EQRM: Description of Inputs Files and Parameters

DRAFT ONLY

EQRM Development Team

Geoscience Australia

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Contents

Chapter 1

The EQRM application

The Earthquake Risk Model (EQRM) is capable of:

1. earthquake scenario ground motion modeling;
2. scenario loss forecasts;
3. probabilistic seismic hazard analysis (PSHA); and
4. probabilistic seismic risk analysis (PSRA).

This chapter describes the EQRM application. Input files and parameters are discussed and directions on how to run the EQRM provided. Readers who are interested in only the EQRM methodology and not the EQRM software package may wish to skip this chapter.

The input files required by the EQRM depend on the nature of the simulation conducted. For example, the inputs for a scenario loss simulation are different to those required for a probabilistic seismic hazard analysis. Table 1.1 provides a summary of the inputs required by the EQRM. The EQRM Demos in `*/eqrm_core/demo` provide examples of each input file and demonstrate how to run the EQRM for each of the four main simulation types. The following section provide an overview of each of the main input files.

Except for the control file all input files are assumed to be in the input directory, `input_dir`, specified in the EQRM control file. If a file is not there it is looked for in `*/eqrm_core/resources/data`.

Table 1.1: Input files required for different types of simulation with the EQRM. The asterisks indicate optional input files, the requirement for which depends on settings in the EQRM control file

	hazard	**risk**
scenario	EQRM control file amplification factors* hazard grid	EQRM control file amplification factors* building database
probabilistic	EQRM control file source file(s) event type control file amplification factors* hazard grid	EQRM controlfile source file(s) event type control file amplification factors* building database

1.1 The EQRM Control File

The EQRM control file is the primary input file for an EQRM simulation. It:

1. contains a series of input variables (or parameters) that define the manner in which the EQRM is operated; and
2. initialises the simulation.

For example, there is a parameter to control whether the EQRM models hazard or risk. Other parameters can be used to identify return periods or indicate whether site amplification is considered. A description of all of the parameters is given below.

Note that it not essential to supply all parameters for each simulation. For example, if amplification is not being used (i.e. `use_amplification` = `False`) it is not necessary to supply the remaining amplification parameters. Furthermore, default values are set by the EQRM for several parameters. These are indicated below when applicable. Omission of these input parameters in the EQRM control file will lead to use of the default values. For example, the default value for `atten_threshold_distance` is 400 km.

The following also provides suggested values for several parameters. Users are free to change these values as desired. The developers are merely suggesting the value they would use in most circumstances. For example, the suggested value for `loss_min_pga` is 0.05.

The term preferred is used to indicate those parameters that the developers believe to be most appropriate. For example, the preferred value for `csm_hysteretic_damping` is `curve`. In this case the alternative choices of `None` and `trapezoidal` would typically only be used for experimental purposes.

A simulation can be started by executing an EQRM control file or by executing `analysis.py` with a control file as the first parameter.

Two ways of running EQRM:

```
>python EQRM_control_file.py
```

OR

```
>python analysis.py EQRM_control_file.py
```

The control file is a Python script, so Python code can be used to manipulate parameter values. Note though that all variables other than the parameter values must be deleted to avoid passing unknown variables into EQRM.

Acronyms:
PSHA is probabilistic seismic hazard analysis
PSRA is probabilistic seismic risk analysis
GMPE is ground motion prediction equation
PGA is peak ground acceleration (usually in units of g)
RSA is response spectral acceleration (usually in units of g)
CSM is capacity spectrum method

Table 1.2: General input for the EQRM control file.

General Input:
run_type: (Mandatory) Defines the operation mode of the EQRM: 'hazard' ⇒ Scenario RSA and PSHA (probabilistic hazard); 'risk_csm' ⇒ Scenario Loss and PSRA (probabilistic risk) based on fragility curves; 'risk_mmi' ⇒ Scenario Loss and PSRA (probabilistic risk) based on user-defined vulnerability curves; 'fatality' ⇒ Scenario Fatality forecast (based on MMI and population from USGS Open-File Report 2009-1136); 'bridge' ⇒ Bridge damage (based on fragility curves from Dale 2004).
is_scenario: (Mandatory) Event simulation type: True ⇒ a specific scenario event (Use Scenario input); False ⇒ probabilistic simulation, PSHA or PSRA (Use Probabilistic input)
site_tag: (Mandatory) String used in input and output file names. Typically used to define the city or region of interest (e.g. newc is used in the demos).
site_db_tag: DEFAULT = '' String used to specify the exposure or building data base. The building data base file name is sitedb_<site_tag><site_db_tag>.csv The exposure data base file name is <site_tag>_par_site<site_db_tag>.csv
return_periods: List whose elements represent the return periods to be considered for PSHA.
input_dir: Directory containing any local input files.
output_dir: Directory for output files. This directory will be created if not present
use_site_indexes: DEFAULT = False True ⇒ sample sites with indices in site_indexes (for testing simulations); False ⇒ No sub-sampling.

site_indexes: List whose elements represent the site indices to be used (if use_site_indexes = True). The index of the first row of data (i.e. first data row in site file) is 1.
fault_source_tag: Tag for specifying a source fault file. If fault_source_tag is defined the filename for the fault source file is <site_tag>_fault_source_<fault_source_tag>.xml. Otherwise it is not used. Note that one of fault_source_tag and zone_source_tag must be set.
zone_source_tag: Tag for specifying a source zone file. If zone_source_tag is defined the filename for the zone source file is <site_tag>_zone_source_<zone_source_tag>.xml. Otherwise it is not used. Note that one of zone_source_tag and fault_source_tag must be set.
event_control_tag: Tag for specifying a event control file. If event_control_tag is defined the filename for the event control is <site_tag>_event_control_<event_control_tag>.xml Otherwise it is not used.

Scenario Input:
`scenario_azimuth`: Azimuth of the scenario event (degrees from true North).
`scenario_depth`: Depth to event centroid (km).
`scenario_latitude`: Latitude of rupture centroid.
`scenario_longitude`: Longitude of rupture centroid.
`scenario_magnitude`: Moment magnitude of event.
`scenario_dip`: Dip of rupture plane (degrees from horizontal).
`scenario_max_width`: (Optional) Maximum width along virtual faults i.e. rupture width can not exceed `scenario_max_width` (km).
`scenario_width`: DEFAULT = `None` Width of rupture centroid (km). If `None`, dip, magnitude, area and `scenario_max_width` used to calculate using a Wells and Coppersmith (1994) conversion.
`scenario_length`: DEFAULT = `None` Length of rupture centroid (km). If `None`, calculated as area/width.
`scenario_number_of_events`: The desired number of copies of the event to be generated. Typically, copies are taken if random sampling is used to incorporate aleatory uncertainty in GMPE (i.e. `atten_variability_method`= 2), amplification (i.e. `amp_variability_method`= 2) or the CSM (`csm_variability_method`= 3).

Probabalistic Input:
All of the parameters in this section can be specified in the fault source or zone source xml files. Specifying them here will override the values in the xml files.
`prob_number_of_events_in_zones`: A list, where each element is the desired number of events for each zone source.
`prob_number_of_events_in_faults`: A list, where each element is the desired number of events for each fault source.

Ground Motion Input:

`atten_models`:
The list of GMPEs, for the logic tree. Specifying them here will override the values in the xml files. This should only be used for scenario simulations. See Chapter 1.3 for GMPE name values.

`atten_model_weights`:
The list of GMPE weights, for the logic tree. The weights must sum to one. Specifying them here will override the values in the xml files.This should only be used for scenario simulations.

`atten_collapse_Sa_of_atten_models`:
DEFAULT = `False`
Set to `True` to collapse the surface acceleration's when multiple GMPEs are used.

`atten_variability_method`:
DEFAULT = 2
Technique used to incorporate GMPE aleatory uncertainty:
None ⇒ No sampling;
1 ⇒ spawning;
2 ⇒ random sampling;
3 ⇒ $+2\sigma$;
4 ⇒ $+\sigma$;
5 ⇒ $-\sigma$;
6 ⇒ -2σ.

`atten_periods`:
Periods for RSA. Values must ascend. The first value must be 0.0.

`atten_threshold_distance`:
DEFAULT = 400
Threshold distance (km) beyond which motion is assigned to zero.

`atten_spawn_bins`:
DEFAULT = 1
Number of bins created when spawning.

`atten_override_RSA_shape`:
DEFAULT = `None`
Use GMPE for PGA only and change shape of RSA. If 'None' use RSA as defined by GMPE, otherwise if
  `'Aust_standard_Sa'` ⇒ use RSA shape from Australian earthquake loading standard;
  `'HAZUS_Sa'` ⇒ use RSA shape defined by HAZUS;
 	
Supported `run_type` = 'risk_csm'

`atten_cutoff_max_spectral_displacement`:
DEFAULT = `False`
  `True` ⇒ cutoff maximum spectral displacement.
  `False` ⇒ no cutoff applied to spectral displacement.
 	
Supported `run_type` = 'risk_csm'

`atten_pga_scaling_cutoff`: DEFAULT = 2 The maximum acceptable PGA in units g. RSA at all periods re-scaled accordingly.

