**TEAM McDisaster Documentation**

**eastQuake**

**Team:** Angelina Abi Daoud, Olivia Maddigan, and Madinakhon Sulaymonova

**Mission Statement**

When we think of earthquakes in Canada, most of us think of the high magnitude Earthquakes that happen on the West Coast, in British Columbia along the Cascadia Subduction Zone. However, approximately 450 earthquakes occur in eastern Canada each year, and the people living there don’t even know the extent of this risk.

Though many earthquakes have occured over time, only some are listed as being historic due to a variety of factors - magnitude, extent of impact from damage, number of casualties. Earthquakes are often measured using the Moment Magnitude scale, which measures the energy released by an earthquake, from 1 to 10. Each step in magnitude is approximately 30 times the amount of energy as the previous step. This means that an earthquake of magnitude 2.0 releases 30 times the energy as a magnitude 1, and a magnitude 3 earthquake releases 900 times the energy of a magnitude 1. However, magnitude alone doesn’t necessarily determine the destructive capabilities of an earthquake, which is often what we as people care about - the resilience of the communities we built, and the lives of those we love.

The proximity of the earthquake to a population centre, how shallow in the Earth it occurs, and the secondary effects such as tsunamis, contamination of water supplies, gas leaks, power outages, landslides, and fires, are all factors that go into the devastation this natural disaster can bring. Although intraplate earthquakes are typically lower magnitudes, the risk in Eastern Canada has more to do with vulnerability.

Intraplate earthquakes, also referred to as within-plate earthquakes, are triggered within plate interiors. The reactivation of old rifts is the main cause of this type of earthquake. In North America, factors such as glacio-isostatic adjustment, weakening of mantle from rifting or a rise of plume, gravitational body forces, large scale mantle convection, and dynamic topography can prompt an intraplate earthquake event to take place. This event can occur indirectly with plate boundaries. As rift-zone faults rupture from rocks within a particular seismic zone begin to become weak and fragmented, then tectonic forces apply stress on the plate boundaries that are being transmitted within the continent leading to earthquake events.

Earthquake prone regions of Eastern Canada are divided based on clusters of earthquake activities: West Quebec, Charlevoix-Kamouraska, Lower St. Lawrence, Northern Appalachians, Laurentian Slope, Eastern Northern Ontario, and Southern Great Lakes. Considering the various zones that exist on the eastern side of Canada, our population is vulnerable to earthquake impacts due to our unpreparedness as a society. That is why it is important to consider disaster risk management as a way to enhance sustainable development within communities of Eastern Canada. This is a crucial pillar when looking for ways to develop a disaster-resilient society. Further advancing and supporting sustainable communities needs the hands of the general public, which is why being aware is crucial so they can prepare. Sustainability is an important aspect to consider for risk management as it ensures preventive measures against threats and earthquakes are set, with hopes that an effective preparedness plan and response can help the community.

The primary purpose of eastQUAKE is to first and foremost raise awareness of earthquake vulnerability in eastern Canada. Seismic hazard maps compare the relative hazard of all of Canada, so eastern Canada will always seem low hazard compared to the West coast. However, we know from historical earthquakes that large magnitude and damaging earthquakes can happen, and will inevitably happen again. Team McDisaster has released two interactive web apps available within the eastQUAKE Story Map, each designed to increase earthquake awareness for Eastern Canadians: eastQUAKEs Near You and eastQUAKE Vulnerability. These applications are designed to communicate risk factors associated with vulnerability to earthquakes.

Starting with the eastQUAKEs Near You, this web app allows Eastern Canadians to learn if they live within a certain distance from a past earthquake that was higher than 2.5 magnitude, in other words it helps with identifying earthquakes that have happened near their communities. On the other hand, eastQUAKE Vulnerability is designed to communicate risk factors associated with vulnerability to earthquakes. A Multi-Criteria Decision Analysis (MCDA) was conducted to determine the top 10 most vulnerable areas in Hamilton, as well as rank the vulnerability of each Hamilton census tract. The MCDA used a pairwise comparison matrix to determine appropriate weights for each factor. There are countless factors that can contribute towards the damage caused by an earthquake. However, social, environmental, and physical factors had appeared most consistently in the relevant literature, and that we felt would provide a comprehensive MCDA for our local study site of focus - Hamilton, Ontario.

