Climatological analysis for hygrothermal performance evaluation: Mid-rise wood: report to Research Consortium for Wood and Wood-Hybrid Mid-Rise Buildings

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REPORT TO RESEARCH CONSORTIUM FOR WOOD AND WOOD-HYBRID MID-RISE BUILDINGS

Climatological Analysis for Hygrothermal Performance Evaluation: Mid-Rise Wood

CLIENT REPORT: A1-100035-03.2

December 31, 2014

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REPORT TO RESEARCH CONSORTIUM FOR WOOD AND WOOD-HYBRID MID-RISE BUILDINGS

Climatological Analysis for Hygrothermal Performance Evaluation: Mid-Rise Wood

S.M. Cornick and M.C. Swinton

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CLIMATOLOGICAL ANALYSIS FOR HYGROTHERMAL PERFORMANCE EVALUATION: MID-RISE WOOD

S.M. Cornick and M.C. Swinton

This report discusses the selection of locations for the hygrothermal simulation task of the project on Mid-rise Wood Buildings and the determination of spray-rates and pressure differentials for the water penetration testing portion of the project.

Part 1. Locations

The objective of the task is to select, from the 679 locations in Table C-2 of the 2010 National Building Code of Canada (NBC 2010) [1], several representative locations for which long-term historical weather data exists. This information from these locations can subsequently be used to determine the exterior boundary conditions for input files for hygrothermal simulation programs and hygrothermal testing in the laboratory.

The design of the exterior walls of proposed mid-rise wood buildings is covered by Part 5, "Environmental Separation," of the NBCC 2010 [1]. Such exterior claddings should be designed by an engineer or architect. Although not specifically mandated, in general, the exterior walls are designed as pressure moderated rainscreen walls, i.e. the walls have a drainage cavity [2].

The exterior walls considered in this report are all assumed to conform to 2011 National Energy Code for Buildings (NECB 2011), specifically Sentence 3.2.2.2.(1) and Table 3.2.2.2 [3]. The NECB 2011 defines six different climatic regions for Canada. Examination of Table 3.2.2.2 shows that there are 5 different insulation requirements for the 6 climate zones; zones 7a and 7b have the same insulation requirements. There are potentially at least 5 different wall systems to evaluate assuming that 5 different insulation levels are proposed. While the NECB 2011 climate zones are strictly thermal zones, the IECC and ANSI/ASHRAE Standard 169 [4][5] further refine the thermal zones into *marine*, *dry*, and *humid*. Although originally defined for HVAC and humidification and dehumidification purposes, the sub-classification of thermal zones into moisture zones can be useful for the purpose of cladding evaluation. For the purposes of this project, the marine and humid zones have been combined into one zone classified as *wet.* For each thermal zone a *dry* and *wet* representative location was selected where possible[1]. Experimenters and modellers should be able to investigate the performance of the proposed exterior wall systems under higher or lower moisture loadings in a given thermal zone if

[1] Zones 7 and 8 are very cold zones that for HVAC purposes are not divided into *dry* and *humid* classes. For moisture related purposes neither are they are generally classified as *humid* or *dry*; these climates tend to be dry given that the climates are very cold, much of the precipitation is delivered in solid not liquid form.

required. A minimum of 9 locations was envisaged, one for each thermal/moisture zone combination.

Classification criteria: thermal and moisture

The first criterion is thermal. Zones are delineated by degree-days below 18°C, hereafter known as HDD18 [6]. This requirement is obtained from the NEBC 2011. The zones are given in Table 1 below along with the prescribed overall thermal transmittance requirements for above-grade opaque walls. In Figure 1 is shown the distribution of the thermal zones in Canada.

The second criterion is moisture related. A practical definition of what constitutes *wet* and *dry* can be gleaned from the NBCC 2010. A moisture index, MI, is defined in the NBCC 2010 [Volume 2, Appendix C, Division B, C-6] (see Figure 2). The exterior cladding design criteria for Part 9 buildings are specified by the clauses *9.27.2.2.5 (a)* and *(b)*. These clauses mandate that exterior walls should include a drainage cavity if MI > 1. For MI ≤ 1 a drainage cavity is not required. Note that Part 9 of the code specifies in climates with MI > 0.9 and HDD18 < 3400 a drainage cavity is required; i.e. the “Victoria exception”. Thus the definition for *wet* and *dry* can be taken as MI >1 and M ≤ 1, respectively. This also admits the possibility of establishing boundary conditions and input files for cases where a proposed exterior wall is not a rainscreen wall. Such walls would be permitted under Part 5 of the NBCC2010. Note that for Zones, 7a, 7b, and 8 (Artic/Subarctic) there are no *wet* locations and similarly for Zone 4 (Mixed) there are no *dry* Canadian locations as per the NBCC 2010.

A third criterion is population. For each thermal and moisture division the largest population center would be selected as the representative location.

Selecting locations

Zone 8: There are 61 locations in Zone 8, 29 of which have long-term data readily available (Table 2). The coldest location in the dataset is Alert NU (82°30′05″N 062°20′20″W) at 13,030 HDD18. The largest, coldest community is Cambridge Bay; with a population of 1477 with 11,670 HDD18. There are three large communities grouped around 10,000 degree-days, Iqaluit being the largest, with a population of 6,699. There is no climatological reason why the coldest location should not be used as a location for this project. However, from a Building Code perspective, a solution that works for all locations is required then Alert should be selected. That being said it is unlikely that any mid-rise wood buildings would ever be constructed in Alert. The most likely place that such a building might be constructed would be Iqaluit. The largest population center in this category is Yellowknife NT.

