Preliminary Findings of Radon Potential Indexes in Five Canadian Cities

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Abstract

Radon has been identified as the second leading cause of lung cancer after tobacco smoking. Since radon in soil is believed to be the main source of radon in Canadian homes, a radon potential index determined from soil radon concentration and soil permeability can be used to describe the indoor radon potential resulting from radon in soil gas. The index increases with increasing radon concentration in soil gas and soil permeability. This study reports detailed measurements of soil gas radon concentrations and soil permeability in a total of 254 sites in five cities, Montreal, Gatineau, Ottawa, Kingston and Toronto. Average radon potential indexes were determined for each individual site of five measurement locations. The results provided additional data for the mapping of radon potentials in Canada.

Keywords: Radon, Soil gas, Soil permeability

1. Introduction

Radon is a naturally occurring radioactive gas generated by the decay of uranium-bearing minerals in rocks and soils. A certain fraction of the radon escapes from the ground into the air. In the open air, radon is diluted to low concentrations and is not a health concern. In indoor environments, radon originating as soil gas is the main source of natural radiation exposure to the population. Radon has been identified as the second leading cause of lung cancer after tobacco smoking (WHO, 2005).

Based on new scientific information and a broad public consultation, the Canadian radon guideline was lowered from 800 to 200 Bqm^{-3} in June 2007 (Health Canada, 2007). To support the implementation of the revised guideline, a National Radon Program (NRP) was developed. A significant component of the NRP is the development of a radon database that will also include a number of targeted mapping activities. In Canada, radon maps are intended to be used mainly by governments to prioritize radon outreach and education efforts, to encourage testing and remediation where necessary, and to assist in community planning and future development. Canadian radon maps will be based on a variety of data, such as ground uranium concentration from airborne gamma ray spectrometric surveys, radon in soil gas, soil permeability, soil geochemistry, surficial geology, bedrock geology, and indoor radon data (Chen, 2009). To assist radon mapping, measurements of soil gas radon concentration and soil permeability have been conducted in cities since 2007. Determination of soil radon potential indexes in five cities (Montreal, Gatineau, Ottawa, Kingston & Toronto) are reported here.

2. Methods

All surveys followed well established protocol of the National Soil Radon Project, a Canadian add-on project to the North American Soil Geochemical Landscapes Project (GSC, 2008). Surveys were conducted on a dry day with a clear sky at least the previous evening. Soil gas radon and soil permeability measurements were conducted in community parks within residential areas. The soil survey sites were areas of about 10x10 m^2 in low-traffic areas of community parks and away from roads. For each site, five soil gas radon measurements and at least two in-situ soil permeability measurements were performed with four probes at each corner and one in the centre of the 10x10m^2 survey area.

Soil gas radon was determined by measuring the concentration of radon in soil gas samples extracted from 80 cm depth below ground surface using the RM-2 system manufactured by Radon v.o.s. in Czech Republic (http://www.radon.eu/rm2.html). Soil gas samples were collected using small-diameter hollow steel probes with a free, sharpened lower end (a lost tip) combined with a syringe. Soil gas samples of 150 ml in a syringe were introduced into ionizing chambers for measurement of radon concentrations. An ionization chamber was only used when its background reading was below 0.7 kBq m^{-3}, as instructed by the manufacture. Soil radon concentrations measured below 1 kBq m^{-3} were excluded. Any potential leakage during the soil gas sampling could result in a lower radon concentration. Therefore, the lowest measured value of soil gas radon was also excluded in the calculation of the average radon concentration for a site.