`atten_smooth_spectral_acceleration`:
DEFAULT = `False`
  `True` ⇒ Smooth RSA;
  `False` ⇒ No smoothing applied to RSA.

Amplification Input:
`use_amplification`: If set to `True` use amplification associated with the local regolith. Nature of amplification varies depending on the GMPE. If GMPE has a V_{S30} term then this will be used to compute RSA on regolith. Otherwise, RSA is computed on bedrock and amplification factors used to transfer this to regolith surface.
`amp_variability_method`: DEFAULT = 2 Technique used to incorporate amplification aleatory uncertainty: None $\Rightarrow$ No sampling; 2 $\Rightarrow$ random sampling; 3 $\Rightarrow$ $+2\sigma$; 4 $\Rightarrow$ $+\sigma$; 5 $\Rightarrow$ $-\sigma$; 6 $\Rightarrow$ -2σ. 7 $\Rightarrow$ -2σ.
`amp_min_factor`: SUGGESTED = 0.6 Minimum accepted value for amplification factor. This minimum is not used for V_{s30} models.
`amp_max_factor`: SUGGESTED = 10000 Maximum accepted value for amplification factor. This maximum is not used for V_{s30} models.

Building Classes Input:
`buildings_usage_classification`: Building usage classification system - `'HAZUS'` or `'FCB'` Supported `run_type` = 'risk_csm', 'risk_mmi'
`buildings_set_damping_Be_to_5_percent`: SUGGESTED = `False` If `True` a damping B_e of 5% will be used for all building structures. Supported `run_type` = 'risk_csm'
`bridges_functional_percentages`: Functional percentages used to estimate the number of days to complete repairs. Normal curves are used using mean and sigma for each damage state as specified in table 8, Dale 2004. Setting this parameter will produce one file per functional percentage, in the format `<site_tag>_bridge_days_to_complete_fp[<func_p>]>.csv`. Supported `run_type` = 'bridge'

Capacity Spectrum Method Input:
`csm_use_variability`: SUGGESTED = `True` `True` ⇒ use the variability method described by `csm_variability_method`; `False` ⇒ no aleatory variability applied. Supported `run_type` = 'risk_csm'
`csm_variability_method`: SUGGESTED = 3 Method used to incorporate variability in capacity curve: None ⇒ No sampling; 3 ⇒ Random sampling applied to ultimate point only and yield point re-calculated to satisfy capacity curve 'shape' constraint. Supported `run_type` = 'risk_csm'
`csm_standard_deviation`: SUGGESTED = 0.3 Standard deviation for capacity curve log–normal PDF. Supported `run_type` = 'risk_csm'
`csm_damping_regimes`: PREFERRED = 0 Damping multiplicative formula to be used: 0 ⇒ PREFERRED: use R_a, R_v, and R_d; 1 ⇒ use R_a, R_v and assign $R_d = R_v$; 2 ⇒ use R_v only and assign $R_a = R_d = R_v$. Supported `run_type` = 'risk_csm'
`csm_damping_modify_Tav`: PREFERRED = `True` Modify transition building period i.e. corner period T_{av}: `True` ⇒ PREFERRED: modify as in HAZUS; `False` ⇒ do NOT modify. Supported `run_type` = 'risk_csm'

`csm_damping_use_smoothing`: PREFERRED = `True` Smoothing of damped curve: `True` ⇒ PREFERRED: apply smoothing; `False` ⇒ NO smoothing. Supported `run_type` = 'risk_csm'
`csm_hysteretic_damping`: PREFERRED = `'curve'` Technique for Hysteretic damping: `None` ⇒ no hysteretic damping `'trapezoidal'` ⇒ Hysteretic damping via trapezoidal approximation; `'curve'` ⇒ PREFERRED: Hysteretic damping via curve fitting. Supported `run_type` = 'risk_csm'
`csm_SDcr_tolerance_percentage`: SUGGESTED = 1.0 Convergence tolerance as a percentage for critical spectral displacement in non-linear damping calculations. Supported `run_type` = 'risk_csm'
`csm_damping_max_iterations`: SUGGESTED = 7 Maximum iterations for nonlinear damping calculations. Supported `run_type` = 'risk_csm'

Loss Input:

`loss_min_pga`:
SUGGESTED = 0.05
Minimum PGA(g) below which financial loss is assigned to zero.

Supported `run_type` = 'risk_csm'

`loss_regional_cost_index_multiplier`:
SUGGESTED = 1
Regional cost index multiplier to convert dollar values in building database to desired regional and temporal (i.e. inflation) values.

Supported `run_type` = 'risk_csm'

`loss_aus_contents`:
SUGGESTED = 0
Contents value for residential buildings and salvageability after complete building damage:
- 0 ⇒ contents value as defined in building database and salvageability of 50%;
- 1 ⇒ 60% of contents value as defined in building database and salvageability of zero.

Supported `run_type` = 'risk_csm'

Vulnerability Input:

`vulnerability_variability_method`:
DEFAULT = 2
Technique used to sample mean loss derived from vulnerability curves:
- None ⇒ No sampling;
- 2 ⇒ random sampling;
- 3 ⇒ $+2\sigma$;
- 4 ⇒ $+\sigma$;
- 5 ⇒ $-\sigma$;
- 6 ⇒ -2σ.
- 7 ⇒ -2σ.

Supported `run_type` = 'risk_mmi'

Save Input:

`save_hazard_map`:
DEFAULT = `False`
`True` ⇒ Save data for hazard maps (Use for saving PSHA results). Specifically spectral acceleration with respect to location, return period and period.

`save_total_financial_loss`:
DEFAULT = `False`
`True` ⇒ Save total financial loss.

Supported `run_type` = 'risk_csm'

`save_building_loss`:
DEFAULT = `False`
`True` ⇒ Save building loss.

Supported `run_type` = 'risk_csm', 'risk_mmi'

`save_contents_loss`:
DEFAULT = `False`
`True` ⇒ Save contents loss.

Supported `run_type` = 'risk_csm'

`save_motion`:
DEFAULT = `False`
`True` ⇒ Save RSA motion (use for saving scenario ground motion results). Specifically spectral acceleration with respect to spawning, ground motion model, recurence model, location, event and period.

`save_prob_strucutural_damage`:
DEFAULT = `False`
`True` ⇒ Save structural non-cumulative probability of being in each damage state. Note this is only supported for a single event.

Supported `run_type` = 'risk_csm', 'bridge'

`save_fatalities`:
DEFAULT = `False`
`True` ⇒ Save fatality forecast (based on MMI and population from USGS Open-File Report 2009-1136).
Setting this parameter will produce the file <site_tag>_fatalities.txt.

Supported `run_type` = 'fatality'

Data Input:

`event_set_handler`:
DEFAULT = `'generate'`
Sets the mode that the event set generator uses to produce an event set to work on.
  `'generate'` ⇒ Generate a new event set sample.
  `'save'` ⇒ Generate a new event set sample, save and exit.
  `'load'` ⇒ Load an event set (generated using `'save'`).

`event_set_name`:
DEFAULT = `'current_event_set'`
Name used to identify the event set data.
For `event_set_handler` options:
  `'save'` ⇒ Save event set to `data_dir/event_set_name`.
  `'load'` ⇒ Load event set from `data_dir/event_set_name`.

`data_dir`:
Directory used to save to and load from event set data files.
For `event_set_handler` options:
  `'generate'` ⇒ If not set default to `output_dir`.
  `'save'` ⇒ Mandatory and must exist.
  `'load'` ⇒ Mandatory and must exist.

`data_array_storage`: DEFAULT = `data_dir` Directory used to store internal data files. Used to reduce the memory footprint of EQRM. Note: It is recommended that this be on a fast local filesystem.
`file_array`: DEFAULT = `True` Turn on/off file based array support.

Log Input:

`file_log_level`:
DEFAULT = ‘`debug`’
Level of verbosity in file log.
Options (in decreasing verbosity):
  ‘`debug`’
  ‘`info`’
  ‘`warning`’
  ‘`error`’
  ‘`critical`’

`console_log_level`: DEFAULT = ‘`info`’ Level of verbosity in console output. Same options as for `log_level`. Must be set to less than or equal verbosity to `log_level`.

The following grey shaded box provides an example of an EQRM controlfile to undertake a PSHA.

```
"""
  EQRM parameter file
All input files are first searched for in the input_dir,then in the
resources/data directory, which is part of EQRM.

All distances are in kilometers.
Acceleration values are in g.
Angles, latitude and longitude are in decimal degrees.

If a field is not used, set the value to None.


"""

from os.path import join
from eqrm_code.parse_in_parameters import eqrm_data_home, get_time_user


# Operation Mode
run_type = "hazard"
is_scenario = False
max_width = 15
site_tag = "newc"
site_db_tag = ""
return_periods = [10, 50, 100, 10000]
input_dir = join('.', 'input')
output_dir = join('.', 'output', 'prob_haz')
use_site_indexes = True
site_indexes = [2255, 11511, 10963, 686]
zone_source_tag = ""
event_control_tag = ""

# Scenario input

# Probabilistic input

# Attenuation
atten_models = ['Sadigh_97']
atten_model_weights = [1]
atten_collapse_Sa_of_atten_models = True
atten_variability_method = 2
atten_periods = [0.0, 0.29999999999999999, 1.0]
atten_threshold_distance = 400
atten_override_RSA_shape = None
atten_cutoff_max_spectral_displacement = False
atten_pga_scaling_cutoff = 2
atten_smooth_spectral_acceleration = None
atten_log_sigma_eq_weight = 0

# Amplification
use_amplification = True
amp_variability_method = 2
amp_min_factor = 0.6
amp_max_factor = 10000

# Buildings

# Capacity Spectrum Method

# Loss
```

```
# Save
save_hazard_map = True
save_total_financial_loss = False
save_building_loss = False
save_contents_loss = False
save_motion = False
save_prob_structural_damage = None

file_array = False

# If this file is executed the simulation will start.
# Delete all variables that are not EQRM attributes variables.
if __name__ == '__main__':
    from eqrm_code.analysis import main
    main(locals())
```

1.2 The Source Files

The EQRM source files for probabilistic modeling (PSHA and PSRA) come in two forms. These are:

- source zones, and
- faults.

