



**GEOLOGICAL SURVEY OF CANADA  
OPEN FILE 7576**

**Fifth Generation Seismic Hazard Model Input Files as  
Proposed to Produce Values for the 2015 National Building  
Code of Canada**

**S. Halchuk, T.I. Allen, J. Adams, and G.C. Rogers**

**2014**



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## Contents

Introduction.....	1
Model Implementation.....	1
GSCFRISK Inputs .....	2
ESRI Shapefiles .....	2
Python Dictionary Files .....	3
GMPE (Ground Motion Prediction Equation) Look-up Tables .....	3
Acknowledgements.....	4
References.....	4
Tables.....	5
Appendix I: GSCFRISK Input Model File Format .....	6
Appendix II: Description of Shapefile Attributes.....	8
Appendix III: Using NBCC2015 Python Dictionary Files .....	10
Getting Started .....	10
Loading a Python Pickle File.....	10
Using the Python Dictionaries – Some Examples .....	11
Appendix IV: Description of Python Dictionary Attributes.....	14
Appendix V: Description of Ground Motion Prediction Equation (GMPE) look-up tables .....	15

## List of Tables

<b>Table 1:</b> Seismic hazard values intended for the 2015 National Building Code of Canada. ....	5
<b>Table 2:</b> Conversion factors from NBCC Class C to the B/C boundary condition. ....	5

## Introduction

This Open File is a rapid publication to release Canada's 5<sup>th</sup> Generation seismic hazard model. The model produces the seismic hazard values proposed for use in the 2015 National Building Code of Canada (NBCC2015). This Open File contains technical files that, when used by experts with their own seismic hazard calculation software, can replicate the seismic hazard values NRCan is proposing for the 2015 National Building Code of Canada. In order to enable rapid release, this report does not discuss the scientific rationale for NBCC2015 hazard model inputs. These details will be provided in forthcoming publications documenting the model. The seismic hazard values proposed for a suite of coordinates are provided (Table 1) to allow users determine whether they have implemented the model correctly in their hazard calculation software.

Earthquake sources for NBCC2015 are provided in three formats:

- GSCFRISK text files;
- ESRI Shapefiles;
- Python dictionaries.

Ground Motion Prediction Equation (GMPE) look-up tables (based on Atkinson and Adams, 2013) to be used with the sources are also provided. A basic description of each format is described herein.

## Model Implementation

The 5<sup>th</sup> Generation model comprises four components; one for each quadrant of Canada. The subdivision of the national model into four components was necessary to reduce computation time. These four components each comprise multiple weighted sub-models. The sub-models are implemented with the following weighing:

- The northwestern and southwestern models comprise a single sub-model, weighted at 1.0;
- The northeastern model comprises two sub-models: Historical (H2) weighted at 0.6 and Regional (R2) weighted at 0.4;
- The southeastern model comprises three sub-models: H2 weighted at 0.4, Hybrid (HY) weighted at 0.4 and R2 weighted at 0.2.

It is intended that hazard be obtained for a particular site near the boundary of the components by determining the hazard separately from each of the two adjacent components and taking the larger of the two hazard values determined for the site. The Stable Continental Core (SCC) zones specified for each component provide the hazard in the middle of Canada.

Alternatively (if computing time is not an issue), the southwestern and northwestern (western Arctic) components could be combined (removing the duplicate sources which extend into the neighboring regions) and the combined model could be used for the western Canada region. The other models cannot be merged without a large penalty of computation time in GSCFRISK (Risk Engineering, 1988), because they comprise different numbers of sub-models.

Also for computational efficiency, all the sub-models use a simplified set of sources to compute the mean hazard from SCC sources. While the mean hazard is computed correctly using this simplified

set, percentiles for the distribution of hazard differ from those from the full stable craton set (Please contact the authors ([shalchuk@nrcan.gc.ca](mailto:shalchuk@nrcan.gc.ca)) if this is an issue for your implementation).

Earthquake recurrence for each earthquake source is described in terms of an asymptotically-truncated Gutenberg-Richter magnitude-frequency distribution following:

$$N(m) = N_0 e^{-\beta m} [1 - e^{-\beta (M_{max} - m)}] \quad (1)$$

where  $N$  is the cumulative number of earthquakes greater than magnitude  $m$ ,  $N_0$  is the number of earthquakes per year with magnitude greater than or equal to 0,  $M_{max}$  is the maximum magnitude considered, and  $\beta$  is a constant that describes the relative number of small-to-large earthquakes, where  $\beta = b \ln(10)$  and  $b$  is the Gutenberg-Richter (1944)  $b$ -value. Herein,  $m$  is assumed to be equivalent to moment magnitude  $M_W$ . For certain fault sources, small values of  $\beta$  are used to approximate a “characteristic” earthquake distribution.