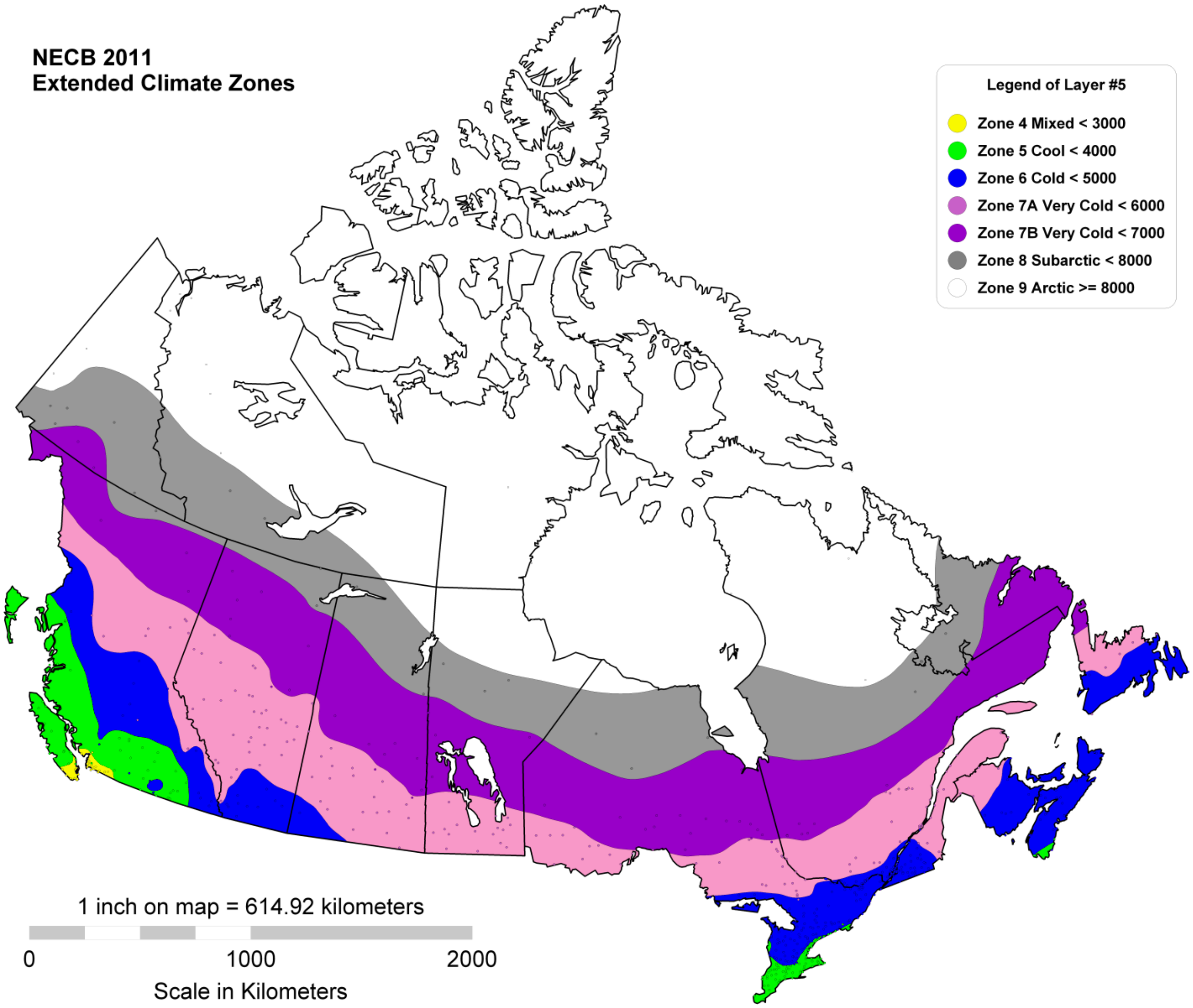

Figure 1 Extended climate zone map of Canada. Zones defined by HDD18.

Table 1 Thermal Zones and Overall Thermal Transmittance Requirements (source: Table 3.2.2.2. NECB 2011)

Description	Zone	HDD18	U-overall $W/(m^2 \cdot K)^*$
Subarctic/Arctic	8/9	>=7000	0.183
Very Cold	7b	<7000	0.210
Very Cold	7a	<6000	0.210
Cold	6	<5000	0.247
Cool	5	<4000	0.278
Mixed	4	<3000	0.315