The EQRM can be run with either of these inputs separately or both together

1.2.1 Source Zone File

If `<zone_source_tag>` is defined then the file name is:
`<site_tag>_zone_source_<zone_source_tag>.xml`

Otherwise the file name is:
`<site_tag>_zone_source.xml`

The source zone file is used to describe one or more areal source zones. Earthquakes are assumed to be equally likely to occur anywhere within a source zone. The magnitude recurrence relationship for each source zone is defined by a bounded Gutenberg-Richter relationship. The following grey shaded box provides an example of a source zone file. A description of the parameters follows.

```
<source_model_zone magnitude_type="Mw">
    <zone area = "5054.035"
  event_type = "crustal fault">
    <geometry
    dip = "35"
    delta_dip = "0"
    azimuth = "180"
    delta_azimuth = "180"
    depth_top_seismogenic = "7"
       depth_bottom_seismogenic = "15.60364655">
        <boundary>
  -32.4000   151.1500
  -32.7500   152.1700
  -33.4500   151.4300
  -32.4000   151.1500
          </boundary>
    </geometry  >
        <recurrence_model
          distribution = "bounded_gutenberg_richter"
```

```
          recurrence_min_mag = "3.3"
          recurrence_max_mag = "5.4"
          A_min = "0.568"
           b = "1">
           <event_generation
           generation_min_mag = "4.5"
           number_of_mag_sample_bins = "15"
           number_of_events = "5000"
            /></recurrence_model>
     </zone>


     <zone area = "57731.425"
   event_type = "crustal fault">
     <geometry
     dip = "35"
     delta_dip = "0"
     azimuth = "180"
     delta_azimuth = "180"
     depth_top_seismogenic = "7"
        depth_bottom_seismogenic = "15.60364655">
         <boundary>
-31.0000   149.5000
  -32.4000   149.5000
  -32.4000   151.1500
  -32.7500   152.1700
  -32.7500   152.7600
  -32.7000   152.8000
  -32.0000   153.1100
  -31.0000   153.2900
  -31.0000   149.5000
</boundary>
     </geometry>
         <recurrence_model
         distribution = "bounded_gutenberg_richter"
          recurrence_min_mag = "3.3"
          recurrence_max_mag = "5.4"
         A_min= "2.53"
          b = "1.14" >
           <event_generation
           generation_min_mag = "4.5"
           number_of_mag_sample_bins = "15"
           number_of_events = "1000" /></recurrence_model>
     </zone>


     <zone area = "56703.105"
   event_type = "crustal fault">
     <geometry
     dip = "35"
     delta_dip = "0"
     azimuth = "180"
     delta_azimuth = "180"
     depth_top_seismogenic = "7"
        depth_bottom_seismogenic = "15.60364655">
         <boundary>
  -35.0000   149.5000
  -32.4000   149.5000
  -32.4000   151.1500
  -33.4500   151.4300
  -32.7500   152.1700
  -32.7500   152.7600
  -34.4000   151.3500
  -34.7400   151.1500
```

```
−35.0000   151.1000
−35.0000   149.5000
       </boundary>
  </geometry>
       <recurrence_model
       distribution = "bounded_gutenberg_richter"
        recurrence_min_mag = "3.3"
        recurrence_max_mag = "5.4"
       A_min= "2.48"
        b = "1.14" >
         <event_generation
         generation_min_mag = "4.5"
         number_of_mag_sample_bins = "15"
         number_of_events = "1000" /></recurrence_model>
  </zone>


  <zone area = "3046.615"
event_type = "crustal fault">
  <geometry
  dip = "35"
  delta_dip = "0"
  azimuth = "180"
  delta_azimuth = "180"
  depth_top_seismogenic = "7"
      depth_bottom_seismogenic = "15.60364655">
       <boundary>
−32.9250   151.4000
−32.7500   151.7500
−33.2500   152.2500
−33.5000   151.9000
−32.9250   151.4000
       </boundary>
  </geometry>
       <recurrence_model
       distribution = "bounded_gutenberg_richter"
        recurrence_min_mag = "5.41"
        recurrence_max_mag = "6.5"
       A_min= "0.0016"
        b = "1." >
         <event_generation
         generation_min_mag = "4.5"
         number_of_mag_sample_bins = "15"
         number_of_events = "1000" /></recurrence_model>
  </zone>


  <zone area = "72204.957"
event_type = "crustal fault">
  <geometry
  dip = "35"
  delta_dip = "0"
  azimuth = "180"
  delta_azimuth = "180"
  depth_top_seismogenic = "7"
      depth_bottom_seismogenic = "15.60364655">
       <boundary>
−31.0000   149.5000
−32.9250   149.5000
−32.9250   151.4000
−32.7500   151.7500
−33.2500   152.2500
−33.2500   152.3300
−32.7000   152.8000
```

```
  −32.0000   153.1100
  −31.0000   153.2900
  −31.0000   149.5000
        </boundary>
    </geometry>
        <recurrence_model
        distribution = "bounded_gutenberg_richter"
         recurrence_min_mag = "5.41"
         recurrence_max_mag = "6.5"
        A_min= "0.014"
         b = "1.118" >
          <event_generation
          generation_min_mag = "4.5"
          number_of_mag_sample_bins = "15"
          number_of_events = "1000" /></recurrence_model>
    </zone>


    <zone area = "44149.044"
  event_type = "crustal fault">
    <geometry
    dip = "35"
    delta_dip = "0"
    azimuth = "180"
    delta_azimuth = "180"
    depth_top_seismogenic = "7"
       depth_bottom_seismogenic = "15.60364655">
        <boundary>
  −35.0000   149.5000
  −32.9250   149.5000
  −32.9250   151.4000
  −33.5000   151.9000
  −33.2500   152.2500
  −33.2500   152.3300
  −34.4000   151.3500
  −34.7400   151.1500
  −35.0000   151.1000
  −35.0000   149.5000
        </boundary>
    </geometry>
        <recurrence_model
        distribution = "bounded_gutenberg_richter"
         recurrence_min_mag = "5.41"
         recurrence_max_mag = "6.5"
        A_min= "0.0086"
         b = "1.118" >
          <event_generation
          generation_min_mag = "4.5"
          number_of_mag_sample_bins = "15"
          number_of_events = "1000"/></recurrence_model>
    </zone>
</source_model_zone>
```

General inputs (`source_model_zone`)

- `magnitude_type`: Earthquake magnitude used to derive the recurrence parameters. NOTE - the EQRM only supports moment magnitude `Mw`.

General zone inputs (`zone`)

- `area`: Area of the source zone in km^2. This is optional. Currently the value is not used.
- `name`: Name for the source zone.
- `event_type`: Pointer to the collection of inputs described in the event type controlfile.

Geometry inputs (`geometry`)

- `azimuth`: Center azimuth for randomly generated synthetic ruptures (degrees).
- `delta_azimuth`: Range over which randomly generated azimuths will be sampled. That is, the azimuth of all synthetic earthquake will be randomly drawn from a uniform distribution between `azimuth`$\pm$`delta_azimuth` (degrees).
- `dip`: Center dip for randomly generated synthetic ruptures (degrees).
- `delta_dip`: Range over which randomly generated dips will be sampled. That is, the dip of all synthetic earthquake will be randomly drawn from a uniform distribution between `dip`$\pm$`delta_dip` (degrees).
- `depth_top_seismogenic`: Depth (km) to the top of the seismogenic zone in km. No component of a synthetic rupture will be located above this value.
- `depth_bottom_seismogenic`: Depth (km) to the bottom of the seismogenic zone in km. No component of a synthetic rupture will be located below this value.
- `boundary`: Boundary of the areal source zone as defined on the surface of the Earth in latitude (column 1) and longitude (column 2). The first and last points must be the same to close the polygon.
- `excludes`: Boundary of any regions in the source in which events are not required. Boundary defined on the surface of the Earth in latitude (column 1) and longitude (column 2). The first and last points must be the same to close the polygon.This parameter is optional. the source zone file may have no `exclude` zones, a single entry or multiple entries.

Recurrence inputs (`recurrence_model`) Note, there is only one recurrence model per zone.