Soil gas permeability was measured 80 cm below ground surface with the use of RADON-JOK also manufactured by Radon v.o.s. in Czech Republic (http://www.radon-vos.cz/?lang=en&lmenu=en_measuring&page=en_measuring_jok). RADON-JOK is based on air withdrawal by means of negative pressure. The soil gas is pumped under constant pressure through a probe (the same probe as used for soil radon collecting) with a constant surface, an active area created in the head of the probe at 80 cm below the ground. The soil gas permeability was calculated based on Darcy's equation (Koorevaar *et al*., 1983). For sites having very low permeability, the in-situ soil gas permeability measurement could potentially take hours to complete. For logistical reasons, in those cases, a default value of 2 $\cdot 10^{-14}$ m^2 is assumed. In the city of Ottawa, in-situ permeability measurements were conducted in all five probes per site while permeability measurements were performed at two out of five probes at each site in other cities. For those sites where only two in-situ permeability measurements were performed, the semi-quantitative estimation of permeability was applied with consideration of how hard to collect soil gas with a syringe at other three probes. For each probe where a soil gas sample was collected with a syringe, a subjective description of how hard to collect soil gas with a syringe was recorded as easy, medium or hard. This provides a semi-quantitative estimation of permeability, especially for those values between in-situ measured permeability and the default value of $2 \cdot 10^{-14}$ m^2.

Soil gas radon concentration and soil permeability are the two most important factors that affect radon flux from soil to air (Neznal *et al*., 2006). Since radon in soil is believed to be the main source of radon in Canadian homes, a radon potential index determined from soil radon concentration and soil permeability can be used to describe the indoor radon potential resulting from radon in soil gas. The index was also called soil radon potential (SRP) index in previous publications (Chen *et al*., 2008a, 2008b), that is defined as:

$$SRP = \frac{C - C_0}{-\log(P) + \log(P_0)}$$

where C is the radon concentration in soil gas in units of kBq m^{-3}, and P is the soil permeability in units of m^2. C_0 and P_0 are set to 1 kBq m^{-3} and $1 \cdot 10^{-10}$ m^2, respectively. In this study, SRP indexes were calculated for each site surveyed.

3. Results and Discussion

For the sites where in-situ permeability measurements were performed in all five probes, an average permeability of the five measurements was assigned to that site. For the sites where only two permeability measurements were performed at each site of five probes for soil radon measurements, an average permeability of the two measurements was assigned to that site where at least one in-situ permeability measurements were successfully performed, i.e. above the default value for very low permeability ($2 \cdot 10^{-14}$ m^2). Some sites surveyed had very low permeability at both probes for in-situ measurement. For those sites, the semi-quantitative estimation of permeability is applied with consideration of how hard to collect soil gas with a syringe at other three probes, as given in a previous publication (Chen *et al*., 2011).

A total of 254 sites were surveyed with 76, 36, 42, 26 and 74 sites in Montreal, Gatineau, Ottawa, Kingston and Toronto, respectively. Soil radon concentrations varied significantly from site to site and also from probe to probe for most sites surveyed. Therefore, an average soil radon concentration was calculated for each site. With the average soil radon concentration and measured and/or assigned permeability, a soil radon potential (SRP) index was calculated to characterize each site. Summary results are given in Table 1. Since radon in soil is believed to be the main source of radon in Canadian homes, the indoor radon potential could have a strong association with the soil radon potential as given in Table 1.

Indoor radon potential for a community could be represented by the percentage of homes above the Canadian guideline value of 200 Bqm^{-3} in that community. It characterises the average radon level in a community, and can not be used to predict radon concentration in any individual homes. From Table 1, one can see that, within certain variations, percentages of homes above 200 Bqm^{-3} could be comparable in the five cities surveyed. This prediction needs to be verified by direct indoor radon measurements when detailed results of the cross Canada radon survey (Health Canada, 2011) become available.

This paper is aimed to provide additional layer of data to the development of Canadian radon potential maps. For this purpose, detailed results for individual sites are given in Tables 2 to 6 for Montreal, Gatineau, Ottawa, Kingston and Toronto, respectively. It should be mentioned that soil radon potential is only one layer of data required in a multi-tier approach of indoor radon potential mapping. Canadian radon maps will be based on a variety of data. Results presented here can be used to fill data gaps in the map, especially in cities where airborne gamma ray spectrometric surveys were restricted.