Many of the parameters in the model use a three-branch representation to capture epistemic uncertainty; the weights can be found by examining the GSCFRISK input files and reviewing the input format description in Appendix I.

## GSCFRISK Inputs

GSCFRISK is a modified version of Risk Engineering’s (1988) proprietary code FRISK88. The original code has been extensively modified, most recently to use GMPE look-up tables, and has been used to determine Canadian seismic hazard at the Geological Survey of Canada (GSC) since the 1990s. Four GSCFRISK model input files (labelled \*.model) are included in this Open File, and their input format is described in Appendix I.

## ESRI Shapefiles

Shapefiles were originally developed by the Environmental Systems Research Institute (ESRI, 1998) and are a geospatial data format for geographic information system (GIS) software, such as ESRI ArcGIS and Quantum GIS. The shapefile format spatially describes geometries as either 'point', 'polyline', or 'polygon' features (OpenStreetMap, 2013). In the case of NBCC2015, we use polygon features to describe areal source zones and polyline features to describe fault sources. For each shapefile feature, specific attributes can be assigned, such as the source name and its corresponding magnitude-recurrence information (see Appendix II).

The shapefile is a grouping of several files to represent different aspects of geodata (OpenStreetMap, 2013):

- .shp: shape format; the feature geometry itself.
- .shx: shape index format; a positional index of the feature geometry to allow quick searching.
- .dbf: attribute format; columnar attributes for each shape, in dBase IV format.

The feature attributes can be examined in the GIS software, or through opening the .dbf file in Microsoft Excel, for example. There are also several optional files in the shapefile format. The most significant of these is the .prj file which describes the coordinate system and projection information used. The shapefiles generated for NBCC2015 hazard model are specified with the WGS84 projection.

Below, we list the sub-model Shapefiles included in the Open File:

- SECan\_H2.shp: H2-model for SE Canada area sources
- SECan\_HY.shp: Hybrid H2- and R2-model for SE Canada area sources
- SECan\_R2.shp: R2-model for SE Canada area sources
- SWCan\_area.shp: SW Canada area sources
- SWCan\_fault.shp: SW Canada fault sources
- EArctic\_H2.shp: H2-model for eastern Canadian Arctic area sources
- EArctic\_R2.shp: R2-model for eastern Canadian Arctic area sources
- WArctic\_area.shp: Western Canadian Arctic area sources
- WArctic\_fault.shp: Western Canadian Arctic fault sources

Note that each model component includes the necessary SCC areal sources that are used to compute the background hazard. A list of feature attributes and their descriptions are provided in Appendix II.

## Python Dictionary Files

In addition to the two aforementioned data types, we also provide the earthquake source data as Python dictionaries. Python dictionaries can be thought of as an unordered set of *key: value* pairs, where the keys correspond to the feature attributes of the shapefiles listed in Appendix II. The shapefile format in the previous section is generated directly from these dictionary files.

The Python dictionaries are saved out to pickle `.pkl` files, which is a method of packaging Python variables. Pickle files are analogous to `.mat` files in Matlab. These files provide pre-parsed data structures that can be used to export into the users' preferred source zone format for implementation into other hazard computation software.

Unlike the shapefile distribution above, both area and fault sources for a given sub-model are included within the one dictionary. Furthermore, feature coordinates are conveniently listed directly as a NumPy array (<http://www.numpy.org/>). Available pickle files are:

- SECan\_H2.pkl: H2-model for SE Canada area sources
- SECan\_HY.pkl: Hybrid H2- and R2-model for SE Canada area sources
- SECan\_R2.pkl: R2-model for SE Canada area sources
- SWCan.pkl: SW Canada area and fault sources
- EArctic\_H2.pkl: H2-model for eastern Canadian Arctic area sources
- EArctic\_R2.pkl: R2-model for eastern Canadian Arctic area sources
- WArctic.pkl: Western Canadian Arctic area and fault sources

Appendix III provides a guide to importing and manipulating Python pickle files. Appendix IV provides the format of the Python dictionary data types and provides equivalence to attributes in the shapefiles (Appendix II).

## GMPE (Ground Motion Prediction Equation) Look-up Tables

The ground motion prediction equations (GMPE) are expressed as look-up tables attached to this Open File. They were modified from tables provided by Gail Atkinson and Tuna Onur (pers. comm., 2013).