Hamilton was used as we wanted to quantify earthquake risk so that Hamiltonians, and ultimately all eastern Canadians, can be prepared well ahead of anything that might happen. Earthquakes are unpredictable, and knowing that your region is earthquake-prone is the first step. Western Canadians are taught earthquake safety from a young age, and for good reason, but eastQUAKE wants every eastern Canadian located in a seismic hazard zone to know the exact course of action to take when one hits. That is why eastQUAKE to make sure you are aware, so you can prepare!

**App Description and Features**

**eastQUAKEs Near You Web App:**

Helps Eastern Canadians identify earthquakes that have happened near their communities.

**Features:**

Earthquakes Near Me?

* Eastern Canadians are often unaware that they live in a seismically active zone where earthquakes have and will happen.
* This feature allows users to define a buffer radius around any Eastern Canadian address (or your current location) to view which earthquake events have happened near you.
* The user is prompted to enter their address, enable their current location, or drop a pin to locate earthquakes near them and display the time and date they happened, their magnitude, and a description of the place.
* Default search radius is 50 km, user can scroll the bar to increase or decrease from 1 km to 100 km.
* This tool is meant for Eastern Canadians to realize whether or not they live near an area where an earthquake has occurred.

Major Cities

* This feature displays 10 major Eastern Canadian cities that, when clicked, automatically takes users to their chosen city.

Filter by Magnitude

* Users can filter the magnitudes of the earthquakes in order to view whatever range they would prefer to see between 2.5 and 7.2

What's displayed on the map?

* The Earthquakes layer displays all earthquakes that are greater than or equal to 2.5 magnitude that have occurred in Eastern Canada from 1600 to 2019.
* The Major Eastern Canadian Cities layer displays a marker for 10 populous cities in Eastern Canada; at least 1 from each province.
* The Population Density layer displays Eastern Canada's 2016 population divided by the census tract areas (km squared), from dark red (high population density) to white (low population density).

**eastQUAKE Vulnerability Web App:**

Designed to communicate risk factors associated with vulnerability to earthquakes. A Multi-Criteria Decision Analysis (MCDA) was conducted to determine the top 10 most vulnerable areas in Hamilton, as well as rank the vulnerability of each Hamilton census tract.

**Features:**

Top 10 Earthquake-Vulnerable Zones

* This feature helps the user pinpoint and navigate through the top 10 most earthquake-vulnerable zones in Hamilton identified through the MCDA.
* The tool includes each Zone, from 1 to 10, clickable for the user with the corresponding zone's colour. The user will then be taken directly to the zone of their choosing, where they can then click on the zone and receive a summary of earthquake vulnerability of the area.

Search Your Address

* Residents of Hamilton can search their address in the search bar
* The user will be taken directly to their address, and can then view which level of vulnerability exists in their community, as well as find out if they live within one of the top 10 most vulnerable zones.
* User can also allow the browser to use your location to automatically take you to your current location

Explore the Multi-Decision Criteria Factors

* Users can explore the criteria that went into calculating the vulnerability of Hamilton to earthquakes.
* In the Layers tool, users can turn layers on and off to compare these different social, environmental, and physical factors to the vulnerability value of their community.
* This allows users to interact with the underlying data that went into the calculation, and see how these factors play into earthquake risk and safety.

What's displayed on the map?

* The top 10 most earthquake-vulnerable regions in Hamilton are shown in purple, with the darkest purple showing Rank 1 (Most vulnerable) and the lightest purple showing Rank 10 (Still vulnerable compared to other parts of Hamilton but the least out of the top 10)
* The Vulnerability layer displays the calculated MCDA per census tract in Hamilton, taking into account the social, environmental, and physical factors discussed above. The dark rest depicts Hamilton's most vulnerable census tracts, with the lighter reds depicting less vulnerable zones.