* - as required by the NECB 2011

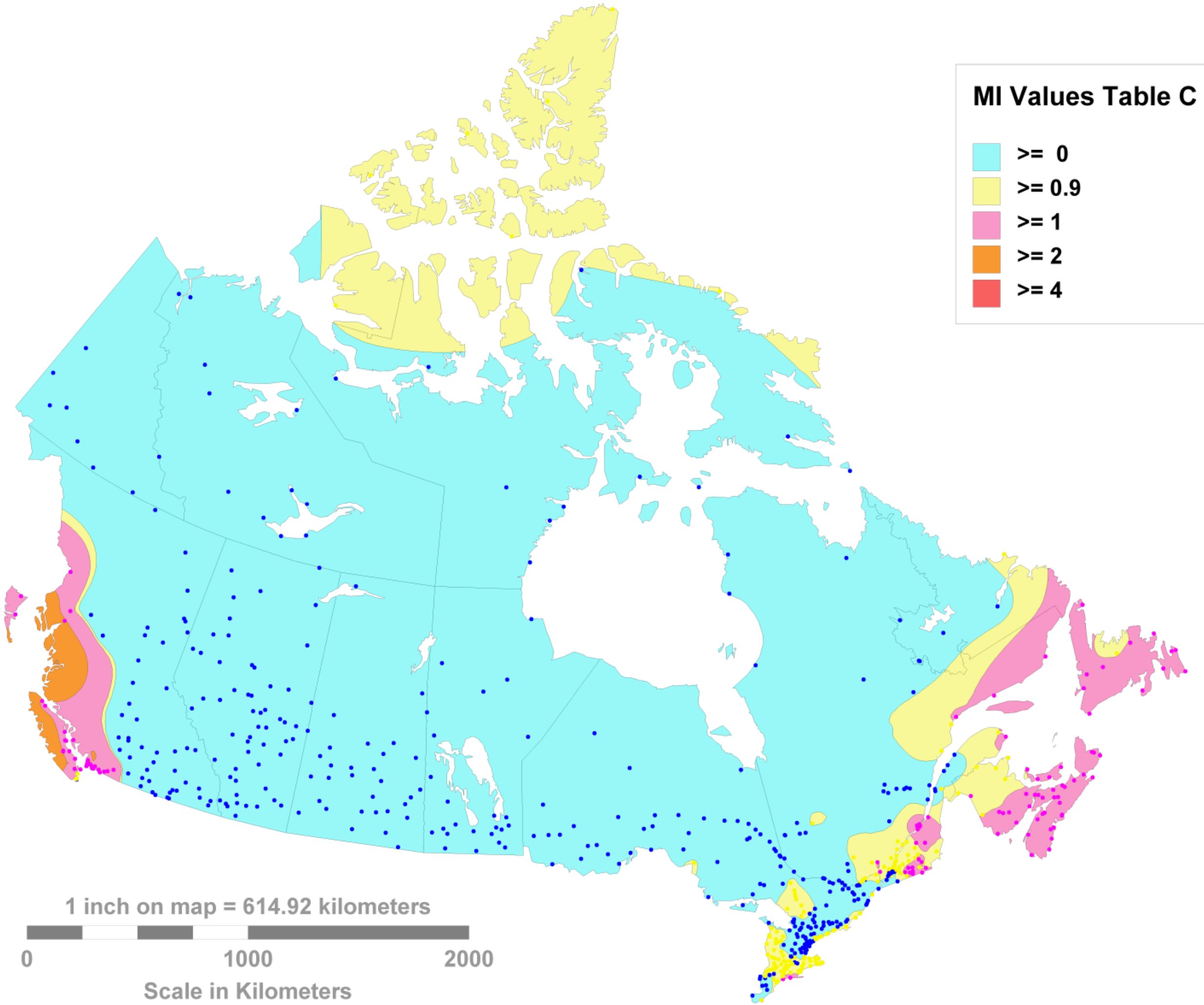

Figure 2 MI values for Table C-2 locations and MI contours for Canada based on 2010 NBC

Zones 7a and 7b: The insulation requirements in the NECB 2011 for zones 7a and 7b are identical; consequently the zones for this analysis have been combined. There are 215 locations in Table C-2 that fall into Zone 7 (Table 3). The bulk of the locations in Zone 7 are *dry* (194). Two representative locations for Zone 7 are required; a *very cold dry* location and a *very cold wet* location. St. Anthony NF is the coldest *wet* location for which long-term data is available (HDD18 = 6440; MI = 1.07). The *wettest very cold* location is Channel-Port aux Basques (5000, 1.43). If there is the assumption that MI is a measure of the risk of moisture damage for a given location, then Port-aux Basques is the recommended location for Zone 7 *wet*. The risk of interstitial vapour condensation in building envelope assemblies is usually higher in a colder climate. If large population centers are of interest then Quebec City (5080/1.04) would be an appropriate for a *cold wet* location, whereas the large population center in Zone 7 having a *cold dry* climate is Winnipeg (5670/0.58).

Table 2 Zone 8: Locations with long-term data

Location	Prov./Terr.	HDD18 2010	NECB 2011 Zone	Ann Rainfall, mm	MI	Pop.
Alert	NU	13030	8	20	0.95	5
Resolute	NU	12360	8	50	0.93	229
Iqaluktuuttiaq (Cambridge Bay)	NU	11670	8	70	0.89	1477
Kanngiqtugaapik (Clyde River)	NU	11300	8	55	0.9	820
Salliq (Coral Harbour)	NU	10720	8	150	0.87	769
Baker Lake	NU	10700	8	160	0.84	1872
Igluligaarjuk (Chesterfield Inlet)	NU	10500	8	175	0.88	322
Kangiqiniq (Rankin Inlet)	NU	10500	8	180	0.87	2358
Iqaluit	NU	9980	8	200	0.86	6699
Inuvik	NT	9600	8	115	0.67	3484
Churchill	MB	8950	8	265	0.82	928
Schefferville	QC	8550	8	410	0.81	202
Kuujjuaq	QC	8550	8	280	0.8	2132
Norman Wells	NT	8510	8	165	0.57	761
Snag	YT	8300	8	290	0.57	0
Yellowknife	**NT**	**8170**	**8**	**175**	**0.58**	**18863**
Dawson	YT	8120	8	200	0.57	1328
Nitchequon	QC	8100	8	500	0.89	0
Kuujjuarapik	QC	7990	8	410	0.85	568
Lynn Lake	MB	7770	8	310	0.62	800
Fort Resolution	NT	7750	8	175	0.61	484
Wabush	NL	7710	8	500	0.82	1739
Fort Simpson	NT	7660	8	225	0.56	1216
Thompson	MB	7600	8	350	0.64	12829
Hay River	NT	7550	8	200	0.62	3648
Uranium City	SK	7500	8	300	0.59	89
Watson Lake	YT	7470	8	250	0.55	1547
Fort Smith	NT	7300	8	250	0.56	2364
Smith River	BC	7100	8	300	0.58	0

For a *cold dry* location Island Lake MB is appropriate (HDD18 = 6900; MI = 0.67).