- `distribution`: Distribution used to define the magnitude recurrence relations. Note that the EQRM currently only supports a Bounded Gutenberg-Richter recurrence relationship for source zones (i.e. `bounded_gutenberg_richter`)
- `recurrence_min_mag`: Minimum magnitude used to define the recurrence relationship
- `recurrence_max_mag`: Maximum magnitude used to define the recurrence relationship. Typically, this is the magnitude of the largest earthquake expected in the zone.
- `A_min`: Expected number of earthquakes with magnitude `recurrence_min_mag` or higher in the source zone per year.
- `b`: Gutenberg-Richter b value for bounded Gutenberg-Richter recurrence relationship
- `generation_min_mag`: Minimum magnitude for synthetic earthquake generation. The EQRM will only generate synthetic earthquakes with magnitudes equal to or greater than `generation_min_mag`.
- `number_of_mag_sample_bins`: Number of magnitude bins used to discretise the recurrence relationship in the magnitude range `generation_min_mag` to `recurrence_max_mag`
- `number_of_events`: Number of syntectic ruptures to be generated in the source zone.

1.2.2 Source Fault File

If `<fault_source_tag>` is defined then the file name is:
`<site_tag>_fault_source_<fault_source_tag>.xml`

Otherwise the file name is:
`<site_tag>_fault_source.xml`

The source faults file is used to describe one or more faults (including crustal faults and subduction interfaces) and/or one or more dipping slabs for intraslab earthquakes. Earthquakes are assumed to be equally likely to occur anywhere within the fault (or slab). The magnitude recurrence for faults can be defined by a bounded Gutenberg-Richter relationship or a combination of bounded Gutenberg-Richter and Characteristic. The magnitude recurrence for the intraslab earthquakes must be defined by a bounded Gutenberg-Richter relationship. The following grey box provides an example of a source fault file with the following source types:

1. *crustal fault* with recurrence defined by a bounded Gutenberg-Richter relationship (`fault 1`),
2. *crustal fault* with recurrence defined by a combined bounded Gutenberg-Richter (for small earthquakes) and a characteristic recurrence for larger earthquakes (`fault 2`),
3. a *subduction interface* with recurrence defined by Gutenberg-Richter (for small earthquakes) and/or a characteristic recurrence for larger earthquakes (`fault 3`),
4. a *3D dipping volume* to represent intraslab earthquakes in the subducting slab (`intraslab 1`).

Many of the parameters in the source fault file are identical to those described in Section 1.2.1 and are not described separately here. A description of the new parameters is provided below.

```
<source_model_fault magnitude_type="Mw">
  <fault
  name = "fault 1"
  event_type = "crustal fault">

    <geometry
         dip= "30"
         out_of_dip_theta = "0"
         delta_theta = "0"
         depth_top_seismogenic = "0"
         depth_bottom_seismogenic = "15"
         slab_width = "0">
        <trace>
             <start lat="-7.5" lon="110.0" />
             <end lat="-7.0" lon="110.5" />
        </trace>
    </geometry>

    <recurrence_model
        distribution = "bounded_gutenberg_richter"
        recurrence_min_mag = "4.0"
        recurrence_max_mag = "7.0"
        slip_rate = "2.0"
        b = "1">
      <event_generation
         generation_min_mag = "4.0"
         number_of_mag_sample_bins = "15"
```

```
        number_of_events = "1500" />
    </recurrence_model>

  </fault>

  <fault
  name = "fault 2"
  event_type = "crustal fault">

    <geometry
        dip= "90"
        out_of_dip_theta = "0"
        delta_theta = "0"
        depth_top_seismogenic = "0"
        depth_bottom_seismogenic = "15"
        slab_width = "0">
        <trace>
            <start lat="-7.5" lon="110.0" />
            <end lat="-7.0" lon="110.5" />
        </trace>
    </geometry>

    <recurrence_model
       distribution = "characteristic"
       recurrence_min_mag = "4.0"
       recurrence_max_mag = "7.0"
       slip_rate= "2.0"
       b = "1">

      <event_generation
        generation_min_mag = "4.0"
        number_of_mag_sample_bins = "15"
        number_of_events = "1500" />
    </recurrence_model>

  </fault>

  <fault
  name = "intraslab 1"
  event_type = "intraslab">

     <geometry
        dip= "20"
        out_of_dip_theta = "90"
        delta_theta = "20"
        depth_top_seismogenic = "10"
        depth_bottom_seismogenic = "100"
        slab_width = "20">
        <trace>
            <start lat="-10.0" lon="115.0" />
            <end lat="-10.0" lon=" 105.0" />
        </trace>
    </geometry>

    <recurrence_model
       distribution = "bounded_gutenberg_richter"
       recurrence_min_mag = "4.0"
       recurrence_max_mag = "7.0"
       A_min = "0.58"
       b = "1">

      <event_generation
        generation_min_mag = "4.0"
        number_of_mag_sample_bins = "15"
```

```
      number_of_events = "3000" />
    </recurrence_model>

  </fault>

</source_model_fault>
```

Parameters unique to the source fault file See Chapter ?? for further detail.

- `dip`: Dip of fault, defined as angle in degrees from horizontal.
- `out_of_dip_theta`: Out of plane dip, used for intraslab events. Angle between fault plane and out of dip rupture plane (degrees).
- `delta_theta`: Bounds the range of dips for intraslab events. That is, all synthetic ruptures will have uniformly random sampled dips in the range `dip + out_of_dip_theta` ± `delta_theta` (degrees).
- `slab_width`: Width of slab (km) when using a fault source to represent intraslab earthquakes in the subducting slab.
- `trace`: Surface trace of the fault along the surface of the Earth. Note that it is the projection of the fault along the direction of dip. It is defined by the latitude (`lat`) and longitude (`lon`) of the start and end of the trace.
- `slip_rate`: Slip rate of fault in mm per year.
- `distribution`: Distribution used to define the magnitude recurrence relations. For faults the EQRM supports (i) a Bounded Gutenberg-Richter recurrence relationship (`bounded_gutenberg_richter`) or (ii) a combined Bounded Gutenberg-Richter and Characteristic model (`characteristic`). For intraslab earthquakes the EQRM supports only `bounded_gutenberg_richter`.
- `recurrence_max_mag`: Maximum magnitude used to define the recurrence relationship. Typically, this is the magnitude of the largest earthquake expected on the fault (or in the subducting slab).

1.3 Event Type Control File

If <event_control_tag> is defined then the file name is:
<site_tag>_event_control_<event_control_tag>.xml

Otherwise the file name is:
<site_tag>_event_control.xml

Filename: <site_tag>_event_control_<event_control_tag>.xml

The event type control file is a second level control file facilitating the variation of selected EQRM parameters with event types. The mechanism for this is an `event_type` parameter which links the `event_type_control` file with individual sources (i.e. specific zones, faults or dipping slabs) in the `fault_source` and/or `zone_source` files.

```
<event_type_controlfile>
  <event_group
     event_type = "background">
    <GMPE
       fault_type = "normal">
      <branch model = "Toro_1997_midcontinent"  weight = "0.3"/>
      <branch model = "Atkinson_Boore_97" weight = "0.4"/>
      <branch model = "Sadigh_97" weight = "0.3"/>
    </GMPE>
    <scaling scaling_rule = "Wells_and_Coppersmith_94"
    scaling_fault_type = "unspecified" />
  </event_group>

  <event_group
     event_type = "crustal fault">
    <GMPE
       fault_type = "reverse">
      <branch model = "Campbell08" weight = "1"/>
    </GMPE>
    <scaling scaling_rule = "Wells_and_Coppersmith_94"
    scaling_fault_type = "reverse" />
  </event_group>


  <event_group
     event_type = "interface">
    <GMPE
       fault_type = "reverse">
      <branch model = "Zhao06_crustalinterface" weight = "0.5"/>
      <branch model = "Atkinson03_interface" weight = "0.5"/>
    </GMPE>
    <scaling scaling_rule = "Wells_and_Coppersmith_94"
```

```
    scaling_fault_type = "reverse" />
  </event_group>

  <event_group
     event_type = "intraslab">
    <GMPE
       fault_type = "reverse">
      <branch model = "Zhao06_slab" weight = "0.5"/>
      <branch model = "Atkinson03_inslab" weight = "0.5"/>
    </GMPE>
    <scaling scaling_rule = "Wells_and_Coppersmith_94"
    scaling_fault_type = "unspecified" />
  </event_group>

</event_type_controlfile>
```

Parameters in the event type control file are separated into event groups. These are blocks of input parameters defined by `<event_group ... </event_group>`. Each of these blocks is linked to a specific source in the source zone or source fault files using `event_type`.

The parameters enclosed within `<GMPE ... </GMPE>` define the use of ground motion prediction equations. These parameters include:

- `fault_type`: fault mechanism used with the GMPE. Allowable options are `normal`, `reverse` and `strike_slip`.
- `branch`: specifies a branch for the GMPE logic tree. There may be a single `branch` in which case a single GMPE is used or multiple `branch`es in which case multiple GMPEs are used in a logic tree. Inside each branch the user must specify the chosen GMPEs (`model`: see below for a list of options) and the weights (`weight`) for each branch. The weights for all branches in a given `GMPE` block must sum to 1.

