with this Agreement.

3. TRANSMISSION OF DATA TO THE RECIPIENT

- 3.1 The Data will be transmitted to the Recipient using a secure and approved method that meets the accepted policies and procedures of the Provider.

4. ACCESS, USE, DISCLOSURE AND RETENTION

4.1 The Recipient will ensure as follows:

- i. that only Authorized Persons have access to the Data and to the Combined Data;
- ii. that the Data and Combined Data are only used for the purposes set out at Appendix B to this Agreement unless the Provider has provided authority to do so;
- iii. that no attempts are made to use the Data or the Combined Data to re-identify an individual; and
- iv. that no linkage occurs other than as set out at Appendix B to this Agreement.

4.2 Except as expressly permitted in this Agreement, the Recipient will not,

- i. sell, distribute or copy the Data or the Combined Data; or
- ii. retransmit or combine the Data or the Combined Data with or into another database, without the written consent of the Provider.

4.3 The Recipient will retain the Data and the Combined Data in a secure, limited access folder system on its servers, accessible only by Authorized Persons based on the “need to know” principle.

4.4 The Recipient understands and agrees that no Personal Information that may be contained in the Data or the Combined Data may be accessed, stored, transmitted, or otherwise made available outside of Canada and that no person outside of Canada shall have access to the Data or the Combined Data in any manner except as expressly approved by the Provider in writing.

4.5 All requests for access and/or use of the Data or the Combined Data will be processed in accordance with the procedure outlined in Appendix C to this Agreement.

5. CUSTODY AND CONTROL

5.1 The Data will be under the custody of the Recipient and under the control of the Provider.

5.2 The Combined Data will be under the custody of the Recipient, and data stewardship of the Combined Data will be done in accordance with the Recipient’s policies and procedures.

6. SECURITY AND PROTECTION OF PRIVACY

6.1 The Recipient will maintain the security and confidentiality of the Data and the Combined Data in its possession by making reasonable security arrangements and setting standards in accordance with the Recipient’s policies and procedures to mitigate the risks of unauthorized access, collection, use, modification of use, disclosure or disposal.

6.2 The Recipient will maintain appropriate records regarding access approvals it grants to Authorized Persons.

6.3 The Recipient will identify to the Provider, upon request, the Authorized Persons responsible for managing the obligations of the Recipient under this Agreement, including the individual responsible for approving access for each Authorized Person and for maintaining appropriate records of all such approvals.

6.4 The Recipient will protect the confidentiality of all passwords, encryption keys and user accounts assigned by it in accordance with this Agreement, and in accordance with the Recipient's policies and procedures.

7. NON-DATA AND CONFIDENTIALITY

7.1 Notwithstanding the definition of "Data" and the agreed terms and conditions of this Agreement, if the Provider transfers written confidential information concerning the Data along with the Data, then to the extent permitted by law, the Recipient agrees to treat in confidence, for a period of ten (10) years from the date of its disclosure, any of the Provider's said confidential information. The Recipient's obligations of confidentiality do not extend to any information that:

- i. can be demonstrated to have been publicly known at the time of disclosure; or
- ii. can be demonstrated to have been in the possession of, or that can be demonstrated to have been, readily available to the Recipient from another source prior to the disclosure;
- iii. becomes part of the public domain or publicly known by publication or otherwise, not due to any unauthorized act of the Recipient;
- iv. can be demonstrated to have been independently developed, or acquired, by Recipient without reference to or reliance upon the Data submitted by the Provider under this Agreement; or
- v. required to be disclosed by law, provided the Recipient takes responsible and lawful actions to avoid and/or minimize such disclosure.

8. PUBLICATIONS

8.1 If the Recipient intends to publish findings or distribute written materials based on the Combined Data, the Recipient agrees to only use aggregate or de-identified data in any such publication.

9. NOTICE OF UNAUTHORIZED ACCESS, USE, DISCLOSURE OR MODIFICATION OF DATA

9.1 The Recipient will notify the Provider immediately of any circumstances, incidents or events which to its knowledge have jeopardized or may in future jeopardize:

- i. the privacy of individuals;
- ii. the security of the Data or the Combined Data; or
- iii. any suspected or apparent risk of a breach, or actual breach, of any term of this Agreement.

- 9.2 The Recipient will take all steps necessary to mitigate any of the circumstances outlined at 9.1 and the Provider reserves the right to proceed under a remedy for breach in accordance with [insert Provider policy if applicable, otherwise can remove this text].

10. REPRESENTATIONS AND INDEMNITY

- 10.1 The Provider makes no representations or warranties regarding the accuracy, completeness, reliability of fitness for use of the Data and submits that the Data is provided on an “as is” and “as available” basis.
- 10.2 To the extent permitted by the laws of British Columbia, the Recipient assumes all liability for damages the Recipient may suffer arising from:
- i. the Recipient’s acceptance, use, handling, storage or disposal of the Data;
 - ii. the Recipient’s use of any results generated from the use of the Data,
- except to the extent such damages are a direct result of the Provider’s negligence or willful misconduct.
- 10.3 The obligations of the Parties under this section 10 survive the expiry or termination of this Agreement.