Table 3 Zones 7a and 7b: Locations with long-term data*

Location	**Prov./Terr.**	**HDD18 2010**	**NECB 2011 Zone**	**Annual Rainfall, mm**	**MI**
Channel-Port aux Basques	NL	5000	7A	1175	1.43
Bonavista	NL	5000	7A	825	1.11
St. Anthony	NL	6440	7B	800	1.07
Buchans	NL	5250	7A	850	1.04
Québec	**QC**	**5080**	**7A**	**925**	**1.04**
Sept-Îles	QC	6200	7B	760	1.01
Gander	NL	5110	7A	775	1.01
Ste-Agathe-des-Monts	QC	5390	7A	820	1
Baie-Comeau	QC	6020	7B	680	0.96
Gaspé	QC	5500	7A	760	0.96
Cape Harrison	NL	6900	7B	475	0.94
Campbellton	NB	5500	7A	725	0.93
North Bay	ON	5150	7A	775	0.93
Moosonee	ON	6800	7B	500	0.84
Rivière-du-Loup	QC	5380	7A	660	0.84
Mont-Joli	QC	5370	7A	610	0.84
Val-d'Or	QC	6180	7B	640	0.83
White River	ON	6150	7B	575	0.8
Sudbury	ON	5180	7A	650	0.79
Geraldton	ON	6450	7B	550	0.77
Atikokan	ON	5750	7A	570	0.77
Roberval	QC	5750	7A	590	0.77
Kapuskasing	ON	6250	7B	550	0.76
Thunder Bay	ON	5650	7A	560	0.76
Armstrong	ON	6500	7B	525	0.75
Graham	ON	5940	7A	570	0.75
Timmins	ON	5940	7A	560	0.75
Earlton	ON	5730	7A	560	0.75
Chapleau	ON	5900	7A	530	0.72
Sioux Lookout	ON	5950	7A	520	0.69
Island Lake	MB	6900	7B	380	0.67
Gimli	MB	5800	7A	410	0.65
Kenora	ON	5630	7A	515	0.64
Edson	AB	5750	7A	450	0.63
Whitecourt	AB	5650	7A	440	0.63
Slave Lake	AB	5850	7A	380	0.62
Wagner	AB	5850	7A	380	0.62

*- shaded rows indicate *wet* climates

Table 3 cont'd Zones 7a and 7b: Locations with long-term data

Location	Prov./Terr.	HDD18 2010	NECB 2011 Zone	Annual Rainfall, mm	MI
Smithers	BC	5040	7A	325	0.6
The Pas	MB	6480	7B	330	0.59
Hudson Bay	SK	6280	7B	340	0.59
Rocky Mountain House	AB	5640	7A	425	0.59
Lac la Biche	AB	6100	7B	375	0.58
Winnipeg	**MB**	**5670**	**7A**	**415**	**0.58**
Fort Nelson	BC	6710	7B	325	0.56
Dauphin	MB	5900	7A	400	0.56
Rivers	MB	5840	7A	370	0.56
Brandon	MB	5760	7A	375	0.56
Yorkton	SK	6000	7B	350	0.54
Red Deer	AB	5550	7A	375	0.54
Beatton River	BC	6300	7B	330	0.53
Cold Lake	AB	5860	7A	320	0.53
Vermilion	AB	5740	7A	310	0.53
Fort McMurray	AB	6250	7B	340	0.52
Teslin	YT	6770	7B	200	0.51
Prince Albert	SK	6100	7B	320	0.51
Portage la Prairie	MB	5600	7A	390	0.51
Peace River	AB	6050	7B	300	0.5
Fort St. John	BC	5750	7A	320	0.5
Whitehorse	YT	6580	7B	170	0.49
Grande Prairie	AB	5790	7A	315	0.49
Broadview	SK	5760	7A	320	0.49
Edmonton	AB	5120	7A	360	0.48
North Battleford	SK	5900	7A	280	0.46
Coronation	AB	5640	7A	300	0.45
Estevan	SK	5340	7A	330	0.43
Saskatoon	SK	5700	7A	265	0.41
Regina	SK	5600	7A	300	0.39
Kindersley	SK	5550	7A	260	0.38
Calgary	AB	5000	7A	325	0.37
Swift Current	SK	5150	7A	260	0.34
Moose Jaw	SK	5270	7A	270	0.33

Table 4 Zones 6: Locations with long-term data*

Location	Prov./Terr.	HDD18 2010	NECB 2011 Zone	Annual Rainfall, mm	MI
Halifax	**NS**	**4000**	**6**	**1350**	**1.49**
Argentia	NL	4600	6	1250	1.47
St. John's	NL	4800	6	1200	1.41
Sydney	NS	4530	6	1200	1.36
Saint John	NB	4570	6	1100	1.27
Stephenville	NL	4850	6	1000	1.19
Debert	NS	4500	6	1000	1.16
Truro	NS	4500	6	1000	1.16
Charlottetown	PE	4460	6	900	1.09
Terrace	BC	4150	6	950	1.08
Greenwood (CFB)	NS	4140	6	925	1.05
Summerside	PE	4600	6	825	1.03
Sherbrooke	QC	4700	6	900	1.03
Fredericton	NB	4670	6	900	1.02
Moncton	NB	4680	6	850	1.02
Miramichi	NB	4950	6	825	0.97
Kingston	ON	4000	6	780	0.96
Montréal-Est	QC	4470	6	830	0.93
Montréal-Nord	QC	4470	6	830	0.93
Saint-Eustache	QC	4500	6	820	0.92
St-Hubert	QC	4490	6	820	0.92
Sault Ste. Marie	ON	4960	6	660	0.89
Dorval	QC	4400	6	760	0.85
Gore Bay	ON	4700	6	640	0.84
Ottawa (M-C Int'l Airport)	**ON**	**4500**	**6**	**750**	**0.84**
Ottawa (Orleans)	ON	4500	6	750	0.84
Peterborough	ON	4400	6	710	0.83
Petawawa	ON	4980	6	640	0.8
Prince George	BC	4720	6	425	0.58
Quesnel	BC	4650	6	380	0.51
Williams Lake	BC	4400	6	350	0.47
Kimberley	BC	4650	6	350	0.38
Cowley	AB	4810	6	310	0.36
Cranbrook	BC	4400	6	275	0.3
Lethbridge	AB	4500	6	250	0.26
Medicine Hat	AB	4540	6	250	0.25

*- shaded rows indicate *wet* climates

Zone 6: There are 252 locations in Zone 6 as given in Table C-2 of the 2010 NBC, 194 classified as *dry* and 58 *wet*. Of those for which long-term data exists there are 15 *wet* locations and 21 *dry* locations (Table 4). Two representative locations for Zone 6 are required; a *cold dry* location and a *cold wet* location. Stephenville NF is the *coldest wet* location for which long-term data is available (HDD18 = 4850; MI = 1.19). The *wettest cold* location is Halifax (4000, 1.49). If the assumption that MI is a measure of the risk of moisture damage for a given location then Halifax is the recommended Zone 6 *wet* location. If large population centers are of interest then Halifax would again be appropriate.