The parameters enclosed within `<scaling` and `/>` control the magnitude to size scaling during the generation of synthetic ruptures. These parameters include:

- `scaling_rule`: Defines the set of scaling rules which link M_w to area, length and/or width. Currently the only allowable options are `Wells_and_Coppersmith_94`, `modified_Wells_and_Coppersmith_94` and `Leonard_SCR`.
- `scaling_fault_type`: Fault mechanism used with the scaling rule. Allowable options are `normal`, `reverse`, `strike_slip` and `unspecified`. Typically, `scaling_fault_type` will be the same as the GMPE `fault_type,` however the EQRM does not enforce this.

Current options for the GMPE are:

"Gaull_1990_WA" ⇒ Gaull *et al.* (1990);
"Toro_1997_midcontinent" ⇒ Toro *et al.* (1997) model for mid-continent USA;
"Atkinson_Boore_97" ⇒ Atkinson *et al.* (1997);
"Sadigh_97" ⇒ Sadigh *et al.* (1997), using Campbell (2003) convention;
"Sadigh_Original_97" ⇒ Sadigh *et al.* (1997);
"Youngs_97_interface" ⇒ Youngs *et al.* (1997) interface (Z_T=0);
"Youngs_97_intraslab" ⇒ Youngs *et al.* (1997) intraslab (Z_T=1);
"Combo_Sadigh_Youngs_M8" ⇒ combined Youngs *et al.* (1997) and Sadigh *et al.* (1997);
"Boore_08" ⇒ Boore *et al.* (2008);
"Somerville09_Yilgarn" ⇒ Somerville (2009) Yilgarn Craton;
"Somerville09_Non_Cratonic" ⇒ Somerville (2009) Average Non Cratonic model.
"Allen_2012" ⇒ Allen's yet to be published model;
"Liang_2008" ⇒ Liang *et al.* (2008)
"Atkinson06_hard_bedrock" ⇒ Atkinson and Boore (2006) model for hard bedrock (V_{s30}=760 ms^{-1})
"Atkinson06_bc_boundary_bedrock" ⇒ Atkinson and Boore (2006) model for V_{s30} at the NEHRP BC boundary
"Campbell03" ⇒ Campbell (2003) hybrid empirical model
"Abrahamson08" ⇒ Abrahamson *et al.* (2008) NGA model
"Chiou08" ⇒ Chiou and Youngs (2008) NGA model
"Campbell08" ⇒ Campbell and Borzorgnia (2008) NGA model
"Akkar_2010_crustal" ⇒ Akkar and Bommer (2010) model for Mediterranean and Middle East
"Zhao_2006_interface" ⇒ Atkinson and Boore (2003) model for earthquakes in the subducting slab
"Atkinson_2003_intraslab" ⇒ Zhao *et al.* (2006) model for earthquakes in the subducting slab near Japan
"Atkinson_2003_interface" ⇒ Atkinson and Boore (2003) model for earthquakes on the subduction interface
"Zhao_2006_intraslab" ⇒ Zhao *et al.* (2006) model for earthquakes on the subduction interface near Japan

1.4 Site Files

The EQRM requires a site file at which either hazard or loss will be modeled.

1.4.1 Hazard Site File

Filename: `<site_tag>_par_site.csv`

The site file for hazard is a csv file containing a header and a list of points at which the hazard (PSHA simulation) or ground motion (scenario simulation) will be computed. An example is given below in the grey shaded box:

```
LATITUDE,LONGITUDE,SITE_CLASS,VS30
-6.4125,110.879166,D,346
-6.4125,110.887497,D,350
-6.4125,110.895836,D,356
-6.4125,110.904167,C,431
-6.4125,110.912498,C,532
-6.4125,110.92083,C,514
-6.4125,110.929169,C,483
-6.4125,110.962502,D,282
-6.4125,110.970833,D,216
-6.4375,110.904167,B,760
-6.4375,110.912498,B,760
-6.4375,110.92083,B,760
-6.4375,110.929169,B,760
```

Parameters in the hazard site file:

- `Latitude`: Latitude of the points of interest.
- `Longitude`: Longitude of the points of interest.
- `SITE_CLASS`: Regolith site class. Typically, this is defined by a letter. Note that the value of this parameter must match with an amplification factor defined in the amplification file (see Section 1.5)
- `VS30`: Average velocity in the top 30 m (i.e. V_{s30}). This is used to incorporate regolith for GMPEs with a V_{s30} term.

1.4.2 Risk Site File (Building Database)

Filename: `sitedb_<site_tag><site_db_tag>.csv`

The site file for risk is a csv file representing a building portfolio. It contains a list of points at which the risk (PSHA simulation) or loss (scenario simulation) will be computed. An example is given below in the grey shaded box:

```
BID,LATITUDE,LONGITUDE,STRUCTURE_CLASSIFICATION,STRUCTURE_CATEGORY, ...
    ...HAZUS_USAGE,SUBURB,POSTCODE,PRE1989,HAZUS_STRUCTURE_CLASSIFICATION, ...
    ...CONTENTS_COST_DENSITY,BUILDING_COST_DENSITY,FLOOR_AREA,SURVEY_FACTOR, ...
    ...FCB_USAGE,SITE_CLASS,
1,-32.945,151.7513, W1BVTILE, BUILDING, RES1, MEREWETHER,2291,0, W1, ...
    ...344.4451,688.8903,150,9.8,111, C,
2,-32.9442,151.7512, S3, BUILDING, RES3, MEREWETHER,2291,0, S3, ...
    ...430.5564,861.1128,480,1,131, C,
3,-32.9419,151.7495, W1TIMBERMETAL, BUILDING, RES1, MEREWETHER,2291,0, W1, ...
    ...292.7784,585.5567,120,9.8,111, D,
4,-32.9414,151.7492, URMLTILE, BUILDING, RES1, MEREWETHER,2291,0, URML, ...
    ...378.8897,757.7793,80,9.8,111, D,
5,-32.9412,151.7486, W1TIMBERTILE, BUILDING, RES1, MEREWETHER,2291,0, W1, ...
    ...292.7784,585.5567,120,9.8,111, C,
6,-32.9409,151.7498, URMLMETAL, BUILDING, REL1, MEREWETHER,2291,0, URML, ...
    ...925.6963,925.6963,150,1,421, D,
7,-32.9431,151.7558, S3, BUILDING, RES3, MEREWETHER,2291,0, S3,...
    ...430.5564,861.1128,288,1,131, D,
8,-32.9431,151.7549, W1TIMBERMETAL, BUILDING, COM8, MEREWETHER,2291,0, W1,...
    ...1087.155,1087.155,600,1,451, D,
9,-32.9416,151.7545, C3L, BUILDING, RES3, MEREWETHER,2291,0, C3L,...
    ...430.5564,861.1128,720,1,131, E,
10,-32.9386,151.7609, C1LMEAN, BUILDING, COM1, THE JUNCTION,2291,1, C1L,...
    ...548.9594,548.9594,4500,1,211, G,
```

Parameters in the building database:

- `BID`: Integer site identifier for EQRM
- `LATITUDE`: Latitude of building
- `LONGITUDE`: Longitude of building
- `STRUCTURE_CLASSIFICATION`: **Expanded** HAZUS building type. See Section 1.4.2.1 Table 1.4, Table 1.3) for a full description of the types.
- `STRUCTURE_CATEGORY`: Type of structure. Currently `BUILDING` only
- `HAZUS_USAGE`: Index to HAZUS usage classification (Section 1.4.2.2)
- `SUBURB`: within which building is located
- `POSTCODE`: Postcode within which building is located
- `PRE1989`: Logical index stating whether the building is pre- (0) or post- (1) the 1989 Newcastle earthquake
- `HAZUS_STRUCTURE_CLASSIFICATION`: HAZUS building type, not expanded. See Section 1.4.2.1 for a full description of the types.
- `CONTENTS_COST_DENSITY`: Replacement cost of contents in dollars per square meter (Section 1.4.2.3)

- `BUILDING_COST_DENSITY`: Replacement cost of building in dollars per square meter (Section 1.4.2.3)
- `FLOOR_AREA`: Total floor area in square meters (summed over all stories)
- `SURVEY_FACTOR`: Survey factor indicating how many 'real' buildings the database entry represents. Multiple buildings are represented by single buildings to reduce computational time.
- `FCB_USAGE`: FCB usage type. See (Section 1.4.2.2) for a list of the usage classification
- `SITE_CLASS`:Regolith site class. Typically, this is defined by a letter. Note that the value of this parameter must match with an amplification factor defined in the amplification file (see Section 1.5)
- `VS30`: Average velocity in the top 30 m (i.e. V_{s30}).

Typically the building database used with the EQRM represents a subset of the true portfolio of interest. When creating a database that sub-samples a larger portfolio, individual database entries are used to represent more than one 'real' building. Such sub-sampling is undertaken to reduce run times and memory requirements. Results from an EQRM loss simulation are scaled to the full portfolio using the `survey factor`. The script `aggregate_building_db.py` in `eqrm_code` can be used to produce a sub-sampled database.