The format of these files is described in Appendix V. The rationale for the GMPEs used is discussed in Atkinson and Adams (2013) with additional detail in Atkinson (2013). Tables have been modified so that the output provided by the FRISKGSC program is given in units of g (acceleration due to gravity) for spectral and peak acceleration, and m/s for peak velocity. The tables have also been modified to provide hazard values directly in terms of Soil Class C ( $V_{S30} = 450$  m/s), which is the reference ground condition for NBCC2015. Table 2 gives the conversion factors used to obtain Class C values from the GMPEs given at the B/C boundary ground condition.

## Acknowledgements

We acknowledge Murray Journey and Nicky Hastings for the provision of critical internal reviews that led to several improvements in this report. Robert Kung is thanked for provision of ArcGIS support and ensuring that the spatial data herein was compliant with NRCan standards.

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- Risk Engineering, Inc. (1988). FRISK88 User's Manual, Version 1.2. For details contact <http://www.riskeng.com/>

## Tables

**Table 1:** Seismic hazard results for a suite of coordinates to allow users to determine whether they have correctly implemented the model. Peak and spectral hazard values are determined for an exceedance of 2%/50 years. Mean values are given in units of g for peak horizontal acceleration and 5% damped spectral horizontal acceleration, and in m/s for peak horizontal velocity. Values are for Site Class C (average shear wave velocity ~450 m/s).

Latitude	Longitude	Sa(0.05)	Sa(0.1)	Sa(0.2)	Sa(0.3)	Sa(0.5)	Sa(1.0)	Sa(2.0)	Sa(5.0)	Sa(10.0)	PGA	PGV
60.72	-135.05	0.1856	0.2699	0.3341	0.3122	0.2575	0.1702	0.094	0.0326	0.0127	0.1544	0.1833
68.35	-133.72	0.1787	0.2581	0.3077	0.2813	0.223	0.1385	0.0722	0.0247	0.0096	0.1449	0.1497
53.26	-132.08	0.9021	1.484	1.6135	1.5743	1.3751	0.8411	0.4506	0.1235	0.0406	0.7573	0.9894
54.32	-130.32	0.119	0.1885	0.2459	0.2659	0.2693	0.2089	0.1359	0.0457	0.0163	0.117	0.3144
49.12	-125.88	0.7904	1.2606	1.462	1.5015	1.3668	0.8843	0.536	0.1707	0.0599	0.6967	0.9447
48.43	-123.37	0.7114	1.0859	1.3061	1.3071	1.1593	0.6781	0.399	0.1247	0.0437	0.5818	0.8334
49.25	-123.12	0.4504	0.6852	0.8469	0.8512	0.7546	0.4252	0.2566	0.0808	0.0286	0.3673	0.5522
53.92	-122.75	0.0587	0.0862	0.1132	0.1105	0.0889	0.0592	0.0398	0.0187	0.006	0.0493	0.0821
49.167	-121.95	0.2892	0.434	0.5385	0.5165	0.4482	0.2767	0.1747	0.0623	0.0214	0.242	0.3468
49.88	-119.48	0.0769	0.1136	0.1428	0.1391	0.1217	0.0909	0.0634	0.0286	0.0091	0.0661	0.1171
62.48	-114.35	0.0398	0.0557	0.0519	0.0424	0.0318	0.0169	0.007	0.0014	0.0007	0.0301	0.0219
51.05	-114.08	0.1296	0.177	0.1921	0.1695	0.1264	0.0725	0.0361	0.0128	0.0046	0.0976	0.0765
49.89	-97.15	0.0421	0.0588	0.0545	0.0440	0.0320	0.0163	0.0065	0.0013	0.0007	0.0318	0.0220
42.3	-83.02	0.0739	0.1012	0.0964	0.0802	0.0626	0.0354	0.0173	0.0040	0.0017	0.0568	0.0480
43.25	-79.86	0.2697	0.3193	0.2603	0.1909	0.1283	0.0614	0.0284	0.0067	0.0027	0.1683	0.1008
43.65	-79.38	0.2519	0.3013	0.2489	0.1846	0.1263	0.0626	0.0295	0.0071	0.0029	0.1602	0.1004
43.10	-79.07	0.3343	0.3918	0.3207	0.2356	0.1566	0.0720	0.0323	0.0076	0.0030	0.2070	0.1217
45.42	-75.69	0.4462	0.5225	0.4389	0.3341	0.2371	0.1181	0.0561	0.0149	0.0054	0.2804	0.1967
45.509	-73.554	0.6329	0.7239	0.5959	0.4473	0.3111	0.1481	0.0682	0.0176	0.0062	0.3782	0.2559
46.35	-72.55	0.3704	0.4375	0.3653	0.2780	0.2005	0.1052	0.0522	0.0144	0.0054	0.2340	0.1706
46.80	-71.23	0.5172	0.5985	0.4929	0.3722	0.2645	0.1329	0.0641	0.0174	0.0062	0.3179	0.2252
47.65	-70.15	1.8993	2.0920	1.7276	1.3285	0.9537	0.4534	0.2029	0.0491	0.0140	1.0420	0.8093
63.73	-68.50	0.0658	0.0905	0.0871	0.0752	0.0648	0.0427	0.023	0.0057	0.0026	0.0512	0.054
45.95	-66.65	0.1872	0.2354	0.2100	0.1675	0.1271	0.0716	0.0364	0.0098	0.0039	0.1328	0.1073
44.65	-63.60	0.0794	0.1110	0.1100	0.0961	0.0821	0.0528	0.0288	0.0077	0.0033	0.0641	0.0698
47.57	-52.72	0.0610	0.0873	0.0899	0.0815	0.0732	0.0487	0.0270	0.0072	0.0032	0.0515	0.0638