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Table 1. Summary of results: averages and standard deviations including measurement ranges in brackets for soil radon surveys in Ottawa (2007) and in Montreal, Gatineau, Kingston and Toronto (2010)

city	sites	C (kBq/m3)	P (m2)	SRP
Montreal	76	28 ± 21(1, 157)	$5.3\cdot10^{-12} \pm 5.5\cdot10^{-12}(2.0\cdot10^{-14}, 2.2\cdot10^{-11})$	20 ± 16(0, 64)
Gatineau	36	17 ± 11(1, 47)	$5.7\cdot10^{-12} \pm 6.6\cdot10^{-12}(4.1\cdot10^{-14}, 2.0\cdot10^{-11})$	12 ± 11(0, 61)
Ottawa	42	22 ± 15(2, 67)	$3.9\cdot10^{-12} \pm 6.0\cdot10^{-12}(2.0\cdot10^{-14}, 2.7\cdot10^{-11})$	12 ± 10(0, 49)
Kingston	26	11 ± 10(1, 42)	$4.0\cdot10^{-12} \pm 5.4\cdot10^{-12}(2.0\cdot10^{-14}, 1.8\cdot10^{-11})$	8 ± 9(0, 35)
Toronto	74	23 ± 14(1, 65)	$2.9\cdot10^{-12} \pm 3.7\cdot10^{-12}(2.0\cdot10^{-14}, 1.5\cdot10^{-11})$	12 ± 10(0, 44)

Table 2. Soil radon survey results (average soil radon concentration in kBq/m^3, average permeability in m^2, and SRP) in 76 community parks in Montreal

Latitude	Longitude	Soil radon kBq/m^3	Permeability m^2	SRP
45.30150	-73.78040	24.7	9.8E-13	11.8
45.40587	-73.95101	55.0	3.8E-12	38.0
45.41670	-73.90944	8.9	2.0E-14	2.1
45.41976	-73.64191	27.1	2.2E-12	15.8
45.42769	-73.87747	26.9	1.3E-11	29.5
45.43219	-73.62305	43.9	2.1E-11	62.7
45.43804	-73.71603	18.7	8.9E-13	8.6
45.43880	-73.67297	12.1	2.2E-11	16.9
45.43894	-73.92964	1.3	2.0E-14	0.1
45.44001	-73.74774	11.5	1.1E-12	5.4
45.44093	-73.48617	28.8	4.9E-13	12.0
45.44133	-73.90016	47.5	5.5E-12	36.9
45.44437	-73.86008	21.5	4.6E-12	15.4
45.44860	-73.75838	49.1	4.9E-12	36.8
45.44971	-73.45987	60.6	9.7E-12	58.8
45.45118	-73.82253	5.8	2.0E-14	1.3
45.45456	-73.60612	24.2	2.0E-14	6.3
45.46059	-73.89482	59.8	2.3E-12	35.7
45.46183	-73.64533	14.9	3.4E-13	5.6
45.46385	-73.85503	23.1	3.4E-12	15.0
45.47278	-73.61444	49.8	4.7E-12	36.7
45.47398	-73.67171	13.4	2.0E-14	3.3
45.48002	-73.58657	21.9	1.5E-11	25.7
45.48237	-73.64624	38.8	6.1E-13	17.1
45.48319	-73.47215	16.5	2.7E-12	9.9
45.48679	-73.45123	2.2	2.0E-14	0.3
45.49319	-73.79730	17.4	1.0E-11	16.3
45.49770	-73.68977	29.2	7.2E-12	24.7
45.50104	-73.39747	157.3	3.6E-13	63.8
45.50388	-73.50397	21.0	2.3E-13	7.6
45.50505	-73.63054	46.1	1.4E-11	53.1
45.50956	-73.70312	31.2	3.4E-12	20.6
45.51095	-73.83920	34.1	1.2E-11	35.2
45.51550	-73.72444	43.6	1.2E-11	45.5
45.51637	-73.58637	48.1	6.0E-12	38.5
45.52441	-73.78796	7.5	7.0E-13	3.0
45.53009	-73.77078	17.8	1.1E-11	17.8
45.53058	-73.92921	18.1	4.8E-12	12.9
45.53273	-73.44504	32.0	1.0E-11	31.1
45.53354	-73.73245	15.5	2.2E-12	8.7
45.53640	-73.68385	9.2	9.5E-12	8.0
45.53772	-73.59417	18.0	2.2E-12	10.3
45.54038	-73.50013	47.4	3.1E-13	18.5
45.54187	-73.89613	14.2	6.8E-12	11.3
45.54707	-73.61889	69.4	2.2E-12	41.5
45.54844	-73.65089	17.6	1.2E-11	18.0
45.54925	-73.54958	6.3	4.8E-12	4.0
45.55303	-73.76755	22.8	1.3E-13	7.6
45.55455	-73.70626	12.6	4.4E-13	4.9
45.55975	-73.47765	24.1	5.8E-12	18.6
45.56041	-73.89622	23.6	8.3E-12	20.9
45.56310	-73.55691	14.4	3.4E-12	9.1
45.57003	-73.61687	20.5	1.0E-11	19.5
45.57098	-73.72966	22.2	4.1E-13	8.9
45.57538	-73.64436	15.1	3.1E-12	9.4