1.4.2.1 Building construction types

Buildings have been subdivided into a number of building types each with their own set of engineering parameters uniquely defining the median capacity curve and the random variability around the median. The building construction types are based upon the HAZUS definitions (FEMA, 1999),with some further subdivisions recommended by Australian engineers for Australian building construction types (Stehle *et al.*, 2001).

In essence, the seven basic HAZUS types are

- Timber frame (W)
- Steel frame (S)
- Concrete frame (C)

- Pre-cast concrete (PC)
- Reinforced masonry (R)
- Unreinforced masonry (URM)
- Mobile homes (MH)

There are further subdivisions of the HAZUS types into subtypes according to numbers of stories in the building. The complete list of HAZUS types is in Table 1.3.

The new Australian sub-types, developed by Australian engineers, create further subdivisions of the HAZUS types (Stehle *et al.*, 2001). In particular, the timber frame category (W1) is subdivided into wall types (timber or brick veneer walls) and roof types (metal or tiled); the unreinforced masonry types (URML and URMM) into roof type (metal, tile or otherwise), and the concrete frame types are subdivided into soft-story or non-soft story types. Soft-story refers to buildings that may have a concrete basement or parking area but wood frame stories.

In total, we currently have 56 possible construction types although some are rarely used. For example; the original HAZUS W1 is still there, however this is rarely used in favor of the more detailed classification into W1TIMBMETAL, W1BVTILE, etc. The expanded HAZUS types is given in Table 1.4.

1.4.2.2 Building usage types

The cost models used by the EQRM require knowledge of the building's use in society. For example the value of a factory's contents will vary from the value of a residents house. Similarly, the cost associated with building a hospital and the cost of building a local shop may differ even if the same materials are used because the buildings may be built to different standards. To transfer this information to the EQRM the building database stores information about each building's usage. There are two different schemes that can be used; the functional classification of building (FCB) usage (ABS, 2001) and the HAZUS usage classification (FEMA, 1999).

The FCB usage is summarised in Table 1.5 and the HAZUS usage classification is summarised in Table 1.6. The EQRM control file parameter `buildings_usage_classification` can be used to switch between the two usage classifications.

Table 1.3: Definitions of the basic HAZUS building construction types.

code	description	Stories
W1 W2	timber frame < 5 000 square feet timber frame > 5 000 square feet	(1–2) (All)
S1L S1M S1H	steel moment frame	Low-Rise (1–3) Mid-Rise (4–7) High-Rise (8+)
S2L S2M S2M	steel light frame	Low-Rise (1–3) Mid-Rise (4–7) High-Rise (8+)
S3	steel frame + cast concrete shear walls	(All)
S4L S4M S4H	steel frame + unreinforced masonry in-fill walls	Low-Rise (1–3) Mid-Rise (4–7) High-Rise (8+)
S5L S5M S5H	steel frame + concrete shear walls	Low-Rise (1–3) Mid-Rise (4–7) High-Rise (8+)
C1L C1M C1H	concrete moment frame	Low-Rise (1–3) Mid-Rise (4–7) High-Rise (8+)
C2L C2M C2H	concrete shear walls	Low-Rise (1–3) Mid-Rise (4–7) High-Rise (8+)
C3L C3M C3H	concrete frame + unreinforced masonry in-fill walls	Low-Rise (1–3) Mid-Rise (4–7) High-Rise (8+)
PC1	pre-cast concrete tilt-up walls	(All)
PC2L PC2M PC2H	pre-cast concrete frames with concrete shear walls	Low-Rise (1–3) Mid-Rise (4–7) High-Rise (8+)
RM1L RM1M	reinforced masonry walls + wood or metal diaphragms	Low-Rise (1–3) Mid-Rise (4+)
RM2L RM2M RM2H	reinforced masonry walls + pre-cast concrete diaphragms	Low-Rise (1–3) Mid-Rise (4–7) High-Rise (8+)
URML URMM	unreinforced masonry	Low-Rise (1–2) Mid-Rise (3+)
MH	Mobile homes	(All)

Table 1.4: Complete list of all building construction types (with those that are rarely used in italics).The integers corresponding to each building construction type represent the integer index used in the building database Column 4 for expanded HAZUS types (column 12 for HAZUS only types).

1: W1	15: S5H	29: RM1L	43: C1LSOFT
2: W2	16: *C1L*	30: RM1M	44: C1LNOSOFT
3: S1L	17: *C1M*	31: RM2L	45: C1MMEAN
4: S1M	18: *C1H*	32: RM2M	46: C1MSOFT
5: S1H	19: C2L	33: RM2H	47: C1MNOSOFT
6: S2L	20: C2M	34: *URML*	48: C1HMEAN
7: S2M	21: C2H	35: *URMM*	49: C1HSOFT
8: S2H	22: C3L	36: MH	50: C1HNOSOFT
9: S3	23: C3M	37: W1MEAN	51: URMLMEAN
10: S4L	24: C3H	38: W1BVTILE	52: URMLTILE
11: S4M	25: PC1	39: W1BVMETAL	53: URMLMETAL
12: S4H	26: PC2L	40: W1TIMBERTILE	54: URMMMEAN
13: S5L	27: PC2M	41: W1TIMBERMETAL	55: URMMTILE
14: S5M	28: PC2H	42: C1MMEAN	56: URMMMETAL

1.4.2.3 Replacement costs

The replacement cost in dollars per square meter for each building and the replacement cost of the contents of each building are contained within the building database (see Section 1.4.4). Typically these costs are a function of the usage classification of the building and are hence also dependent on whether the HAZUS or FCB classification system is used. The EQRM does not cross check how the costings were created. In some instances it may be appropriate to use costings created from one usage classification with the EQRM using the other usage mode (effects cost splits - see below) and in some instance it may not be appropriate to do so. Users are encouraged to familiarise themselves with database metadata to ensure that they are using the EQRM appropriately for their own application.

Table 1.5: Functional classification of building (FCB) (?) .

Residential: Separate, kit and transportable homes
111: Separate Houses
112: Kit Houses
113: Transportable/relocatable homes
Residential: Semi-detached, row or terrace houses, townhouses
121: One storey
122: Two or more storeys
Residential: Flats, units or apartments
131: In a one or two storey block
132: In a three storey block
133: In a four or more storey block
134: Attached to a house
Residential: Other residential buildings
191: Residential: not otherwise classified
Commercial: Retail and wholesale trade building
211: Retail and wholesale trade buildings
Commercial: Transport buildings
221: Passenger transport buildings
222: Non-passenger transport buildings
223: Commercial carparks
224: Transport: not otherwise classified
Commercial: Offices
231: Offices
Commercial: Other commercial buildings
291: Commercial: not otherwise classified
Industrial: Factories and other secondary production buildings
311: Factories and other secondary production buildings
Industrial: Warehouses
321: Warehouses (excluding produce storage)
Industrial: Agricultural and aquacultural buildings
331: Agricultural and aquacultural buildings
Industrial: Other industrial buildings
391: Industrial: not otherwise classified
Other Non-Residential: Education buildings
411: Education buildings
Other Non-Residential: Religion buildings
421: Religion buildings
Other Non-Residential: Aged care buildings
431: Aged care buildings
Other Non-Residential: Health facilities (not in 431)
441: Hospitals
442: Health: not otherwise classified
Other Non-Residential: Entertainment and recreation buildings
451: Entertainment and recreation buildings
Other Non-Residential: Short term accommodation buildings
461: Self contained, short term apartments
462: Hotels (predominately accommodation), motels, boarding houses, hostels or lodges
463: Short Term: not otherwise classified
Other Non-Residential: Other non-residential buildings
491: Non-residential:not otherwise classified

Table 1.6: HAZUS building usage classification (**?**).

Residential
RES1: Single family dwelling (house)
RES2: Mobile home
RES3: Multi family dwelling (apartment/condominium)
RES4: Temporary lodging (hotel/motel)
RES5: Institutional dormitory (jails, group housing - military, colleges)
RES6: Nursing home
Commercial
COM1: Retail trade (store)
COM2: Wholesale trade (warehouse)
COM3: Personal and repair services (service station, shop)
COM4: Professional and technical services (offices)
COM5: Banks
COM6: Hospital
COM7: Medical office and clinic
COM8: Entertainment and recreation (restaurants, bars)
COM9: Theaters
COM10: Parking (garages)
Industrial
IND1: Heavy (factory)
IND2: Light (factory)
IND3: Food, drugs and chemicals (factory)
IND4: Metals and mineral processing (factory)
IND5: High technology (factory)
IND6: Construction (office)
Agriculture
AGR1: Agriculture
Religion/Non/Profit
REL1: Church and non-profit
Government
GOV1: General services (office)
GOV2: Emergency response (police, fire station, EOC)
Education
EDU1: Grade schools
EDU2: Colleges and Universities (not group housing)