**Table 2:** Conversion factors from NBCC Class C (450 m/s) to the B/C (760 m/s) boundary condition, ordered in decreasing period.

Period (s)	10.0	5.0	2.0	1.0	0.5	0.3	0.2	0.1	0.05	0.02(PGA)	0.01(PGV)
Factor	1.406	1.481	1.466	1.443	1.369	1.259	1.176	1.14	1.164	1.208	1.369

Note: To obtain B/C values from the Class C values provided in the look-up tables, divide by the above conversion factors

## Appendix I: GSCFRISK Input Model File Format

Explanatory comments are given in red text, following the ! symbols at the end of each line. The FRISK88 manual (Risk Engineering, 1988) should be used as a more complete reference.

```
o treat this model file as old type model file that does not contain completeness data data
Western model Trial 3E - using CONVERTED CLASS C GMPEs ! model titles
Probabilities of Exceedence for INTERP Subroutine in GSCFRISK.
4 0.01 0.0021 0.001 0.000404 ! Probability levels
Data Set for Integrations in GSCFRISK.
3 Value of natts that is used
3 50 5.0 5.0 0.10 4 2 ! Array sizes and control variables
24 1. 3. 10. 13.5 17.5 23.5 30. 42. 60. 75. 100. 135. 175. 235. 300. 420. 600. 750. 1000. 1350. 1750. 2350.
3000. 4200. ! Ground motion interpolation points
3 1 0.5 2 0.2 3 0.3 ! Weights Ground motion prediction equations (GMPEs)
B ! Both areal and fault sources used
DUMMY LINE - SEE TABLES FOR VALUES Boore/Joyner/Fumal(1993) Attenuation; PSA (0.2s) ! GMPE parameters
3.764 0.309 -0.090 -0.00259 -0.924 0.190 7.02 0.0 0.0 11 0.495 0 0.0 ! NOTE NOT USED when GMPE
DUMMY LINE - SEE TABLES FOR VALUES Boore/Joyner/Fumal(1993) Attenuation; PSA (0.2s) ! tables are implemented,
3.464 0.309 -0.090 -0.00259 -0.924 0.190 7.02 0.0 0.0 11 0.495 0 0.0 ! as is the case for all
DUMMY LINE - SEE TABLES FOR VALUES Boore/Joyner/Fumal(1993) Attenuation; PSA (0.2s) ! NBCC 2015 models
3.164 0.309 -0.090 -0.00259 -0.924 0.190 7.02 0.0 0.0 11 0.495 0 0.0
1 1.0 ! Number of alternative "global" models, weight of each
ROGERS' 2011 SOURCE ZONES
30 3 3 3 37 60 ! Number of: sources, M-R pairs, MMax, depths, total source
alternatives, maximum coordinates in any source
0.6 0.3 0.1 ! Weights for Maximum magnitudes (Mmax)
0.68 0.16 0.16 ! Weights for magnitude recurrence (M-R)
0.50 0.25 0.25 ! Weights for depths (Dep)
1 1 1 1 ! flags for dependent Mmax, M-R, Dep, GMPE
BRO - BROOKS PENINSULA ! Source abbreviation and full name
1 ! Number of alternatives for this source
W CANADA R2 ! Portion of the model
1.0 ! Weight of this alternative
area ! Source type
10.0 5.0 15.0 ! Depth of source in the order best, lower, upper alternative
4 ! Number of corners to the zone
-127.670 50.360 ! Longitude and latitude for each corner
-127.390 50.220
-127.920 49.930
-128.150 50.080
```

```

4.8 7.2 6.9 7.5 ! Minimum magnitude, followed by maximum magnitude (best, lower, upper)
1 ! Flag for (truncated) exponential model of magnitude distribution
11.95 1.0733 19.86 1.3561 7.50 0.7905 1.73x Beta spread ! standard Beta spread 11.95 1.0733 15.23
1.2368 9.62 0.9098
Wcrust_med_clC.txt, Wcrust_low_clC.txt, Wcrust_high_clC.txt ! GMPE tables used for this source
...
... sample fault source
...
CASCADIA INTERFACE SOURCE ! Source name
1 ! Number of alternatives for this source
CIS - Best estimate landward extent of rupture - 27 km depth
1.0 ! Weight of this alternative
fault ! Source type
8.5 12 5.0 15.0 27.0 ! Dips and depths of fault subsurface geometry
8.5 12 5.0 15.0 31.0 ! two dips, followed by top, middle, bottom depth of active fault
8.5 12 5.0 15.0 23.0
3.01 0.001 0.01 !-1.085 0.389 0.01 ! Rupture length equation parameters
17 ! Number of corners to the fault
-125.95 40.35 ! Longitude and latitude for
-126.17 41.00 ! SURFACE EXPRESSION OF FAULT TRACE
-126.36 42.00
-126.40 43.00
-126.36 44.00
-126.28 44.80
-126.22 45.34
-126.10 46.00
-126.00 46.40
-125.85 47.00
-125.83 47.24
-125.87 47.36
-126.00 47.44
-127.00 47.89
-127.25 48.00
-128.00 48.34
-128.13 48.42
8.5 9.11 9.02 9.22 ! Minimum magnitude, followed by maximum magnitude (best, lower, upper)
1 ! Flag for (truncated) exponential model of magnitude distribution
0.002 -3.5 0.002 -5.0 0.002 -5.0 ! Magnitude recurrence pairs (Beta and N0 values)
WinterfaceCombo_medclC.txt, WinterfaceCombo_lowclC.txt, WinterfaceCombo_highclC.txt ! GMPE tables used for source
...
...

