Is Vancouver Truly Ready for the "Big One"?

A GEOB 270 Project

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Table of Contents

Abstract

The western side of British Columbia is highly susceptible to earthquakes due to its location on the Cascadia subduction zone along the Ring of Fire. Focused on the City of Vancouver, this project analyzes and assesses the risks posed by this natural disaster and the city's preparedness. Aided by data obtained through Statistics Canada and the City of Vancouver's open data catalogue, our team created three maps. The first map shows the surface geology of the Greater Vancouver Area, the second map visually represents which schools have and have not been seismically upgraded within the city, and the third map demonstrates the location of disaster support hubs as well as our proposition for additional hubs. Through our representation of the surface geology, we were able to delineate hazard zones within the city. Because Vancouver is moderately safe, further research allowed us to identify different risks, such as Seismically Upgraded (or not) schools in our second map. In our third map, the preparedness of the city was assessed by creating buffers and identifying areas that would not be supported should there be a disaster. These maps were useful in determining which places in the city need spots for safe gathering when citizens require support services. With this information in mind, we propose that there should be 9 additional hub locations.

Description of Project, Study Area and Data

This project consists of identifying the risk areas within the Greater Vancouver Area should the region experience a high magnitude earthquake. Because geology is independent of city boundaries, we decided to look at the "bigger picture" to understand the nature of it. Based on our results from this broad map, we then focused on the city of Vancouver. The idea was to further recognize whether or not buildings, particularly schools, had undergone the Siesmic Mitigation Upgrade (1970) to check for their susceptibility should there be an earthquake. Finally, we also wanted to cross-check existing disaster-support hubs with population density in order to analyze how prepared the city truly is for a big earthquake. With this disaster-hub analysis we proposed potential locations where the city could add more of these hubs in case there were not enough providing post-disaster support.

Our data was obtained from various resources. To begin with, we got our Geology shapefile and DEM raster file from the Geography Departments G Drive, accessible to all students in the department. For the creation of our maps on schools and disaster support hubs, data and shapefiles were imported through the City of Vancouver's open data catalogue as well as the Statistics Canada website. We were able to create 3 different maps visualizing our findings.

Geology of Vancouver map

Our geology map shows the following cities: Vancouver, Richmond, Delta, Coquitlam, North Vancouver, West Vancouver, Port Moody, Maple Ridge, Langley, Burnaby, Surrey, White Rock and Pitt Meadows. For simplicity purposes, we have chosen to show the 3 broad groups from the data set using Symbology: "Ice Age sediments in uplands", "bedrock in mountains" and "modern sediments in lowlands". Below is a table that summarizes what categories fall into each group with their designated colour, allowing us to show a more generalized representation of the geology of the Greater Vancouver Area. Additionally, we are aware that not everyone understands the geologic implications of detailed information such as "gravel and sand", further supporting our decision to use 3 groups as opposed to 10 categories. We also obtained a DEM raster file, and using the ArcToolbox's Spatial Analyst, we were able to show the slope on the DEM in order to better represent the geology polygon. By doing this, we were able to show that most of the bedrock is found in the steeper mountains, whereas the larger portion of the modern sediments are found around the rivers and lowlands.

Group	Material (category)	Colour (vulnerability)
Bedrock in Mountains	Granitic rock	Green (low vulnerability)
	Foliated sedimentary and volcanic rock	
	Sandstone	
	Volcanic rock	
Ice Age Sediments in uplands	Gravel and sand	Yellow (moderate vulnerability)
	Steepland sediments	
	Silt and clay	
Modern Sediments in lowlands	Gravel and sand	Red (high vulnerability)
	Landfill	
	Peat	
	Silt and clay	

Once this was done, we lowered the transparency of the Geology polygon in order to show the slope effect behind it. Lastly, once these two layers were placed one on top of the other, we proceeded to add 100m contours from the 3D Analyst tool to further highlight not only the slope but also the geology of the area shown in the map.

We found that for the geology map there is a total area of 2343.2 square kilometers, of which 35% is at high risk, 35.7% moderate risk and 29.3% low risk. However, much of the City of Vancouver, our focus for the other two maps, is composed mostly of Ice Age sediments in uplands, with some marginal Modern sediments in lowlands to the south, south-east and even lesser Bedrock in mountains. We thus determined the City of Vancouver to be at a moderate susceptibility, further supported by the lack of 100m contours and the low slope from the elevation file. Subdividing the danger shown in the map, which is smaller than that mentioned earlier because of the size of the polygon, is roughly 50% is at moderate risk, 20% at low risk and 30% at high risk. Because we were unable to separate our area of interest from the rest of the geology polygon, we chose to calculate the entire area regardless, to give an estimate of the distribution of the risk.

