**Calculating Earthquake Damage to Critical Infrastructure**

**using Hazus Risk Analysis Tool**

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**Objectives**

As part of the Disaster Risk Recovery (DRR) Pathways Project, the critical infrastructure were analyzed for potential damage for the chosen earthquake event (Juan de Fuca, Magnitude 6.8). Open Quake is an international, open source software used to assess earthquake hazard and risk, developed by the Global Earthquake Model (GEM) Foundation. The Open Quake engine can model potential damage due to earthquakes for point data but not linear data.

Hazus, the hazard analysis software developed by the USA Federal Emergency Management Agency (FEMA), runs on the ESRI ArcGIS platform and performs analysis on aggregated data, individual buildings, and linear features. Hazus has analysis algorithms for specific infrastructure features such as Essential Facilities (hospitals, schools, fire and police stations), Transportation (roads, railways tacks and stations), and Utilities (water and wastewater pipelines and facilities, oil or natural gas pipelines and facilities, electric power facilities, communication facilities). For the Pathways project, Hazus was used to assess potential damage to linear critical infrastructure and specific utility facilities.

**Background on Hazus**

The Hazus program comes with data sets for each US state that includes aggregated demographic and building information for Census polygons. Data include population statistics, number of buildings in different use categories (residential, commercial, industrial, etc.), total square footage of buildings in different use categories, and estimated replacement costs for buildings in different use categories. The state database also includes limited information on transportation, utilities, and essential facilities.

The Hazus user can make use of the aggregated demographic and building data for analysis of an earthquake using available shaking events provided with the program or enter shaking information for a specific event of interest. The user can also update the aggregated data if they have more up-to-date information and/or enter information for individual building, facilities, and linear infrastructure. User-defined earthquake data for a particular event include shaking parameters (Peak Ground Acceleration, Peak Ground Velocity, and Spectral Acceleration at two time periods) and can also include additional information on Soil classes, Landslide Susceptibility, and Liquefaction Susceptibility. All data entered into the Hazus database or shaking files must be formatted and attributed according to the Hazus database structure. Default attributes are available within the Hazus program, however, as with all analysis programs, the more accurate the attributes the more appropriate the analysis results will be.

The first step in Hazus analysis is to generate a Study Region of the area of interest using the aggregated data for the area. Even though the user’s analysis may only be for particular features, such as the linear infrastructure or utilities, the study region must be created using the aggregated demographic and building data.

Natural Resources Canada (NRCan) generated an aggregated dataset for Canada, based on 2011 Canada Census data, for use with an earlier version of Hazus which had been adapted, by NRCan, for use in Canada (Hazus Canada). With a change in the data file structure for more recent versions of the FEMA Hazus software, and the upgrades of Hazus to be used on updated ArcGIS versions, NRCan now uses the USA version of Hazus. Because Hazus currently only accepts data with USA state codes, Canadian data must be incorporated into a chosen state database. To use Hazus for this DRR Pathways study, the Washington state database was replaced with a set of aggregated data for British Columbia generated from 2016 Canada Census data.

**Critical Infrastructure Data Sources**

In 2017, NRCan contracted the consulting firm Spatial Visions Group (SVG) to collect available open source critical infrastructure digital data for British Columbia for the ten nationally defined critical infrastructure sectors[[1]](#footnote-1): Energy, Finance, Food, Health Care, Information and Communication Technology, Government, Manufacturing, Safety, Transportation, and Water. Through another contract in 2019 with the DRR Pathways project, SVG added more data within the Pathways study area. This new data includes purchased data sets and proprietary data (with data sharing agreements). Reports from these two contracts are not yet published. Information from both of these collections was used in the DRR Pathways study and was supplemented with further data investigation.

**Roads**

Government of Canada Topographic digital data, CanVec, are available online (<https://geogratis.gc.ca/>) based on 50,000 scale and 250,000 scale NTS (National Topographic Series) paper maps. Also, GeoBC publishes the Digital Road Atlas (DRA) which includes an extensive set of resource roads making it useful for studies that may cover rural areas of BC. This DRA dataset was used for the Pathways study. There are many attributes for the digital road data including road name, highway/road number, left- and right-side municipality, number of lanes, and speed limit.

**Railway**

Government of Canada Topographic digital data, CanVec, provide the National Railway Network (NRWN). The NRWN dataset includes tracks lines, stations, junctions, and crossings. The attributes for the track segments line features include track ownership and operator, use (freight and/or passenger), operational status, and other attributes.

**Potable Water and Wastewater Pipelines**

The location and details for potable water and wastewater pipelines was obtained from municipal data sources. Many communities in the Metro Vancouver area have GIS and Open Data sources online, from which data can be downloaded. The attributes required for Hazus to analyze pipelines include pipe diameter and pipe material. The diameter may need to be converted to inch units, the material types need to be classified as Brittle or Ductile, and the length of each segment calculated in kilometres. Note that different municipalities may use different names or acronyms to identify the pipe material, which need to be interpreted before determining whether the pipe is Brittle or Ductile.