45.57819	-73.89899	43.4	5.3E-14	12.9
45.57867	-73.67905	51.6	9.0E-12	48.3
45.58144	-73.55377	9.7	4.3E-13	3.7
45.58376	-73.60902	3.1	3.4E-12	1.4
45.58416	-73.92610	23.5	2.0E-14	6.1
45.58490	-73.86031	47.6	6.1E-13	21.0
45.59213	-73.59074	39.9	1.3E-12	20.5
45.59382	-73.44754	24.4	4.1E-12	16.8
45.59425	-73.52003	34.2	1.8E-13	12.1
45.60024	-73.63714	29.5	5.0E-12	21.9
45.60196	-73.65794	41.1	1.4E-11	46.4
45.60431	-73.56923	17.4	3.6E-12	11.3
45.60814	-73.53729	41.1	1.3E-11	45.2
45.61039	-73.59530	20.4	9.6E-12	19.1
45.61565	-73.62405	25.6	1.1E-11	25.6
45.62732	-73.59251	19.1	9.4E-12	17.6
45.63969	-73.49861	19.9	3.2E-12	12.6
45.64398	-73.58823	16.6	1.0E-11	15.9
45.65448	-74.09345	16.7	1.7E-13	5.7
45.65529	-73.50076	26.0	2.3E-12	15.2
45.66244	-73.55072	27.6	2.2E-11	40.6

Table 3. Soil radon survey results (average soil radon concentration in kBq/m^3, average permeability in m^2, and SRP) in 36 community parks in Gatineau