The colour scheme chosen accompanies the risk assessed for each area. For instance, those areas with "modern sediments in lowlands" are at higher risk because these modern surficial and unconsolidated sediments are more susceptible to liquefaction should there be an earthquake. This means that the shaking would be intensified by the unconsolidated nature of these sediments, causing them to shake like jelly or water in a glass. On the other hand, we considered the "Ice Age sediments in uplands" are less susceptible to liquefaction because while they are glacial deposits, they have likely been solidified by previous, younger glaciation events, thus reducing the unconsolidated nature of sediments. Lastly, we identified bedrock as the safest lithology based on the fact that they tend to shake less because those rocks are far more compacted than sediments. Nonetheless, it is also important to consider the fact that these constitute the mountains, where we can find steep slopes, shown by abundant 100m contours, that suggest this area may pose other threats during earthquakes regardless of their geologic nature such as rock falls, landslides, etc. However, these should be accounted for using some other software and are out of the scope of this project.

Vancouver Schools map

As we have seen from the geology of Greater Vancouver, Metro Vancouver is moderately vulnerable to an overdue earthquake. In order to further examine Vancouver's preparedness, we examined social safety plans and precautions through schools and disaster support hubs. Since schools are an important public institution that contains a concentrated amount of youths, they are points of interest and protection in the midst of an earthquake.

The data obtained for this map includes a data set of all the schools in Vancouver and Vancouver's local area boundary, which were both downloaded from Vancouver open data catalogue. We also mapped out existing disaster support hubs based on data from City of Vancouver. In order to assess the safety and location of schools in Vancouver, we took two factors into account: their location in relation to disaster support hubs and the year the schools were built or whether or not a seismic upgrade has been done. Our methodology included the use of Clipping, Buffering, Unifying and Querying our data in order to label and symbolize the safety of schools.

The National Building Code of Canada's first true seismic precautions were passed in 1970 through reinforcing construction standards (Mitchell et al., 2010). Thus, we researched the year each school was built or if upgrades were done to set apart the schools that would likely be demolished in an earthquake with ones that would not. Using the tabular data created, we were able to select schools by attribute in their year built. Visualizing this through colours green, yellow and red, we were able to clearly differentiate Vancouver School Board's current situation if an earthquake were to hit. Schools like Vancouver Technical School and Gordon Elementary are labelled in green regardless of their location within a buffer since their buildings are earthquake prepared because they have undergone upgrading or were built after 1971. Every other school in yellow and red are in moderate and serious danger respectively. The schools in yellow represent ones that were built before 1971 or had no seismic mitigation upgrading yet including Lord Byng Secondary and Macdonald Elementary. Lastly, in red, are the schools that not only are not built under earthquake cautious conditions but also are not within a distance of 1km to a buffer. This becomes crucial later on in our third map. The location of schools is an important factor in our analysis because it connects with our third map of Vancouver's disaster support hubs (which will be covered in the next section in detail). After mapping out each support hub location using a new polygon feature layer, we created a buffer of 1 km around each polygon, we were able to assess the safety of schools based on their location. Location querying for schools completely within the source layer selected all schools that were within our now unified polygon of the disaster support hub and its buffer. Doing so, we can also clearly see which schools need immediate disaster relief precautions because they are not located within an area with a support hub, thus indicated by schools in red. As we continue in our project, we take these results into consideration as we discuss potential areas for new disaster support hubs based on the absence of safety hubs near some schools.

Population Map map

Data for our proposed disaster support hubs plan was taken from the open data catalogue of the City of Vancouver, as well as through census information from statistics Canada. For the creation of these maps, we took into account the population density of different neighborhoods as well as the location of existing support hubs. By classifying our population through 10 000 intervals via manual break, we could consistently demonstrate and compare the population differences between neighborhoods.

According to the City of Vancouver, "disaster support hubs are designated locations where you can initially gather to coordinate your efforts and offer assistance to other members of your community" (vancouver.ca). Their intent is to help guide citizens to take the necessary actions in the event of a disaster. Such disasters are not limited to earthquakes, but due to the nature of our project, this is the type of disaster we are basing our analysis on. Existing support hubs are sporadically distributed throughout the city. Some are located within neighborhood boundaries and others are located on the borders. Neighborhoods that are more densely populated have more disaster hubs than others. For example, the Downtown neighborhood has 3 support hubs whereas the West Point-Grey neighborhood only has one. In total, there are 25 disaster support hubs.