For a *cold dry* location Petawawa ON is appropriate (HDD18 = 4980; MI = 0.80). The coldest large population center in Zone 6 is Ottawa (4500/0.86).

Zone 5: There are 123 Zone 5 locations in Table C-2 of the 2010 NBC, 89 classified as *dry* and 34 *wet*. Of those for which long-term data exists there are 6 *wet* locations and 10 *dry* locations (Table 5). Two representative locations for Zone 5 are required; a *cool dry* location and a *cool wet* location. Yarmouth NS is the *coolest wet* location for which long-term data is available (HDD18 = 3990; MI = 1.32). The *wettest cool* location is Tofino BC (3150, 3.36). If the assumption that MI is a measure of the risk of moisture damage for a given location, the Tofino is the recommended Zone 5 *wet* location. If large population centers are of interest then Prince Rupert BC would be appropriate.

Table 5 Zone 5: Locations with long-term data*

Location	Prov./Terr.	HDD18 2010	NECB 2011 Zone	Annual Rainfall, mm	MI
Tofino	BC	3150	5	3275	3.36
Prince Rupert	BC	3900	5	2750	2.84
Port Hardy	BC	3440	5	1775	1.92
Yarmouth	NS	3990	5	1125	1.32
Comox	BC	3100	5	1175	1.28
Nanaimo	BC	3000	5	1000	1.13
London	ON	3900	5	825	0.94
Hamilton	ON	3460	5	810	0.9
St. Catharines	ON	3540	5	770	0.9
Toronto (city hall)	ON	3520	5	720	0.86
Windsor	ON	3400	5	800	0.85
Toronto (LBP Int'l Airport)	ON	3890	5	685	0.81
Castlegar	BC	3580	5	560	0.64
Lytton	BC	3300	5	330	0.33
Kelowna	BC	3400	5	260	0.29
Kamloops	BC	3450	5	225	0.23

*- shaded rows indicate *wet* climates

For a cool *dry* location, London ON is appropriate (HDD18 = 3900; MI = 0.94), with a relative higher MI among all the locations. The coldest large population center in Zone 5 is, however, Toronto.

Zone 4: There are 28 Zone 4 locations in Table C-2 of the 2010 NBC, 24 classified as *dry* and 4 *wet* (Table 6). Of those for which long-term data exists, there are 4 *wet* locations and 1 *dry* location. Only one representative location for Zone 4 is required. Why? The reason is based on the NBCC Part 9 requirement, Clause 9.27.2.2.5 (a), which defines the *wet* criterion to be MI > 0.9 for all Canadian Zone 4 locations. The *coldest* location for which long-term data is available is Duncan BC (HDD18 = 2980; MI = 1.13). The *wettest* location is Port Renfrew BC (2900, 3.64). If large population centers are of interest, then Vancouver would be an appropriate choice of location.

Table 6 Zone 4: Locations with long-term data*

Location	Prov./Terr.	HDD2010	NECB 2011 Zone	AnnR, mm	MI
Port Renfrew	BC	2900	4	3600	3.64
Vancouver Int'l	BC	2925	4	1325	1.44
Duncan	BC	2980	4	1000	1.13
Crofton	BC	2880	4	925	1.06
Victoria	BC	2650	4	800	0.98

*- all climates in this zone are *wet* climates

Criteria for selecting locations

Three selection criteria are possible: (1) the largest population center in a 2011 NECB zone or moisture class; (2) a thermal criterion, i.e., most degree-days below 18°C, and; (3) a moisture-based criterion, i.e., the MI. Suggested locations are taken from the respective list of locations having long-term climate data provided in Tables 2 to 6.

Recommendations

It is recommended that the locations listed in Table 7, and shown in Figure 3, selected using the population based criteria, be used for this project. These locations represent large markets within the specified climate zones where mid-rise wood buildings are likely to be built. Locations selected using the other two criteria are given in the Appendix.

Table 7 Recommended locations primarily based on population

Zone Description	Zone	Wet (MI > 1)	Dry (MI ≤1)
Subarctic/Arctic	8/9	n/a	Yellowknife (8170/0.58)*
Very Cold	7	Quebec City (5080/1.04)	Winnipeg (5670/0.58)
Cold	6	Halifax (4000/1.49)	Ottawa Int'l (4500/0.84)
Cool	5	Prince Rupert (3900/2.84)	Toronto (Pearson)(3980/0.86)
Mixed	4	Vancouver (Int'l) (2925/1.44)	n/a