Latitude	Longitude	Soil radon kBq/m^3	Permeability m^2	SRP
45.38678	-75.84184	14.5	2.0E-11	19.1
45.39283	-75.82639	29.7	1.5E-13	10.1
45.39747	-75.80582	6.2	1.2E-11	5.7
45.40888	-75.79626	24.9	3.9E-13	9.9
45.41597	-75.84550	18.8	1.6E-11	22.0
45.41943	-75.75222	15.5	7.8E-12	13.1
45.42370	-75.43270	1.0	4.1E-14	0.0
45.42482	-75.75936	30.4	4.2E-12	21.4
45.42628	-75.73347	12.8	1.8E-11	15.8
45.43012	-75.71562	13.2	2.9E-12	7.9
45.43458	-75.70768	23.6	3.4E-12	15.4
45.43724	-75.79552	1.0	6.1E-13	0.0
45.43803	-75.72375	7.5	3.4E-12	4.4
45.44196	-75.78279	13.9	3.4E-13	5.2
45.44271	-75.77666	11.4	1.6E-12	5.8
45.45326	-75.74669	31.8	4.1E-12	22.3
45.45481	-75.75191	34.1	2.6E-13	12.8
45.45612	-75.42739	7.6	9.9E-12	6.5
45.46356	-75.75406	16.7	4.5E-13	6.7
45.46471	-75.07679	18.2	2.7E-12	11.0
45.47722	-75.68531	28.2	3.1E-12	18.1
45.47852	-75.63909	14.4	1.4E-11	15.7
45.48140	-75.48140	36.6	1.1E-13	12.0
45.48678	-75.48678	19.3	1.1E-13	6.2
45.49138	-75.69865	2.7	1.1E-13	0.6
45.49157	-75.59798	9.0	1.1E-13	2.7
45.50209	-75.68008	3.6	6.1E-13	1.2
45.50438	-75.65306	4.9	3.4E-12	2.6
45.50454	-75.60797	21.6	3.2E-12	13.8
45.50556	-75.59229	16.4	7.0E-12	13.3
45.50748	-75.57867	10.8	5.1E-12	7.5
45.52714	-75.64064	1.0	3.4E-12	0.0
45.52861	-75.91411	47.0	1.8E-11	61.0

45.53447	-75.82533	22.5	1.9E-11	29.9
45.58932	-75.90336	16.2	1.7E-12	8.7
45.86171	-75.40004	13.5	2.0E-11	17.7

Table 4. Soil radon survey results (average soil radon concentration in kBq/m^3, average permeability in m^2, and SRP) in 42 community parks in Ottawa

Latitude	Longitude	Soil radon kBq/m^3	Permeability m^2	SRP
45.13938	-75.60484	2.4	5.6E-12	1.1
45.19650	-75.83875	32.6	9.6E-14	10.5
45.22243	-75.68892	40.0	1.2E-12	20.2
45.23742	-75.47831	29.8	1.9E-12	16.7
45.24482	-75.59020	66.8	4.4E-12	48.6
45.24509	-75.70149	29.4	2.9E-13	11.2
45.24937	-75.59959	4.3	2.0E-14	0.9
45.26222	-75.94209	6.4	3.5E-12	3.7
45.26739	-75.91285	12.8	2.3E-12	7.2
45.26797	-75.82615	38.9	3.4E-12	25.8
45.27486	-75.69083	22.3	1.3E-13	7.4
45.27795	-75.85137	14.7	2.3E-14	3.8
45.28189	-75.76294	31.8	1.8E-13	11.2
45.28757	-75.71651	18.8	2.5E-13	6.8
45.29297	-75.87672	22.6	9.5E-14	7.2
45.30376	-75.90224	24.1	1.3E-11	25.6
45.31915	-75.82758	28.8	3.0E-12	18.3
45.32766	-75.89394	25.5	2.9E-14	6.9
45.32770	-75.78418	25.6	2.1E-13	9.2
45.33664	-75.60621	27.3	5.9E-12	21.4
45.34114	-75.76836	22.9	1.6E-13	7.8
45.34118	-75.63457	10.8	1.6E-11	12.3
45.34984	-76.03506	17.2	1.8E-11	21.4
45.35117	-75.92391	58.6	9.8E-14	19.1
45.35170	-75.62634	16.0	8.3E-12	13.9
45.35212	-75.94211	64.8	1.1E-12	32.4
45.35295	-75.72057	11.9	2.4E-13	4.2
45.35709	-75.78975	19.6	2.3E-12	11.3
45.36686	-75.67605	10.3	2.0E-14	2.5
45.37131	-75.72701	21.2	7.6E-12	18.1
45.38297	-75.71412	12.4	1.8E-12	6.5
45.39597	-75.65003	29.7	1.8E-12	16.5
45.39830	-75.69313	11.1	1.4E-11	12.0
45.39857	-75.75342	9.8	7.8E-12	8.0
45.40779	-75.47556	33.1	2.2E-14	8.8
45.41925	-75.42059	27.2	8.9E-13	12.8
45.43303	-75.66850	6.8	2.7E-11	10.3
45.43745	-75.52745	6.8	2.0E-14	1.6
45.44819	-75.68486	22.5	1.2E-11	23.4
45.46217	-75.46953	11.6	2.3E-13	4.0
45.46473	-75.48168	4.0	2.0E-14	0.8
45.47072	-75.47569	2.8	2.0E-14	0.5