**Calculations**

Calculations for the Hamilton Vulnerability Index were done following a typical Multi-Criteria Decision Analysis (MCDA) procedure using a Pairwise Comparison Matrix, with the Weighted Overlay Tool. All calculations were made using Microsoft Excel and the Field Calculator in ArcGIS Pro Version 2.8.6.

The Index was calculated using 12 indicators that were weighted and combined to form the index. The data from which the 12 factors were derived are outlined in detail in Table 2 of the “Geospatial Open Data Sources” section.

The Euclidian Distance Tool was used to determine distances from hospitals, fire stations, watercourses, and roads. The distances to hospitals and fire stations matter because in an emergency, it is ideal to be close to emergency responders. Distance to watercourses matters and is worse the closer you are to the water because in an earthquake, streams can cause liquefaction of the soil which can be very damaging. Distance to roads is good because the closer you are to a road, the more opportunity and access you have to escape.

The Feature to Raster Tool was used to convert the polygon data (population density, ages, lithology, soil type) into raster form. Higher population density is bad in the case of an earthquake because more people will be prone to injury in more cramped settings, especially apartment buildings where floors can collapse. Young people and Seniors are more likley to be victims of an earthquake because they are the most vulnerable populations. Lithology is important because types of rocks react differently to earthquakes, as with soil type.

To obtain building heights (taller buildings are more of a risk in earthquakes), the Digital Elevation Model was subtracted from the Digital Surface Model.

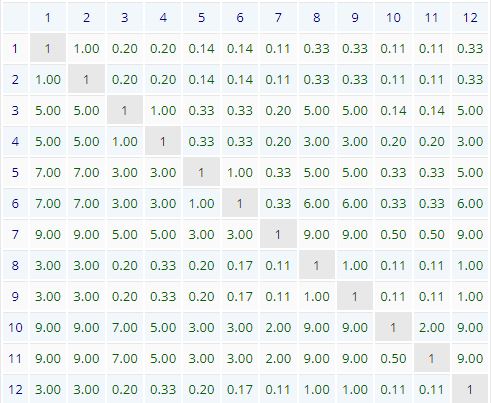
##### ***Part 1 - Indicator Standardization***

The rasters were all put through the Reclassify tool to reclassify the data on a scale of 1 - 10, with 10 being the most susceptible to earthquake risk and 1 being the least. Equal Intervals were used for all datasets.

##### **Part 2 - Assigning weights and weight standardization**

Each indicator was assigned a weight reflective of its proportion to its influence using a Pairwise Comparison Matrix.

###### **Table 1. Pairwise Comparison Matrix**

****

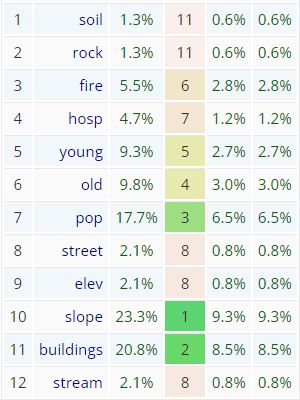
The composite weight for each indicator was calculated using the following formula, which was done in Microsoft Excel by Team McRaster:

Indicator Weight = (Factor Score1 \* Eigenvalue1) + (Factor Score2 \* Eigenvalue2) + (Factor Score3 \* Eigenvalue3)

Once the indicator weights were calculated, they were standardized so the sum of all weightings equal 1, using this formula:

Standardized Indicator Weight = Indicator Weight / Sum of all Indicator Weights

###### **Table 2. Final weights (in %) of all 12 indicators**

****

##### ***Part 3 - Calculating the Vulnerability Index***

All of the reclassified rasters and their weights were loaded into the Weighted Overlay Tool. The output was the Vulnerability surface. Zonal Statistics were used to determine the average vulnerability for each CT in Hamilton, and the Locate Regions Tool was used to locate the top ten regions at risk from earthquakes.