* - bracketed terms are HDD18 and MI respectively

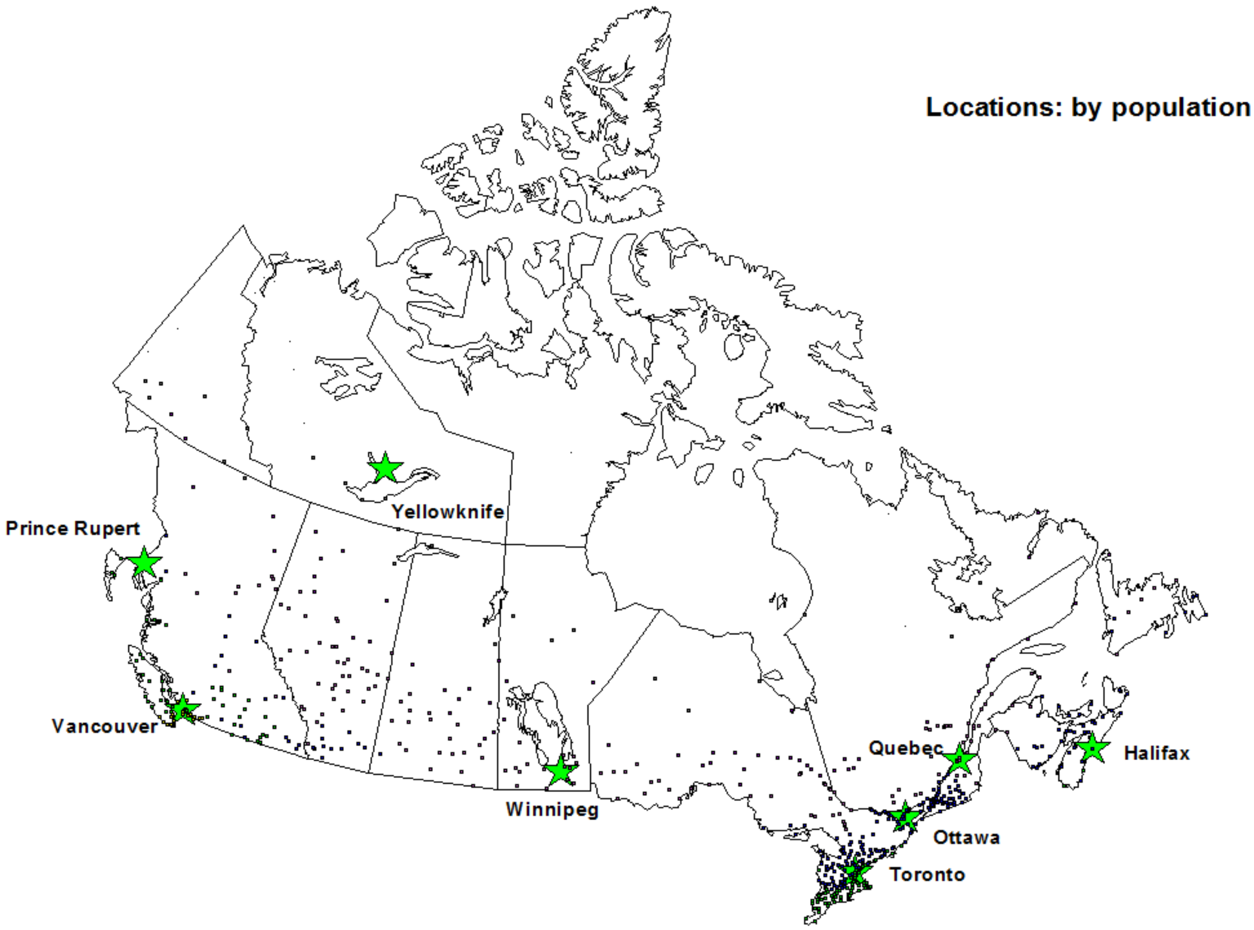

Figure 3 Recommended locations selected on the basis of population.

Part 2. Driving-rain wind pressure and spay rates for water entry testing

Upper limit values were determined for water entry testing of the proposed mid-rise wood walls (see the water penetration test report). The test protocol consisted of three deposition rates horizontally deposited directly above deficiencies placed in each wall specimen. The deposition rates were 0.58 l/min-m^2, 1.16 l/min-m^2, and 1.74 l/min-m^2. The range of spray rates cover the maximum observed and expected hourly Wind-Driven Rain (WDR) intensities for a 1 in 50 year return period for most locations in Canada (see Figure 4)[2].

Generally when considering shorter averaging periods the horizontal rainfall intensity is increased from hourly intensity [7]. The calculation of WDR, however, is not directly proportional to horizontal rainfall intensity. Larger raindrop sizes tend to occur at higher rainfall intensities and can actually reduce the amount of WDR rain over a 10-minute averaging period, the reduction ranging between 85 and 95% [8][9][10]. A conservative assumption is to assume no reduction in WDR intensity for shorter averaging periods.

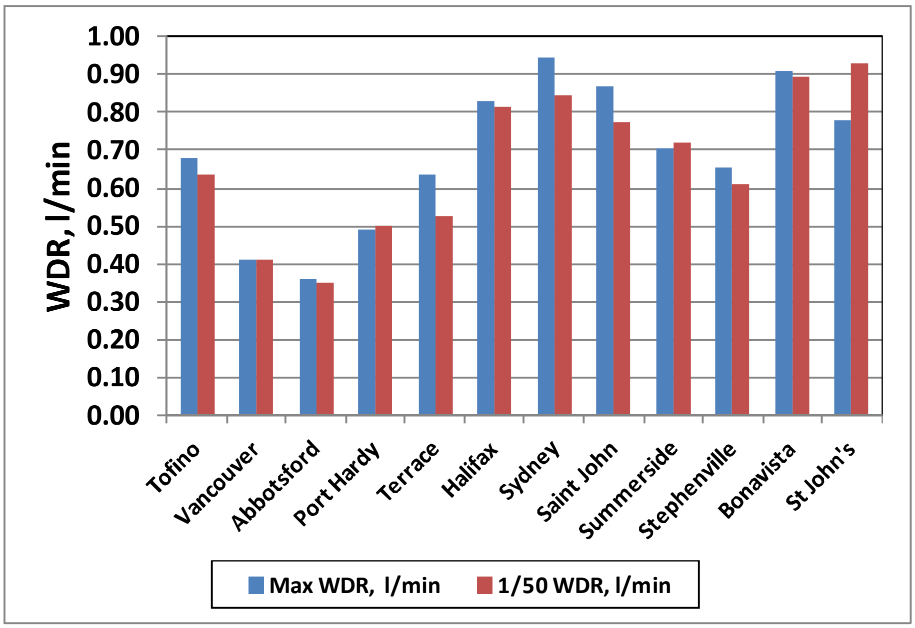

Figure 4 WDR rates for various locations in Canada.