```

## Appendix II: Description of Shapefile Attributes

### Description of shapefile attributes for areal sources:

SRC\_NAME: Name of source area

CODE: Short naming code given to source zone

SRC\_REGION: The sub-model from which the area source is derived

SRC\_TYPE: Either "area" or "fault" source

SRC\_WEIGHT: Weighing given to the source zone within the sub-model

DEP\_BEST: Preferred depth of earthquakes in the source zone in units of km (given 0.50 weighting in hazard calculation)

DEP\_LOWER: Lower depth of earthquakes in the source zone in units of km (given 0.25 weighting in hazard calculation)

DEP\_UPPER: Upper depth of earthquakes in the source zone in units of km (given 0.25 weighting in hazard calculation)

MIN\_MAG: Minimum magnitude considered for the magnitude-frequency distribution

MMAX\_BEST: Preferred maximum magnitude in the source zone for bounded magnitude-frequency distribution (given 0.60 weighting in hazard calculation)

MMAX\_LOWER: Maximum magnitude for bounded magnitude-frequency distribution for lower curve (given 0.30 weighting in hazard calculation)

MMAX\_UPPER: Maximum magnitude for bounded magnitude-frequency distribution for lower curve (given 0.10 weighting in hazard calculation)

NO\_BEST: Preferred number of earthquakes per year with magnitude greater than or equal to 0 (given 0.68 weighting in hazard calculation)

NO\_LOWER: Number of earthquakes per year with magnitude greater than or equal to 0 for the lower curve (given 0.16 weighting in hazard calculation)

NO\_UPPER: Number of earthquakes per year with magnitude greater than or equal to 0 for the upper curve (given 0.16 weighting in hazard calculation)

BETA\_BEST: Preferred rate of small to large earthquakes, where  $\beta = b \ln(10)$  (given 0.68 weighting in hazard calculation)

BETA\_LOWER: Rate of small to large earthquakes for the lower curve (given 0.16 weighting in hazard calculation)

BETA\_UPPER: Rate of small to large earthquakes for the upper curve (given 0.16 weighting in hazard calculation)

SRC\_GMPE: The median Ground-motion model used for the central magnitude-frequency curve. Names of corresponding upper and lower GMPEs are not provided. Ground-motion models are based on those developed by Atkinson and Adams (2013).