**Geospatial Open Data Sources**

| **Purpose** | **Data Layer** | **Data Source** |
| --- | --- | --- |
| Historical Earthquake Data | Provinces and Territories of Canada | esri\_canada |
| Earthquakes in Canada (1985-2019) | Government of Canada; Natural Resources |
| Significant Canadian earthquakes (1600-2006) | GEOSCAN  Geological Survey of Canada |
| Multi-Criteria Decision Analysis and eastQUAKE Vulnerability | Population Density in 2016 by CT | <https://open.hamilton.ca/datasets/3470c8be2fd64103a774c6ad857dbbcc_2/explore>  City of Hamilton |
| Hamilton CTs | City of Hamilton |
| Hospitals | <https://open.hamilton.ca/datasets/a5867b5375544ceb8f06544a5ed349a5_15/explore?location=43.243107%2C-79.843051%2C13.18>  City of Hamilton |
| Fire stations | <https://open.hamilton.ca/datasets/dbb028cd6bcc4b218c607952b760fd04_5/explore?location=43.259500%2C-79.910650%2C11.81>  City of Hamilton |
| Age by CT in 2016 | <https://data-spatialsolutions.opendata.arcgis.com/datasets/cdc66a4b09a147c39eeb747c15d5f9d8_4/explore?showTable=true>  City of Hamilton |
| Streets | <https://open.hamilton.ca/datasets/f7af2fb9139444a0b3331f4663c16b15_14/explore?location=43.291554%2C-79.935150%2C11.18>  City of Hamilton |
| Watercourse (rivers) | <https://open.hamilton.ca/datasets/6b303eed313244a992b1fdf3935cc1dd_7/explore?location=43.259900%2C-79.934300%2C11.21>  City of hamilton |
| buildings | City of hamilton |
| Soil Landscapes of Canada | Soil Landscapes of Canada Working Group, 2011. Soil Landscapes of  Canada version 3.2. Agriculture and Agri-Food Canada. |
| Digital Elevation Model (DEM) - Provincial Tiled Dataset | Ontario Geospatial Data Exchange (OGDE), Ministry of Natural Resources (OMNR) Ontario, Canada |
| Digital surface model derived from imagery | <https://geohub.lio.gov.on.ca/maps/mnrf::ontario-digital-surface-model-imagery-derived/explore?location=43.541814%2C-79.509764%2C7.68>  Ontario GeoHub |
| lithology | https://www.geologyontario.mndm.gov.on.ca/mndmaccess/mndm\_dir.asp?type=pub&id=MRD126-REV1 |
| eastQUAKEs Near You | Earthquakes in Canada (1985-2019) | Government of Canada; Natural Resources |
| Significant Canadian earthquakes (1600-2006) | GEOSCAN  Geological Survey of Canada |
| Census Subdivisions of Canada 2016 | The Living Atlas |
| Population Centres 2018 | Derived from Administrative Boundaries in Canada |

## **References**

Earthquake:<https://www.thecanadianencyclopedia.ca/en/article/earthquake>

Earthquakes: Information & Facts:

<https://www.redcross.ca/how-we-help/emergencies-and-disasters-in-canada/types-of-emergencies/earthquakes/earthquakes-information-facts>

EARTHQUAKES IN EASTERN CANADA: A THREAT THAT CAN BE

MITIGATED:

<http://www.geohazard.ggl.ulaval.ca/0_Keynotes/lamontagne.pdf>

Earthquakes and Plate Tectonics:

<https://openpress.usask.ca/physicalgeology/chapter/12-3-earthquakes-and-plate-tectonics-2/>

Understanding intraplate earthquakes:

<https://blogs.egu.eu/divisions/gd/2020/07/08/intraplate_earthquake/>

The 1929 Magnitude 7.2 "Grand Banks" earthquake and tsunami:

<https://earthquakescanada.nrcan.gc.ca/historic-historique/events/19291118-en.php>

Earthquake zones in Eastern Canada:

<https://www.seismescanada.rncan.gc.ca/zones/eastcan-en.php>

Preparing for an earthquake: <https://www.ready.gov/earthquakes#:~:text=Prepare%20Before%20an%20Earthquake&text=Make%20an%20Emergency%20Plan%3A%20Create,fire%20extinguisher%20and%20a%20whistle>.