1.4.3 Bridge Site File

Filename: bridgedb_<site_tag><site_db_tag>.csv

The site file for bridges is a csv file containing a header and a list of points at which the ground motion will be computed, and bridge damage estimated. An example is given below in the grey shaded box:

```
BID,LATITUDE,LONGITUDE,STRUCTURE_CLASSIFICATION,STRUCTURE_CATEGORY, ...
    ...SKEW,SPAN,SITE_CLASS
2,-35.352085,149.236994,HWB17,BRIDGE, ...
    ...0,2,E
3,-35.348677,149.239383,HWB17,BRIDGE, ...
    ...32,3,F
4,-35.336884,149.241625,HWB17,BRIDGE, ...
    ...20,6,G
5,-35.345209,149.205986,HWB22,BRIDGE, ...
    ...4,2,D
6,-35.340859,149.163037,HWB3,BRIDGE, ...
    ...0,1,E
7,-35.301472,149.141364,HWB17,BRIDGE, ...
    ...0,1,F
8,-35.293012,149.126767,HWB10,BRIDGE, ...
    ...12,3,G
9,-35.320122,149.063810,HWB28,BRIDGE, ...
    ...0,3,C
10,-32.822962,151.685346,HWB17,BRIDGE, ...
    ...0,4,E
11,-32.823370,151.685797,HWB22,BRIDGE, ...
    ...0,6,C
12,-32.872624,151.717496,HWB3,BRIDGE, ...
    ...0,7,F
13,-32.878718,151.733289,HWB10,BRIDGE, ...
    ...0,10,G
14,-32.884673,151.786362,HWB28,BRIDGE, ...
    ...0,2,D
15,-32.848043,151.696107,HWB10,BRIDGE, ...
    ...0,3,C
16,-32.753763,151.744744,HWB3,BRIDGE, ...
    ...0,3,D
17,-32.751578,151.727342,HWB17,BRIDGE, ...
    ...0,2,C
```

Parameters in the hazard site file:

- `Latitude`: Latitude of the bridge of interest.
- `Longitude`: Longitude of the bridge of interest.
- `STRUCTURE_CLASSIFICATION`: HAZUS bridge type. See Table 1.7 for a description of the types.

- `STRUCTURE_CATEGORY`: Type of structure. Currently `BRIDGE` only.
- `SKEW`: Bridge skew (degrees).
- `SPAN`: Number of spans in the bridge.
- `SITE_CLASS`: Regolith site class. Typically, this is defined by a letter. Note that the value of this parameter must match with an amplification factor defined in the amplification file (see Section 1.5).

Table 1.7: Definitions of the HAZUS Highway Bridge Classification.

code	description
HWB1	Major Bridge - Length > 150m (Conventional Design)
HWB2	Major Bridge - Length > 150m (Seismic Design)
HWB3	Single Span (Not HWB1 or HWB2) (Conventional Design)
HWB4	Single Span (Not HWB1 or HWB2) (Seismic Design)
HWB5	Concrete, Multi-Column Bent, Simple Support (Conventional Design), Non-California (Non-CA)
HWB6	Concrete, Multi-Column Bent, Simple Support (Conventional Design), California (CA)
HWB7	Concrete, Multi-Column Bent, Simple Support (Seismic Design)
HWB8	Continuous Concrete, Single Column, Box Girder (Conventional Design)
HWB9	Continuous Concrete, Single Column, Box Girder (Seismic Design)
HWB10	Continuous Concrete, (Not HWB8 or HWB9) (Conventional Design)
HWB11	Continuous Concrete, (Not HWB8 or HWB9) (Seismic Design)
HWB12	Steel, Multi-Column Bent, Simple Support (Conventional Design), Non-California (Non-CA)
HWB13	Steel, Multi-Column Bent, Simple Support (Conventional Design), California (CA)
HWB14	Steel, Multi-Column Bent, Simple Support (Seismic Design)
HWB15	Continuous Steel (Conventional Design)
HWB16	Continuous Steel (Seismic Design)
HWB17	PS Concrete Multi-Column Bent, Simple Support - (Conventional Design), Non-California
HWB18	PS Concrete, Multi-Column Bent, Simple Support (Conventional Design), California (CA)
HWB19	PS Concrete, Multi-Column Bent, Simple Support (Seismic Design)
HWB20	PS Concrete, Single Column, Box Girder (Conventional Design)
HWB21	PS Concrete, Single Column, Box Girder (Seismic Design)
HWB22	Continuous Concrete, (Not HWB20/HWB21) (Conventional Design)
HWB23	Continuous Concrete, (Not HWB20/HWB21) (Seismic Design)
HWB24	Same definition as HWB12 except that the bridge length is less than 20 meters
HWB25	Same definition as HWB13 except that the bridge length is less than 20 meters
HWB26	Same definition as HWB15 except that the bridge length is less than 20 meters and Non-CA
HWB27	Same definition as HWB15 except that the bridge length is less than 20 meters and in CA
HWB28	All other bridges that are not classified (including wooden bridges)

1.4.4 Fatality Site File

Filename: `<site_tag>_popexp.csv`

The site file for fatalities is a csv file containing a header and a list of points at which the ground motion will be computed and converted to Modified Mercali Intensity (MMI), with which the population fatalities are estimated. An example is given below in the grey shaded box:

```
LATITUDE,LONGITUDE,SITE_CLASS,VS30,POPULATION
-6.4125,110.837502,D,301,61193
-6.4125,110.845833,D,273,106031
-6.4125,110.854164,D,299,120168
-6.4125,110.862503,D,318,27594
-6.4125,110.870834,D,338,83677
-6.4125,110.879166,D,346,85991
-6.4125,110.887497,D,350,57844
-6.4125,110.895836,D,356,146482
-6.4125,110.904167,C,431,105003
-6.4125,110.912498,C,532,37983
-6.4125,110.92083,C,514,63246
-6.4125,110.929169,C,483,58269
-6.4125,110.962502,D,282,14986
-6.4125,110.970833,D,216,45301
```

Parameters in the hazard site file:

- `Latitude`: Latitude of the points of interest.
- `Longitude`: Longitude of the points of interest.
- `SITE_CLASS`: Regolith site class. Typically, this is defined by a letter. Note that the value of this parameter must match with an amplification factor defined in the amplification file (see Section 1.5)
- `VS30`: Average velocity in the top 30 m (i.e. V_{s30}). This is used to incorporate regolith for GMPEs with a V_{s30} term.
- `POPULATION`: Population of the point of interest. An estimate of fatalities comes from the fatality rate as per the formula from USGS Open-File Report 2009-1136 multiplied by `POPULATION`.

1.5 Amplification File

Filename: `<site_tag>_par_ampfactors.xml`

Local soil conditions (or regolith) are capable of amplifying bedrock (or hard rock) ground motion. Consequently, it can be important to incorporate regolith in hazard and/or risk studies. The choice to use regolith is controlled by the EQRM control file parameter `use_amplification`. The manner in which regolith (or amplification) is considered depends on the GMPEs used. If a GMPE explicitly incorporates regolith with a V_{S30} term, then the EQRM will use this. Otherwise the RSA is computed on bedrock and then amplified to the regolith surface using a transfer function (or amplification factor). An example of an input file containing amplification factors is provided in the grey box below.

```
<amplification_model name = "example_par_ampfactors">
  <moment_magnitude_bins>
        4.50000000 5.50000000
  </moment_magnitude_bins>
  <pga_bins>
        0.00000000 0.15290000 0.2548000 0.35680000
  </pga_bins>
  <site_classes>
        CDE
  </site_classes>
  <periods>
        0.00000000 0.40000000 0.50000000 2.00000000
  </periods>

  <site_class class="C">
        <moment_magnitude mag_bin="4.50000000">
          <pga pga_bin="0.00000000">
                <log_amplification
                        site_class = "C"
                        moment_magnitude = "4.50000000"
                        pga_bin = "0.00000000">
                                0.13976194 0.13976194 0.25464222 0.25464222
                </log_amplification>
                <log_std
                        site_class = "C"
                        moment_magnitude = "4.50000000"
                        pga_bin = "0.00000000">
                                0.01000000 0.01000000 0.01000000 0.01000000
                </log_std>
          </pga>

          <pga pga_bin="0.15290000">
                <log_amplification
                        site_class = "C"
                        moment_magnitude = "4.50000000"
                        pga_bin = "0.15290000">
                                0.09531018 0.09531018 0.23111172 0.23111172
                </log_amplification>
                <log_std
```

```
                        site_class = "C"
                        moment_magnitude = "4.50000000"
                        pga_bin = "0.15290000">
                                0.01000000 0.01000000 0.01000000 0.01000000
                </log_std>
            </pga>

            <pga pga_bin="0.2548000">
                <log_amplification
                        site_class = "C"
                        moment_magnitude = "4.50000000"
                        pga_bin = "0.2548000">
                                0.03922071 0.03922071 0.20701417 0.20701417
                </log_amplification>
                <log_std site_class = "C"
                        moment_magnitude = "4.50000000"
                        pga_bin = "0.2548000">
                                0.01000000 0.01000000 0.01000000 0.01000000
                </log_std>
            </pga>
            <pga pga_bin="0.35680000">
                <log_amplification
                        site_class = "C"
                        moment_magnitude = "4.50000000"
                        pga_bin = "0.35680000">
                                -0.02020270 -0.02020270 0.17395331 0.17395331
                </log_amplification>
                <log_std site_class = "C"
                        moment_magnitude = "4.50000000"
                        pga_bin = "0.35680000">
                                0.01000000 0.01000000 0.01000000 0.01000000
                </log_std>
            </pga>
        </moment_magnitude>

        <moment_magnitude mag_bin="5.50000000">
                ...
        </moment_magnitude>
  </site_class>

  <site_class class="D">
        <moment_magnitude mag_bin="4.50000000">
                ...
        </moment_magnitude>

        <moment_magnitude mag_bin="5.50000000">

        </moment_magnitude>
  </site_class>

  <site_class class="E">
        <moment_magnitude mag_bin="4.50000000">
                ...
        </moment_magnitude>

        <moment_magnitude mag_bin="5.50000000">
                ...
        </moment_magnitude>
  </site_class>

</amplification_model>
```

The amplification of seismic ground motion depends on the composition of the regolith. The EQRM accounts for variation in regolith material by assigning amplification factors to different site classes. The EQRM also recognises that amplification of seismic waves is a non-linear process. That is, the degree of amplification is a function of the level of ground motion. To account for this non-linearity, the EQRM allows users to specify a number of amplification factors which are grouped according to the level of bedrock ground motion (as measured by PGA) and the size of the event (as measure by M_w).