Each deposition rate was tested at several steps of pressure differential across the specimen. The pressure differential ranged from 0 Pa, up to 1150 Pa. A comprehensive survey of extreme Driving-Rain Wind Pressures (DRWP) was undertaken by Welsh, Skinner, and Morris [11]. The highest extreme hourly DRWP values in the report were calculated for a 1 in 30 year return period at minimum rainfall intensity of 1.8 mm/h. Since the report also provided the mean and standard deviation of the sets of extreme values, it was straightforward to estimate 1 in 50 values. The values reported were at the standard World Meteorological Organization height of 10 m above grade. With respect to the variation of wind speed with height, most of the wind speed data came from airport locations which are open environments. The assumption that the building

[2] The intensity, in L/min, lasts for the entire hour.

is located in similar terrain is conservative in that the wind speed will increase with height. If the building is assumed to be located in urban terrain then translating the wind speed from an open environment to an urban environmental will result in a decrease in wind speed for the same height on the order of 50 to 70%. The wind pressure values were adjusted using a power law for the estimated height of a 6 storey mid-rise wood building, 18 m. Assuming an exponent of 1/7 for urban areas the scaling factor for wind pressures measured from the standard height was 1.18 or 18% [12]. The highest expected 1 in 50 values for DRWP for a mid-rise building, derived from Welsh, Skinner, and Morris, and are listed below in Table 8 [11].

The limit of the current test apparatus at NRC is 1250 Pa, the maximum upper range of the pressure sensors. The effective safe limit for laboratory testing was determined to be 1150 Pa. A 1150 Pa peak pressure covers all of Canada except for the south western tip of Newfoundland (St. Andrews) and the western side of Haida Gwaii (the Queen Charlotte Islands). The locations are listed in Table 8. Therefore all the locations listed in Table 7 are adequately by this testing pressure.

Each pressure step is conducted at each water deposition rate for 10 minutes. Even if the wind pressures are increased by 14% to account for a 10-minute averaging period, most Canadian locations are adequately covered [13].

Table 8 1 in 30 and 1 in 50 Year DRWP's for various locations in Canada, Pa [11]

Location	1 in 30 DRWP @ 10m	1 in 50 DRWP @ 10m	1 in 50 DRWP @ 18m	10-minute wind
Cape St. James	1240	1338	1582	1804
St. Andrews	1191	1296	1533	1745
Spring Island	902	969	1147	1307
Grind Stone Island	754	810	958	1092
Battle Harbour	668	727	860	980
Sandspit	625	659	779	888
Sable Island	617	669	791	902
Summerside	602	660	781	890
Port Aux Basques	600	648	767	874
St. John's	593	647	765	872
Daniel's Harbour	583	634	749	854
Twillingate	583	636	753	858

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Appendix A Additional Climate Information

Table A.1 Locations selected using thermal based criteria (HDD18)

Zone Description	Zone	Wet (MI > 1)	Dry (MI ≤1)
Arctic/Subarctic	8	n/a	Alert (13030/0.95)*
Very Cold	7	St. Anthony (6440/1.07)	Island Lake (6900/0.67)
Cold	6	Stephenville (4850/1.19)	Petawawa (4980/0.8)
Cool	5	Yarmouth (3990/1.39)	London (3900/0.94)
Mixed	4	Duncan (2980/1.1.3)	n/a

Table A.2 Locations selected using moisture based criteria (MI)

Zone Description	Zone	Wet (MI > 1)	Dry (MI ≤1)&
Arctic/Subarctic	8	n/a	Watson Lake (7470/0.55)
Very Cold	7	Channel-Port aux Basques (5000/1.43)	Moose Jaw (5270/0.33)
Cold	6	Halifax (4000/1.49)	Medicine Hat (4540/0.25)
Cool	5	Tofino (3150/3.36)	Kamloops (3450/0.23)
Mixed	4	Port Renfrew (2900/3.64)	n/a

* - bracketed terms are HDD18 and MI respectively

& - These locations are provided for completeness only. Limited information on moisture performance is to be gained from evaluating the driest location in a thermal zone.