11. NOTICES

- 11.1 Any notice or other communication required or permitted to be given under this Agreement must be in writing and may be delivered by hand (including commercial courier), mailed by registered mail, or sent by fax or email to the address, fax number or email address of each party set out below:

If to the Recipient:

Address: British Columbia Centre for Disease Control
Environmental Health Services
655 West 12th Avenue, Vancouver, BC V5Z 4R4

Telephone Number: 604-707-2449

Fax Number: 604-707-2441

Email: Sarah.Henderson@bccdc.ca

Attention: Sarah Henderson, PhD
Senior Scientist, Environmental Health Services

If to the Provider:

Address:

Telephone Number:

Fax Number:

Email:

Attention:

Or to such other address, fax number or email address as either Party may specify by notice in writing to the other Party

- 11.2 Notice will be deemed to have been given on (i) the day the notice is hand delivered; (ii) three (3) business days after notice is mailed by registered mail; (iii) the day the notice is faxed or sent electronically provided the sender has received confirmation of transmission from the receiving party.

12. TERMINATION

- 12.1 Either Party may terminate this Agreement on no less than sixty (60) calendar days' written notice to the other Party.
- 12.2 Either Party may, by written notice to the other Party, immediately terminate the Agreement if the other Party a) breaches any term of the Agreement and the breach is not:
- i. remedied within thirty (30) calendar days' of the receipt of notice from the first Party requiring it to remedy the breach; or
 - ii. capable of being remedied.
- 12.3 Upon termination of this Agreement for any reason, the Recipient will promptly remove the Data from the Combined Data, and return or destroy the Data, and then advise the Provider in writing to confirm the removal and return or the destruction of the Data.
- 12.4 The Recipient's obligations to maintain the privacy, security and confidentiality of the Data and the Combined Data will survive the termination of this Agreement.

13. GENERAL PROVISIONS

- 13.1 Nothing in this Agreement creates an agency relationship, a joint venture or a partnership between the Parties.
- 13.2 This Agreement will be binding upon and ensure to the benefit of the Parties and their respective successors and assigns.
- 13.3 If a term of this Agreement is invalid or unenforceable, said term will be severed and the remainder of the Agreement will remain in full force and effect.
- 13.3 Neither Party's failure nor neglect to enforce any rights under this Agreement will be deemed to be a waiver of said Party's rights.
- 13.4 All terms which reference they survive the termination of this Agreement will survive the termination of this Agreement as well as any terms of this Agreement which, by their nature, are intended to survive the termination of the Agreement, will survive said termination.
- 13.5 This Agreement
- i. is governed by the laws of the province of British Columbia and the laws of Canada applicable therein. Each of the Parties attorns to the exclusive jurisdiction of the courts of the province of British Columbia in respect of any matters arising out of this Agreement;
 - ii. including Appendices A, B and C, constitutes the entire agreement between the Parties as to the subject matter of the Agreement;

- iii. may be signed in counterparts, and may be delivered by fax or email, all of which together evidence the same Agreement;
- iv. may only be amended if agreed to in writing by both parties;
- v. may not be assigned without the written consent of both parties.

IN WITNESS WHEREOF the Parties have executed this Agreement effective as of the Effective Date.

Provider

Per its authorized signatory:

Name:

Title:

Signature:

Date:

Recipient

Per its authorized signatory:

Name:

Title:

Signature:

Date:

Recipient Acknowledgement

I have read this Agreement. I understand the obligations of the Recipient and acknowledge my obligations as the lead of the BC Radon Data Repository as a Senior Scientist within Environmental Health Services.

Name: Sarah Henderson, PhD

Signature:

Date:

APPENDIX A

Data to be provided to the Recipient

[describe Provider data holdings covered under this agreement here]

APPENDIX B

Vision, Uses, Data Manipulation, and Data Linkage

A. Vision

The Repository is a provincial data repository housed on the Recipient's premises that includes all eligible radon samples collected by the Recipient to date, and will continue to include eligible radon samples collected from data providers in the future.

B. Accepted uses of data contained the Repository

Accepted uses of data in the Repository consist of:

- i. public health surveillance of ecological radon exposure in British Columbia;
- ii. Mapping of the distribution of indoor radon concentrations to support health protection and policy initiatives in British Columbia;
- iii. Conducting research into a variety of radon-related purposes in British Columbia – for example, epidemiological, etc.