**Potable Water and Wastewater Facilities**

The locations of water treatment plants and wastewater treatment plants in the Metro Vancouver area are available through an online search for MetroVan facilities. The size/capacity of the treatment plants must be determined, or a default chosen, so that the appropriate Hazus code can be applied to the facilities.

Potable water pumping stations and wastewater pumping/lift stations information was available from some of the municipal data sources. The size/capacity of these stations, information necessary to code the facility for analysis in Hazus, was set to “Medium” for this study.

**Gas and Oil Facilities**

The locations of oil and natural gas refineries and storage terminals were obtained from the information gathered by SVG data for this study. The Pathways study area includes one Liquid Natural Gas processing plant and seven refinery and terminal locations.

**Electric Power Facilities**

The data collection from the SVG contracts provided the locations for the analysis of 103 transformer stations (substations) and three hydroelectric generation sites within the study region. Data sources include BC Hydro, Energy BC, and DataBC.

Note that Hazus does analyze electric power transmission lines.

**Information and Communications Technology**

Twelve central offices or technology communication centres were analyzed. These are buildings containing switching equipment and communication towers. The Pathways project partner with Defence Research and Development Canada (DRDC) provided the locations of these centres.

**Analysis and Results**

Hazus reports potential earthquake damage for buildings as probability of damage levels as None, Slight, Moderate, Extensive, or Complete. Hazus provides descriptive comments on what each of these levels means in terms of physical damage to a building in the Hazus Earthquake Model Technical Manual. The user can view these probability values to determine which buildings have high probability of damage at each level. For critical infrastructure facilities, using the damage values, Hazus also calculates the expected functionality of the facility for specific days following the event (1 day, 3, 7, 14, 30, and 90 days). Results for road and railway segments are also reported as probability of damage level and functionality. For pipelines, Hazus reports earthquake damage as estimated breakage breakage and leakage rates per specified length of pipe.

**Transportation**

In the analysis of roads and railways, NRCan had issues with getting the Hazus program to run. After emails with the Hazus Help Desk it was determined there were “too many roads.” To reduce the number of roads, road segments with the attribute Speed Limit at 70 (km/hr) or higher were selected. Because this selection did not include some major roads in the urban areas (e.g. Granville Street in Vancouver is Highway 99 but in the city the speed limit is 50 km/hr) roads with three or more lanes were added to the selection.

After reducing the number of road segments, the analysis still produced incomplete results. Further communication with Hazus Help Desk determined that the Hazus program had a serious bug for all Transportation features. As a result, earthquake analysis on the road and railway linear features could not be performed.

**Potable Water and Wastewater Pipelines**

To reduce the number of elements in both pipeline files, the features were merged (unsplit) by adjoining line features had matching attributes (diameter and material). Hazus reports potential earthquake damage to pipelines as breakage rate and leakage rates per kilometre of pipe. Because these values can be very small, it is more meaningful to compare the values relative to each other rather than view the actual numbers (i.e. compare pipelines or areas of pipelines with higher or lower values than surrounding areas). Hazus also calculates estimated repair time per kilometre based on default parameters (size of pipe, number of workers required to repair/replace pipe, number of hours in a day shift) within the program. These parameters can be adjusted by the user if such information is known, however the parameters were not adjusted for this study.

**Utility Facilities**

Upon examination of the results for the utility facilities, it was found that the values did not correspond to the algorithms shown in the Hazus Earthquake Model Technical Manual. The University of Victoria partner communicated with the Hazus Help Desk and confirmed that the software algorithms were incorrect. The damage results were recalculated manually using the information from the Hazus manual.

**Information and Communications Technology**

After completion of the analysis, it was found that additional communications buildings were missing from the critical infrastructure inventory. The project partner interested in the buildings in this CI sector used the results from the Open Quake analysis to get the expected damages for the specific individual buildings.

**Deliverables**

The results from the Hazus analysis for building/facility damage estimates and post-event functionality were provided to the project partners. The pipeline breakage and leakage values were also provided. The results in Shapefile format were shared with the Pathways team members at University of Victoria and DRDC.

**Challenges and Recommendations**

The analysis results from Hazus must be considered as a model of “possible” damage results and repair times, based on the default parameters. These default values for the parameters are based on the research done by FEMA to develop the software. Many of these parameters can be adjusted by the user if they are known, however, this would require detailed knowledge of the infrastructure features, local constructions practices, and local workforce/repair times.

As noted above, the NRCan analysts spent time attempting to successfully perform analysis steps and achieve complete results. Time was spent testing different alternatives before it was determined that there is a software bug for linear Transportation linear features.

Although the aggregated base data were not analyzed in this study, these data files are necessary for the Hazus program to function. It is time consuming to generate the aggregated data files for the Canada census areas into the appropriate file formats for use in the USA version of Hazus. To date, only British Columbia has been prepared.

Further work could be performed to complete the analysis of the Transportation features and the Utility facilities when Hazus fixes the software bugs.

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1. https://www.publicsafety.gc.ca/cnt/rsrcs/pblctns/srtg-crtcl-nfrstrctr/index-en.aspx [↑](#footnote-ref-1)