## Description of shapefile attributes for fault sources:

SRC\_NAME: Name of source area

CODE: Short naming code given to source zone

SRC\_REGION: The sub-model from which the area source is derived

SRC\_TYPE: Either "area" or "fault" source

SRC\_WEIGHT: Weighing given to the source zone within the sub-model

DIP\_UPPER: Dip of upper fault segment between DEP\_UPPER and DEP\_MIDDLE.

DIP\_LOWER: Dip of upper fault segment between DEP\_MIDDLE and DEP\_LOWER.

DEP\_UPPER: Depth to the top of the fault plane in units of km

DEP\_MIDDLE: Hinge point of the fault zone in units of km - allows variable dip values (see DIP\_UPPER and DIP\_LOWER)

DEP\_LOWER: Depth to the bottom of the fault plane in units of km. Note, only the preferred depth values are provided. The only fault source that uses alternative depth values is CIS in the SWCan\_T3E\_fault1 model. This is to add uncertainty associated with the down-dip rupture edge of the Cascadia subduction interface. See GSCFRISK input files for details.

MIN\_MAG: Minimum magnitude considered for the magnitude-frequency distribution

MMAX\_BEST: Preferred maximum magnitude in the source zone for bounded magnitude-frequency distribution (given 0.60 weighting in hazard calculation)

MMAX\_LOWER: Maximum magnitude for bounded magnitude-frequency distribution for lower curve (given 0.30 weighting in hazard calculation)

MMAX\_UPPER: Maximum magnitude for bounded magnitude-frequency distribution for lower curve (given 0.10 weighting in hazard calculation)

NO\_BEST: Preferred number of earthquakes per year with magnitude greater than or equal to 0 (given 0.68 weighting in hazard calculation)

NO\_LOWER: Number of earthquakes per year with magnitude greater than or equal to 0 for the lower curve (given 0.16 weighting in hazard calculation)

NO\_UPPER: Number of earthquakes per year with magnitude greater than or equal to 0 for the upper curve (given 0.16 weighting in hazard calculation)

BETA\_BEST: Preferred rate of small to large earthquakes, where  $\beta = b \ln(10)$  (given 0.68 weighting in hazard calculation)

BETA\_LOWER: Rate of small to large earthquakes for the lower curve (given 0.16 weighting in hazard calculation)

BETA\_UPPER: Rate of small to large earthquakes for the upper curve (given 0.16 weighting in hazard calculation)

SRC\_GMPE: The median Ground-motion model used for the central magnitude-frequency curve. Names of corresponding upper and lower GMPEs are not provided. Ground-motion models are based on those developed by Atkinson and Adams (2013).

## Appendix III: Using NBCC2015 Python Dictionary Files

The reference below gives a quick guide to loading and using the source zone information contained in the Python dictionaries. All commands below can be incorporated to Python `.py` file for simple scripting.

### *Getting Started*

At a minimum, usage of these files requires Python 2.X (where “X” is 5-7) and NumPy. Python 2.X ships with the OSX operating system. However, NumPy is still required for this platform. Installation packages for these programs can be downloaded here:

<http://python.org/download/> (as 3<sup>rd</sup> party software is not yet complete for Python 3, Python 2.7.X is the currently preferred version for scientific computing)

<http://sourceforge.net/projects/numpy/files/NumPy/>

Also recommended (but not immediately necessary) are SciPy, Matplotlib, Shapley and pyshp:

<http://sourceforge.net/projects/scipy/files/scipy/>

<http://matplotlib.org/downloads.html>

<https://pypi.python.org/pypi/Shapely>

<http://code.google.com/p/pyshp/> (download `shapefile.py` and add path to PYTHONPATH in your environmental variables)

A simple way to ensure all key packages are installed is to download and install Python XY (Windows only):

<http://code.google.com/p/pythonxy/wiki/Downloads?tm=2>

### *Loading a Python Pickle File*

In any Python command line interpreter, `cd` to the directory where the `.pkl` files are located:

```
In [1]: cd path\to\pkl\files
```

To load the file `SWCan.pkl`:

```
In [2]: import pickle
In [4]: pklfile = open('SWCan.pkl', 'rb')
In [5]: model = pickle.load(pklfile)
```

The `.pkl` file is now stored as the variable `model`.