The amplification factor file must specify the following parameters at the beginning:

- `moment_magnitude_bins`: centroids of the moment magnitude M_w bins for which amplification factors are defined.
- `pga_bins`: centroids of the PGA bins for which amplification factors are defined.
- `site_classes`: List of site classes for which amplification factors are defined. The EQRM assumes that each site class is defined by a single letter (e.g. `site_class` = B).
- `periods`: RSA periods at which the amplification factors are defined. Note that these periods need not be the same as those in `atten_periods` from the EQRM control file. The EQRM will interpolate as required.

The xml amplification factor file is then composed of a sequence of blocks, each of which defines:

- the `site_class` using the parameter `class`.
- the `moment_magnitude` bin centroid using the parameter `mag_bin`.
- the `pga` bin centroid using the parameter `pga_bin`.

Finally the inside of each block specifies:

- `log_amplification`: the logarithm of the median amplification factor defined at each of the RSA periods in `periods`.

- `log_std`: the standard deviation of the amplification factor. The EQRM assumes that the amplification factor is log-normally distributed when using this standard deviation. The standard deviation can be set to an arbitrarily small number such as 0.01 (as shown in grey shaded box above) when not known. Use of this standard deviation is controlled by the EQRM control file parameter `amp_variability_method` which can also be set to `None`.

1.6 Vulnerability File

Filename: <site_tag>_vulnerability.xml

Vulnerability curves in EQRM use the Natural Hazard's Risk Markup Language (NRML) specified by The GEM Foundation for use in OpenQuake. An example vulnerability file is shown in the grey box below.

```
<?xml version="1.0"?>
<nrml xmlns="http://openquake.org/xmlns/nrml/0.3"
 xmlns:gml="http://www.opengis.net/gml" gml:id="nrml">
 <vulnerabilityModel>
  <discreteVulnerabilitySet vulnerabilitySetID="HAZUS"
   assetCategory="buildings" lossCategory="economic_loss">
   <IML IMT="MMI">5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11</IML>
   <discreteVulnerability vulnerabilityFunctionID="NEL_1.4.1"
    probabilisticDistribution="N">
    <lossRatio>2.01E-07 1.94E-05 0.000587335 0.007251983 0.044241602
     0.155404744 0.356384523 0.594100748 0.790940996 0.911550187
     0.968789668 0.990643449 0.997571724
    </lossRatio>
    <coefficientsVariation>0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3
     0.3 0.3
    </coefficientsVariation>
   </discreteVulnerability>
   <discreteVulnerability vulnerabilityFunctionID="NEH_4.1.1"
    probabilisticDistribution="N">
    <lossRatio>1.01E-13 3.73E-10 2.01E-07 2.37E-05 0.000840624
     0.011332954 0.070471569 0.237465156 0.5 0.750428967 0.906081768
     0.973002925 0.993935756
    </lossRatio>
    <coefficientsVariation>0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3
     0.3 0.3
    </coefficientsVariation>
   </discreteVulnerability>
   <discreteVulnerability vulnerabilityFunctionID="NEL_2.1.1"
    probabilisticDistribution="N">
    <lossRatio>8.80E-17 3.08E-12 8.87E-09 3.57E-06 0.000301138
     0.007243107 0.063879826 0.255612903 0.563409229 0.824333664
     0.952020555 0.990906067 0.998762343
    </lossRatio>
    <coefficientsVariation>0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3
     0.3 0.3
    </coefficientsVariation>
   </discreteVulnerability>
   <discreteVulnerability vulnerabilityFunctionID="ER_1.1.1.1"
    probabilisticDistribution="N">
    <lossRatio>1.60E-25 1.23E-17 8.52E-12 1.46E-07 0.000132954
     0.01170814 0.164580979 0.593551025 0.916184727 0.993076378
     0.999755826 0.999995957 0.999999965
    </lossRatio>
    <coefficientsVariation>0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3
     0.3 0.3
    </coefficientsVariation>
   </discreteVulnerability>
   <discreteVulnerability vulnerabilityFunctionID="NEL_3.2.1"
```

```
    probabilisticDistribution="N">
    <lossRatio>1.48E-08 1.46E-06 5.10E-05 0.00079375 0.006486951
     0.031635882 0.101942058 0.235937951 0.420815277 0.614746564
     0.775778887 0.885233282 0.947862317
    </lossRatio>
    <coefficientsVariation>0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3
     0.3 0.3
    </coefficientsVariation>
   </discreteVulnerability>
   <discreteVulnerability vulnerabilityFunctionID="NEL_1.2.1"
    probabilisticDistribution="N">
    <lossRatio>0.000113882 0.00240425 0.021250659 0.096643474
     0.265261475 0.5 0.721302041 0.872407761 0.951287624 0.98418236
     0.995542434 0.998889016 0.999750924
    </lossRatio>
    <coefficientsVariation>0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3
     0.3 0.3
    </coefficientsVariation>
   </discreteVulnerability>
   <discreteVulnerability vulnerabilityFunctionID="EC_2.2.2.1"
    probabilisticDistribution="N">
    <lossRatio>4.98E-06 7.76E-05 0.000681337 0.003805858 0.014823619
     0.043189199 0.099472641 0.18932183 0.308769217 0.444766991
     0.580456473 0.701364547 0.799114523
    </lossRatio>
    <coefficientsVariation>0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3
     0.3 0.3
    </coefficientsVariation>
   </discreteVulnerability>
   <discreteVulnerability vulnerabilityFunctionID="NEL_3.1.1"
    probabilisticDistribution="N">
    <lossRatio>3.78E-07 8.13E-06 9.54E-05 0.000693954 0.003434796
     0.012443628 0.034924284 0.079457911 0.15205226 0.252314833
     0.372489214 0.5 0.621770257
    </lossRatio>
    <coefficientsVariation>0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3
     0.3 0.3
    </coefficientsVariation>
   </discreteVulnerability>
   <discreteVulnerability vulnerabilityFunctionID="NEH_3.1.1"
    probabilisticDistribution="N">
    <lossRatio>1.38E-07 9.65E-06 0.000249076 0.002942808 0.018745441
     0.073088279 0.193120023 0.376258115 0.580939953 0.756728869
     0.877406954 0.945826618 0.978749341
    </lossRatio>
    <coefficientsVariation>0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3
     0.3 0.3
    </coefficientsVariation>
   </discreteVulnerability>
  </discreteVulnerabilitySet>
 </vulnerabilityModel>
</nrml>
```

The top level attributes are defined in `discreteVulnerabilitySet`:

```
<discreteVulnerabilitySet vulnerabilitySetID="HAZUS"
   assetCategory="buildings" lossCategory="economic_loss">
```

EQRM supports a single loss category option, `economic_loss`, and the two other attributes are not currently used.

The curves in the set are all based on the intensity measure levels defined in `IML`:

```
<IML IMT="MMI">5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11</IML>
```

This is a list of intensity measure levels specified by the intensity measure type (IMT) attribute. EQRM supports conversion from spectral acceleration to Modified Mercalli Intensity, `MMI`, as per the example above.

The mean loss ratio and sigma are defined for each site type in `discreteVulnerability`:

```
<discreteVulnerability vulnerabilityFunctionID="NEL 1.4.1"
  probabilisticDistribution="N">
 <lossRatio>
  2.01E-07 1.94E-05 0.000587335 0.007251983 0.044241602
  0.155404744 0.356384523 0.594100748 0.790940996 0.911550187
  0.968789668 0.990643449 0.997571724
 </lossRatio>
 <coefficientsVariation>
  0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3
 </coefficientsVariation>
</discreteVulnerability>
```

Where:

- `vulnerabiltyFunctionID`: This specifies the site type that for this curve. It must match the `STRUCTURE_CLASSIFICATION` defined in the `sitedb` file.
- `probabilisticDistribution`: Options are `LN` (lognormal) and `N` (normal). The sampling technique will depend on the EQRM input parameter `vulnerability_variability_method`.
- `lossRatio`: Mean loss values that correspond to the configured `IML`.
- `coefficientsVariation`: Coefficient of variation that corresponds to the configured `lossRatio`, where

$$CoV = \frac{\sigma}{\mu} \tag{1.1}$$