DISASTER PREPAREDNESS AND SUSTAINABLE DISASTER RISK MANAGEMENT IN A CHANGING ENVIRONMENT: <https://www.witpress.com/Secure/elibrary/papers/SDP20/SDP20036FU1.pdf>

**Video and Audio references:**

Stock footage credits: <https://www.pexels.com/videos/>

<https://www.videvo.net/>

National Geographic: <https://www.youtube.com/watch?v=_r_nFT2m-Vg&t=39s>

<https://www.youtube.com/watch?v=e7ho6z32yyo>

EarthScience Western Australia: <https://www.youtube.com/watch?v=FjXb97qR5C8>

Background music credits: [https://www.bensound.com](https://www.bensound.com/)

**Image credits to:**

* <https://doi.org/10.1016/j.pepi.2008.03.017> (Schematic cross-section of the subduction)
* <https://earthquakescanada.nrcan.gc.ca/historic-historique/events/19291118-en.php> (Grand Banks earthquake images and newspaper)
* <https://www.seismescanada.rncan.gc.ca/zones/eastcan-en.php> (Earthquake zones in Eastern Canada)
* <https://www.cgsentinel.com/uploads/images/2018/12/a31e02a5560bef97d5eee2ff136b4542.jpg> (story map seismic background)
* <https://www.pexels.com/photo/building-construction-industry-house-11460993/> (Mike)
* <https://www.pexels.com/photo/people-water-building-bridge-5903489/> (Andrey Karpov)
* <https://www.pexels.com/photo/magnifying-glass-and-wind-rose-on-maps-7412095/> (Monstera)
* <https://www.pexels.com/photo/houses-near-trees-2079223/> (Emre Can Acer)
* Halifax skyline (<https://banffventureforum.com/home-2/halifax-skyline/>)
* Hamilton skyline (<https://en.wikipedia.org/wiki/List_of_tallest_buildings_in_Hamilton,_Ontario>)
* Toronto skyline (<https://unsplash.com/s/photos/toronto-skyline>)
* Ottawa skyline (<https://www.istockphoto.com/photos/ottawa-skyline>)
* Montreal skyline (<https://www.alamy.com/stock-photo/montreal-skyline.html>)
* Quebec skyline (<https://www.shutterstock.com/image-photo/quebec-city-skyline-panorama-over-river-154975961>)
* Charlottetown skyline (<https://www.myconsultant.ca/EN/A-Newcomers-Guide-to-Charlottetown>)
* Saint John skyline (<https://www.paulsaulnier.com/2017/07/23/hometown-saint-john-new-brunswick/>)
* Moncton skyline (<https://commons.wikimedia.org/wiki/File:Skyline_of_Moncton_in_2015_(cropped).jpg>)
* St.John’s skyline (<https://www.123rf.com/photo_85839178_st-john-s-cityscape-with-a-port-capital-city-of-newfoundland-and-labrador-canada.html>)
* Earthquakes Canada reported a 5.2 magnitude earthquake hit near Shawville, Quebec image <https://www.ctvnews.ca/canada/central-canada-quakes-a-closer-look-at-the-region-s-risk-of-tremors-1.1286076>
* <https://www.pexels.com/photo/first-aid-kit-on-gray-background-5673523/> (Roger Brown)
* <https://www.pexels.com/photo/photo-of-a-person-covering-her-head-with-her-sweater-6951520/> (cottonbro)