Table 5. Soil radon survey results (average soil radon concentration in kBq/m^3, average permeability in m^2, and SRP) in 26 community parks in Kingston

Latitude	Longitude	Soil radon kBq/m^3	Permeability m^2	SRP
44.21220	-76.57608	5.2	3.4E-12	2.8
44.22547	-76.48976	21.1	4.7E-12	15.1
44.22940	-76.58295	19.8	3.4E-12	12.8
44.23313	-76.49822	1.9	3.4E-12	0.6
44.23347	-76.62688	8.7	2.0E-14	2.1
44.23378	-76.51591	1.6	2.0E-14	0.1
44.23600	-76.59685	24.8	5.8E-12	19.2
44.24282	-76.48576	7.2	1.4E-11	7.2
44.24408	-76.58569	31.6	1.4E-11	35.2
44.24673	-76.54391	1.4	1.1E-13	0.1
44.24808	-76.60774	4.0	1.1E-13	1.0
44.25007	-76.50255	20.4	2.0E-14	5.2
44.25039	-76.48431	15.6	2.6E-13	5.7
44.25314	-76.56139	1.2	2.0E-14	0.1
44.25512	-76.45796	3.4	1.1E-13	0.8
44.25569	-76.38628	42.4	3.4E-12	28.2
44.25691	-76.52547	8.3	1.3E-11	8.3
44.26266	-76.57763	15.9	1.8E-11	19.8
44.26642	-76.48907	11.7	6.3E-13	4.8
44.26657	-76.44809	7.2	1.1E-13	2.1
44.27066	-76.61889	17.2	6.4E-12	13.6
44.27283	-76.45376	7.0	1.1E-11	6.1
44.30674	-76.46206	8.9	1.2E-13	2.7
44.31048	-76.52122	2.8	2.0E-14	0.5
44.31144	-76.44620	2.4	3.4E-12	1.0
44.31862	-76.50040	1.8	1.1E-13	0.3

Table 6. Soil radon survey results (average soil radon concentration in kBq/m^3, average permeability in m^2, and SRP) in 74 community parks in Toronto

Latitude	Longitude	Soil radon kBq/m^3	Permeability m^2	SRP
43.34579	-79.33396	18.0	1.8E-12	9.7
43.60918	-79.52940	38.7	3.4E-12	25.7
43.61890	-79.66148	21.5	1.9E-12	11.8
43.62470	-79.50678	24.8	6.2E-13	10.8
43.63042	-79.57863	65.4	3.4E-12	43.9
43.63816	-79.51971	11.8	3.0E-12	7.1
43.64351	-79.49246	16.4	1.1E-12	7.9
43.64540	-79.47480	6.1	1.2E-11	5.6
43.64943	-79.41703	23.8	2.3E-12	13.9
43.65176	-79.54321	20.1	6.0E-13	8.6
43.65937	-79.50150	14.7	1.5E-12	7.4
43.66014	-79.58431	27.0	2.0E-14	7.0
43.66410	-79.39142	9.0	6.0E-12	6.5
43.66565	-79.43405	11.3	3.7E-12	7.2
43.66567	-79.36214	6.0	3.7E-12	3.5
43.66836	-79.47835	9.7	5.2E-12	6.8
43.66945	-79.32852	1.0	2.0E-14	0.0
43.67371	-79.45970	15.4	4.6E-13	6.1
43.67581	-79.49953	12.5	2.5E-12	7.2
43.68326	-79.41036	15.3	1.8E-12	8.1
43.68347	-79.42651	40.2	1.8E-12	22.4
43.68577	-79.37061	23.9	1.8E-13	8.3
43.68750	-79.46001	38.8	7.2E-14	12.0
43.68917	-79.56194	4.3	2.0E-14	0.9