## Using the Python Dictionaries – Some Examples

The variable `model` we have just loaded is actually an array of dictionaries for each area and fault source. Python uses zero-indexing. Consequently, the first source dictionary in the array can be accessed at index 0. To view the keys (or attributes) of the first index, we can type:

```
In [8]: model[0].keys()
Out[8]:
['max_mag',
 'src_beta',
 'src_type',
 'src_weight',
 'gmpe',
 'src_reg',
 'src_code',
 'src_dep',
 'src_shape',
 'min_mag',
 'src_name',
 'src_N0',
 'fault_dip']
```

To examine the values of these attributes for the first source zone dictionary, we type:

```
In [9]: model[0]
Out[9]:
{'fault_dip': nan,
 'gmpe': 'Wcrust_med_clC.txt',
 'max_mag': array([ 7.19999981,  6.9000001 ,  7.5          ], dtype=float32),
 'min_mag': 4.7999999999999998,
 'src_N0': array([ 11.94999981,  19.86000061,  7.5          ], dtype=float32),
 'src_beta': array([ 1.0733      ,  1.35609996,  0.79049999], dtype=float32),
 'src_code': 'BRO',
 'src_dep': array([ 10.,   5.,  15.], dtype=float32),
 'src_name': 'BRO - BROOKS PENINSULA',
 'src_reg': 'W CANADA R2',
 'src_shape': array([[ -127.67,   50.36],
                    [ -127.39,   50.22],
                    [ -127.92,   49.93],
                    [ -128.15,   50.08],
                    [ -127.67,   50.36]]),
 'src_type': 'area',
 'src_weight': 1.0}
```

Because floating-point decimal values generally do not have an exact binary representation, some loss of precision is expected in the Python dictionary files. This is common to all computational applications and is a function of the system hardware. Consequently, real numbers represented in the Python dictionary files will often possess small errors when expressed as floating-point values. Users should consult `*.model` files to determine the appropriate number of significant decimals and round appropriately. Nevertheless, any discrepancies these values are expected to be too small to affect hazard computations.

Now, we can see how to extract a given value from the dictionary (e.g. print  $M_{max}$  for each areal source):

```
In [10]: for src in model:
.....:     if src['src_type'] == 'area':
.....:         print src['src_code'], str("%0.1f" % src['max_mag'][0])
.....:
BRO 7.2
CAS 7.2
CST 7.2
EXP 7.0
FHL 7.3
FTH 7.0
GTP 7.2
HEC 7.2
JDFE 7.0
JDFN 7.0
NBC 7.2
NOFR 7.0
OFS 7.0
OLM 7.5
PGT 7.5
ROCN 7.2
ROCS 7.2
SBC 7.2
VICM 7.5
SCCWCH 7.0
SCCECHW 7.0
WLB 7.0
QCFA 6.5
FWFA 7.1
```

To find the index in `model` of all fault sources:

```
In [12]: index = [i for i, src in enumerate(model) \
                 if src['src_type'] == 'fault']
In [13]: index
Out[13]: [2, 4, 5, 6, 26, 27, 28, 29, 30, 31, 32, 33]
```

To examine the last fault source of the index array:

```
In [14]: model[index[-1]]
Out[14]: {'fault_dip': array([ 90.,  90.], dtype=float32),
          'gmpe': 'WcrustFRjb_med_T3.txt',
          'max_mag': array([ 8.27,  8.12,  8.42], dtype=float32),
          'min_mag': 6.90,
          'src_N0': array([ 14830.44727,  18699.54492,  11836.55078], dtype=float32),
          'src_beta': array([ 1.84210002,  1.84210002,  1.84210002], dtype=float32),
          'src_code': 'FWF',
          'src_dep': array([ 0.,  10.,  20.], dtype=float32),
          'src_name': 'FWF - FAIRWEATHER FAULT beta = 1.84',
          'src_reg': 'FAIRWEATHER FAULT SOURCE',
          'src_shape': array([[ -135.062,   55.559],
                             [-135.331,   55.863],
                             [-135.958,   56.88 ],
                             [-136.539,   57.618],
                             [-136.756,   57.938],
                             [-137.17 ,   58.483],
                             [-137.495,   58.684],
                             [-137.782,   58.922],
                             [-138.486,   59.469],
                             [-138.851,   59.737],
                             [-139.425,   60.088]]),
          'src_type': 'fault',
          'src_weight': 0.5}
```