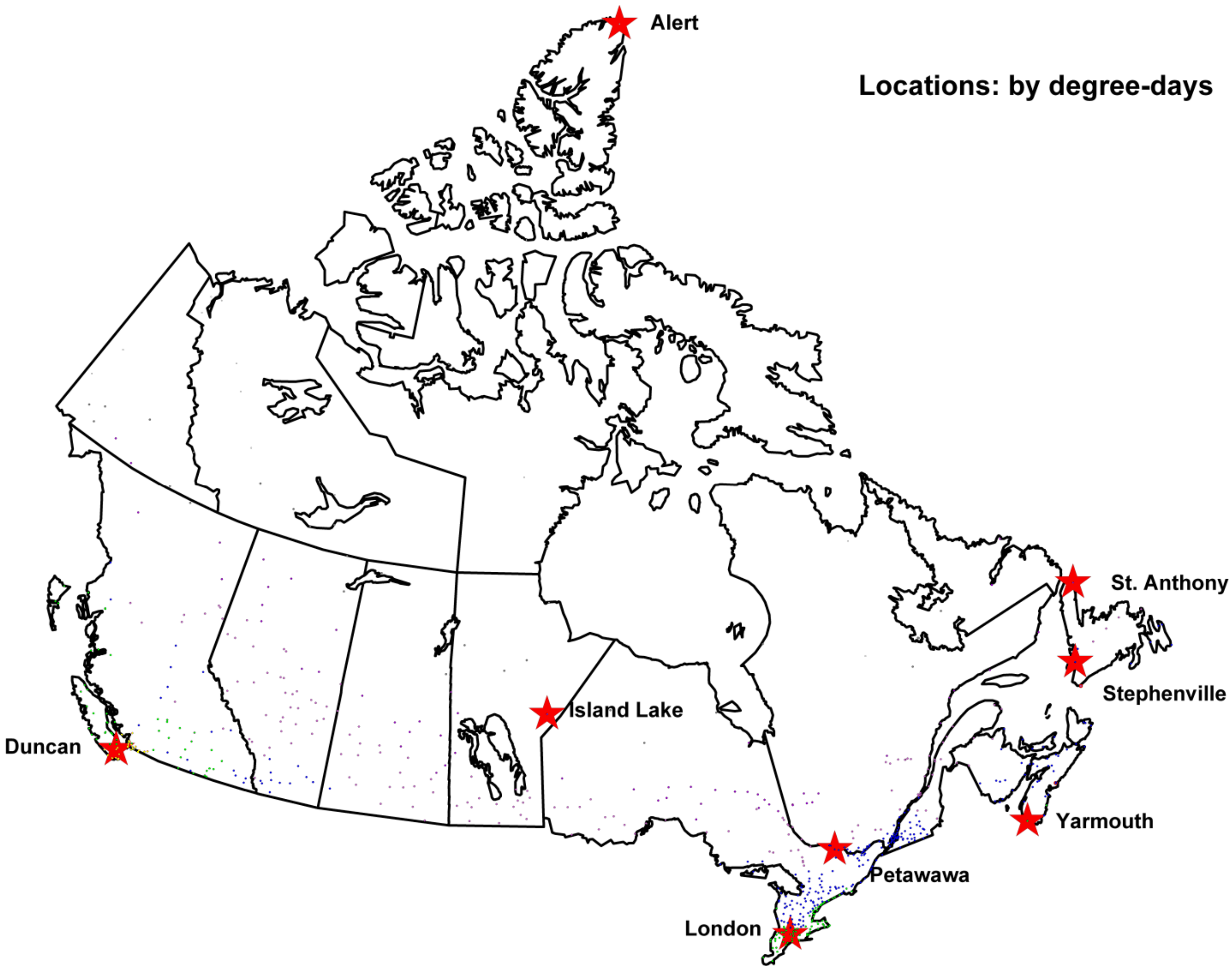

Figure A.1 Locations selected on the basis of HDD18.

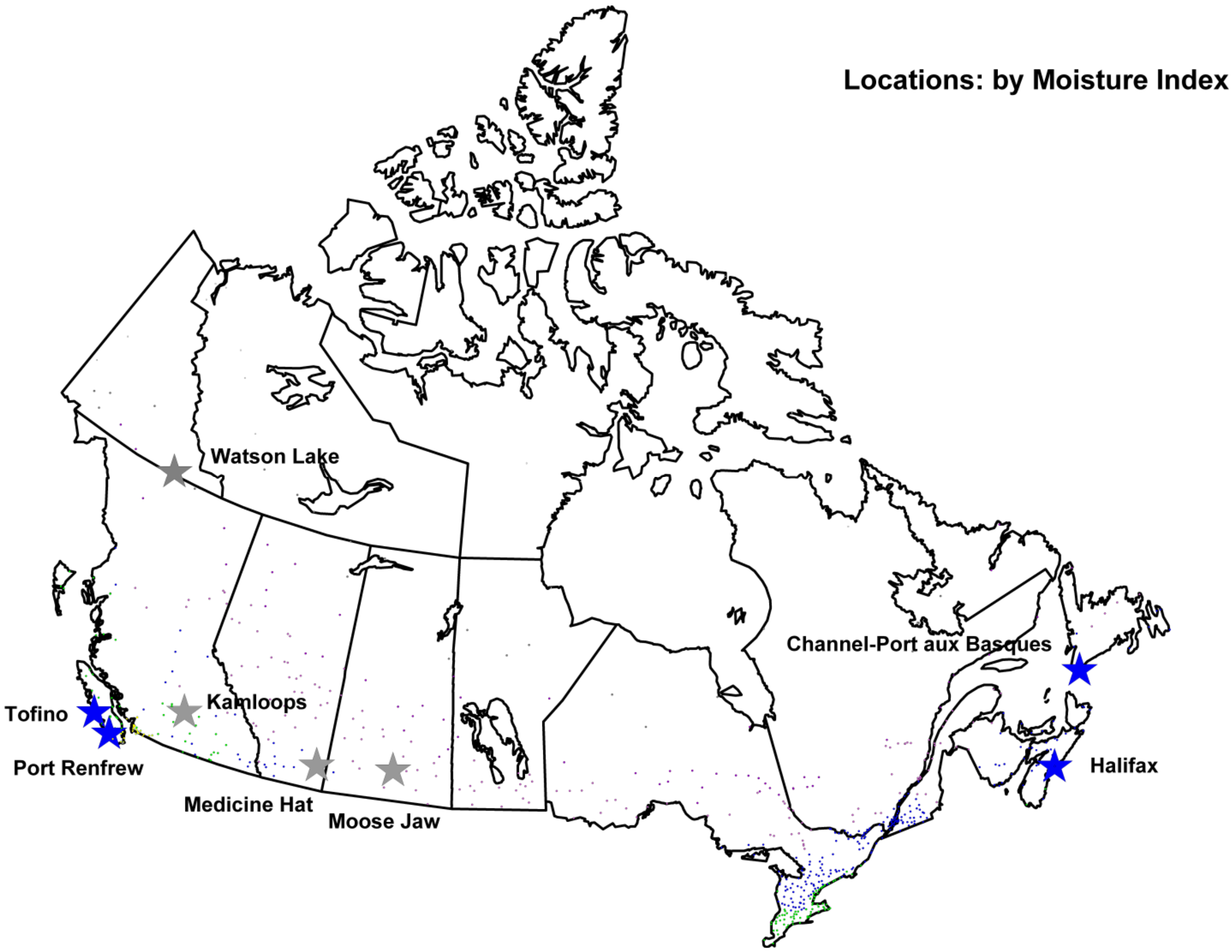

Figure A.2 Locations selected on the basis of moisture.