43.69247	-79.26651	15.8	8.4E-12	13.8
43.69752	-79.40038	14.5	1.5E-11	16.1
43.69876	-79.31641	11.8	5.1E-12	8.3
43.70271	-79.33817	17.4	1.5E-13	5.8
43.70290	-79.54681	26.3	4.0E-13	10.5
43.70382	-79.27402	22.3	3.1E-12	14.1
43.70566	-79.29594	11.5	7.7E-12	9.4
43.70633	-79.51646	22.9	1.0E-12	11.0
43.70899	-79.45675	17.0	1.2E-12	8.3
43.71018	-79.37551	11.1	3.4E-13	4.1
43.71045	-79.62254	12.0	8.1E-14	3.5
43.71305	-79.26787	9.4	1.9E-13	3.1
43.71466	-79.41013	31.8	1.7E-12	17.4
43.71653	-79.49280	1.9	2.0E-14	0.2
43.71664	-79.55861	48.0	1.1E-12	23.9
43.71784	-79.29843	24.8	4.9E-13	10.3
43.72232	-79.53916	2.5	5.9E-13	0.7
43.72414	-79.57750	1.3	3.4E-12	0.2
43.72699	-79.63577	14.9	3.4E-12	9.5
43.72956	-79.39249	42.1	7.6E-13	19.4
43.73623	-79.50703	45.7	6.3E-12	37.3
43.73721	-79.55965	15.8	1.5E-12	8.2
43.73842	-79.20522	23.7	6.5E-13	10.4
43.73863	-79.59448	31.0	1.1E-12	15.4
43.74288	-79.27210	32.5	3.4E-12	21.5
43.74616	-79.43920	43.3	6.9E-12	36.5
43.74857	-79.54277	37.3	2.8E-12	23.4
43.75008	-79.33860	21.1	1.4E-11	23.9
43.75009	-79.48457	12.0	1.1E-13	3.7
43.75051	-79.31631	10.5	1.0E-12	4.7
43.75105	-79.60550	17.0	2.0E-14	4.3
43.75294	-79.39159	24.1	4.3E-13	9.8
43.75534	-79.49978	30.7	7.2E-13	13.9
43.76334	-79.57137	8.7	7.3E-12	6.8
43.77104	-79.51894	48.8	1.9E-13	17.5
43.77188	-79.43933	46.1	6.8E-12	38.7
43.77693	-79.15668	43.0	5.9E-12	34.1
43.77731	-79.21012	56.8	1.1E-13	18.8
43.77766	-79.30016	30.1	9.2E-12	28.2
43.78058	-79.35970	18.8	1.3E-11	20.2
43.78201	-79.31683	6.6	2.0E-14	1.5
43.78511	-79.44293	27.9	2.0E-13	10.0
43.78767	-79.37325	52.7	1.2E-13	17.6
43.79105	-79.79105	15.7	1.8E-12	8.4
43.79606	-79.40191	35.6	3.9E-13	14.4
43.80942	-79.17261	20.0	1.3E-11	21.7
43.81607	-79.32127	25.2	2.0E-12	14.3
43.81748	-79.31017	26.9	6.9E-13	12.0
43.82333	-79.27926	17.4	1.3E-13	5.7
43.83133	-79.23157	7.5	2.0E-14	1.7