Below is an example of a simple python script to write areal zone coordinates to file for each source in the current working directory. This text can be saved as a `.py` file and run in a Python interpreter.

```
import pickle
from numpy import savetxt

# read pickle file
pkfile = open('filename.pkl', 'rb')
model = pickle.load(pkfile)

# loop through sources in "model" and get all "area" zones
for src in model:
    if src['src_type'] == 'area':
        # set output file name
        outfile = ''.join((src['src_code'], '.zon'))
        f = open(outfile, 'wb')

        # write file header
        f.write(src['src_name'] + '\n')
        f.close()

        # reopen file for appending numpy array
        f = file(outfile, 'ab')
        savetxt(f, src['src_shape'], delimiter='\t', fmt='%.3f')
        f.close()
```

## Appendix IV: Description of Python Dictionary Attributes

The attributes of the Python dictionaries are slightly different to those described for the shapefiles in Appendix II. Whilst the information is consistent, the data types are stored differently. We define the Python data types here. The equivalence to attributes in Appendix II is given in square parentheses.

`fault_dip`: NumPy 1 × 2 float array [DIP\_UPPER, DIP\_LOWER]. Value is nan if `src_type = area`

`gmpe`: GMPE for median model (string) [SRC\_GMPE]

`max_mag`: NumPy 1 × 3 float array [MMAX\_BEST, MMAX\_LOWER, MMAX\_UPPER]

`min_mag`: NumPy 1 × 1 float [MIN\_MAG]

`src_N0`: NumPy 1 × 3 float array [N0\_BEST, N0\_LOWER, N0\_UPPER]

`src_beta`: NumPy 1 × 3 float array [BETA\_BEST, BETA\_LOWER, BETA\_UPPER]

`src_code`: Short naming code (string) [SRC\_CODE]

`src_dep`: NumPy 1 × 3 float array. Specified as [DEP\_BEST, DEP\_LOWER, DEP\_UPPER] for area sources and [DEP\_UPPER, DEP\_MIDDLE, DEP\_LOWER] for fault sources

`src_name`: Extended source zone name (string) [SRC\_NAME]

`src_reg`: The sub-model from which the area source is derived (string) [SRC\_REGION]

`src_shape`: NumPy n × 2 array of zone/fault coordinates in longitude, latitude. This variable is implicitly given in the shapefile format, but not directly given in the feature attributes.

`src_type`: Either 'area' or 'fault' [SRC\_TYPE]

`src_weight`: NumPy 1 × 1 float [SRC\_WEIGHT]

## Appendix V: Description of Ground Motion Prediction Equation (GMPE) look-up tables

Line 1 – header information description of GMPE type, soil class, distance metric, hazard units, original data file. NOTE in all tables that peak ground acceleration (PGA) has been labelled with period 0.02 seconds, peak ground velocity (PGV) with period 0.01 seconds (note that line 1 wraps onto a second line in this description?).

Line 2 – number of magnitudes, distances and periods in the table

Line 3 – period, in seconds, of each hazard value

Line 4 – sigma (a measure of aleatory uncertainty) for each period, expressed in natural log (ln).

Line 5 and subsequent – Magnitude ( $M_w$ ), distance (km),  $\log_{10}$ (hazard value) for each period. Spectral and peak acceleration value units are cm/s/s. Peak velocity values have been adjusted<sup>a</sup> to ensure the output from GSCFRISK is expressed in m/s

Western North America median crustal ground motion CLASS C, distance is Rhypo (depth 10 km). Log10 hazard values in cgs units PGA 0.02 PGV 0.01. Original file GMPet\_Wcrust\_med.dat, provided by G Atkinson 20120807

19	30	11	: nmag, ndist, nperiod									
		10	5	2	1	0.5	0.3003	0.2	0.1	0.05	0.02	0.01
		0.62	0.62	0.62	0.62	0.58	0.54	0.53	0.53	0.53	0.53	0.62
4.50	10.05	-1.7281	-0.4161	1.0155	1.7132	2.1698	2.2847	2.4936	2.7187	2.5503	2.3721	1.9041
4.50	10.08	-1.7281	-0.4161	1.0155	1.7132	2.1698	2.2847	2.4936	2.7187	2.5503	2.3721	1.9041
...												
...												
...												
9.00	794.39	-0.2624	0.4198	1.2546	1.1734	0.6940	0.2041	-0.1713	-0.3400	-0.3182	-0.4049	1.2951

<sup>a</sup> The FRISK program is expecting input in cm/s/s and provides output in g. Therefore to adjust the output from GSCFRISK to give m/s, the PGV entry in the look-up tables has been multiplied by 9.81. The original table values for PGV (in cm/s) could be obtained by dividing by 9.81.