C. Procedure

Upon receipt of a radon data set from a data provider the following process applies:

- i. the data set file is saved in the Recipient's central data repository – it is expected that data set files may be received in various formats including spread-sheets, spatial data files, reports, forms, etc. – any data set files received in the original format from a data provider will not be edited and will be considered to be the data provider's "**Raw Original Files.**"
- ii. the Raw Original Files will be examined by the Recipient to determine how the data is organized and what variables are present.

The table below shows the type of data sought by the Recipient and the variables that may be extracted from Raw Original Files – Note: the list below is not exhaustive – data providers may submit additional data elements.

Type of data	Example Variables
Core sampling information (required for inclusion)	<ul style="list-style-type: none">the radon concentration (in pCi/L or Bq/m³)start date of measurementend date/duration of measurementsix (6) character postal codein lieu of six (6) character postal code, an exact address or longitude and latitude coordinates

Methodology (desirable, but not required)	<ul style="list-style-type: none"> • testing device used (e.g., long-term alpha tracking monitors) • testing device unique serial number • reason for testing • sampling strategy (e.g., convenience sampling) • specific testing protocols
Building information (desirable, but not required)	<ul style="list-style-type: none"> • building use (e.g., residence, school) • structural building type (e.g., low/ high rise) • location of testing within building (e.g., basement, main floor) • building square footage • age of building • number of windows • heating system • air conditioning • separation between basement and main floor • building foundation

- iii. Manipulate the Raw Original Files into a clean tabular format that will be considered a data provider's "**Cleaned Data Files.**" All Cleaned Data Files will have an accompanying code to detail exactly what revisions and manipulations have been made. Cleaning steps relevant to all data received are listed in steps (a) to (d) below.
 - a. If any Personal Information or Personal Identity Information is found at this state, such information will be removed in this step in the procedure with the exception of the six (6) character postal code or the address or coordinates provided in lieu of it.
 - b. If an address is provided for an observation without a six (6) character postal code, pass the address string through the Government of British Columbia's Physical Address Batch Geocoder to acquire the address' longitude and latitude coordinates. The address string would then be removed.
 - c. Acquire the longitude and latitude coordinates of each observation with a six (6) character postal code. The six (6) character postal code would then be removed.
 - d. To every observation's longitude and latitude coordinates, apply a random jitter to a degree inversely proportional to the location population density of the coordinates.
- iv. Integrate the data provider's Cleaned Data Files into the Combined Data that holds Cleaned Data Files from all data providers. Only jittered longitude and latitude coordinates and geographic units of a reasonable minimum size (e.g., Community Health Service Area) would be included in the Combined Data as spatial variables. No variables that could be used to identify a data provider will be included in the Combined Data.
- v. Assign a unique ID to each observation while keeping an internal record of how IDs were assigned. If a data provider decides to terminate this Agreement, this

unique ID will support the removal of the data provider's observations from the Repository.

As such, the Repository will retain:

- i. the Raw Original Files from each data provider;
- ii. the Cleaned Data Files that develop from the manipulation and revision of the Raw Original Files; and
- iii. the Combined Data as outlined under this procedure.

D. Data Linkage

The Data, once submitted into the Combined Data, will be linked by general geographic area only.

APPENDIX C

Data Access Process and Release Procedure

A. Submitting a data access request

Access to the Combined Data in the Repository will be administered through the Recipient's data access request procedure - all requests can be submitted using the Data Access Request Template available on the Recipient's Data Access Request page at:

<http://www.bccdc.ca/Health-Professionals-Site/Documents/Public%20Health%20Data%20Request%20Application%20Form%2020151208%20-%20fillable.pdf>

Requests for access to data contained in the Repository need to include, at minimum:

- i. name of the Principal Investigator and team members on the project;
- ii. a statement of the project objectives;
- iii. a statement of the expected outcomes for the project.

B. Data Release and Re-identification Risks

The Repository contains six (6) character postal codes which is considered a quasi-identifier, that is a variable that creates re-identification risk. To mitigate this risk, prior to releasing information in response to a request, the Recipient will map all values according to the six (6) character postal code and add random jitter to the latitude and longitudinal coordinates, inversely proportional to the population density. This process aligns with the Recipient's Policy 110: GIS Mapping of Protected Health Information.

C. Request procedure

Once an approved request for data from the Repository has been received, the following procedure will be followed by the Recipient:

- i. review the approved data request application and determine if any subsets to the Combined Data need to be made (e.g., requested only observations within a specified health authority region)
- ii. extract data as per the request parameter, and make a record of this.

- iii. review requested data against applicable Recipient data release policies (see part B above).
- iv. send requested data accompanied by a metadata document to the requester via a Recipient approved method (i.e. Secure File Transfer)
- v. create a folder for each request on the BCCDC CDR including the request, a file with a list of the Providers included in the request, and all material sent to fill the request along with any email communications related to the request.

D. Publication procedure

All publications and written materials to be distributed using the Combined Data must include the Recipient as a co-author.