During the first few hours until the first few days after an Earthquake, these hubs will be used as places for families and neighbours to meet up, share resources and supplies from emergency kits, as well as places to share information (vancouver.ca). After these initial reactions to the disaster, the support hubs expand their services. Such services include “group lodging and shelter, distribution of food, water, and supplies, recovery information and support for reuniting families” (vancouver.ca). This will be run by staff and volunteers and the availability of such services “will depend on the impacts to the community” (vancouver.ca).

In the event of a disaster, citizens who live within less densely populated areas may have difficulties reaching their nearest hub, or their local hubs may overfill. This is why we have proposed 9 more hub locations. Provided below is a list of existing disaster support hubs:

1. Britannia Community Services Centre 1661 Napier Street
2. Champlain Heights Community Centre 3350 Maquinna Drive
3. Coal Harbour Community Centre 480 Broughton Street
4. Creekside Community Recreation Centre 1 Athletes Way
5. Douglas Park Community Centre 801 West 22nd Avenue
6. Dunbar Community Centre 4747 Dunbar Street
7. False Creek Community Centre 1318 Cartwright Street
8. Fraserview Branch – Vancouver Public Library 1950 Argyle Drive
9. Hastings Community Centre 3096 East Hastings Street
10. Hillcrest Centre 4575 Clancy Loranger Way
11. Kensington Community Centre 5175 Dumfries Street
12. Kerrisdale Community Centre 5851 West Boulevard
13. Killarney Community Centre 6260 Killarney Street
14. Kitsilano War Memorial Community Centre 2690 Larch Street
15. Marpole-Oakridge Community Centre 990 West 59th Avenue
16. Mount Pleasant Community Centre 1 Kingsway
17. Oppenheimer Park 400 Powell Street
18. Renfrew Park Community Centre 2929 East 22nd Avenue
19. Roundhouse Community Arts and Recreation Centre 181 Roundhouse Mews
20. Strathcona Community Centre 601 Keefer Street
21. Sunset Community Centre 6810 Main Street
22. Thunderbird Community Centre 2311 Cassiar Street
23. Trout Lake Community Centre 3360 Victoria Drive
24. West End Community Centre 870 Denman Street
25. West Point Grey Community Centre 4397 West 2nd Avenue

(vancouver.ca)

In the event that these buildings are damaged from the impact of an earthquake, the city of Vancouver states that "there is [still] enough outdoor space for the public to gather" (vancouver.ca). With additional hub locations around the city, this would ensure and further guarantee that every citizen will have access to the necessary aid. In proposing such locations, we took into account the population density of certain areas. For example, in the Renfrew-Collingwood neighborhood where the population ranges from 45001 - 54690, we have added an additional hub at this spot. We also took into account distance that some people may have to travel in order to reach their nearest support hub. In the South-Vancouver neighborhood, we added an additional hub so that citizens living farther away from the existing hub will have access to another location. Another concern is that the support hubs that are located in the more densely populated areas will fill up, not leaving enough space or resources for the people who live further away, even if they live in low density areas. To resolve these conflicts, a 1km buffer was created to encompass each of the 25 existing hubs to see which areas may benefit from additional support hubs or stations. The buffer layer ended up covering about 77% of the overall area that is mapped indicating that the majority of the city should be able to easily access

Error and Uncertainty

When it comes to projects like these, there are always errors and uncertainties. For instance, initially we wanted to focus on the ages of houses rather than schools. But, due to setbacks such as very large data sets, failure to join two data sets among other things we had to change this focus on our project to a similar feature, schools.

Another issue was related to the resolution of the geology polygons. When looking for shapefiles in both the Geological Survey of Canada and BC, they were all very coarse, showing the Greater Vancouver Area as one type of lithology and with a very generalized outline. This detail made it very difficult to use, which is why we chose to use the data provided by the G Drive. However, this map had a larger E-W area than we needed, while we needed more N-S coverage. In fact, we chose to show the DEM in the top right corner of our map because the geology polygon was missing that piece of information and our map looked incomplete. Additionally, there is only so much analysis one can do with 2D maps. In order to get a proper risk assessment for our geology map, we would need 3D modelling to see how each sediment type behaves. Our biggest error is that it is overly simplified and based on multiple assumptions.

There is also room for potential error in our schools map. Even though the source of our data comes from NBCC and the provincial government's assessment of school upgrades, it does not eliminate agendas. Since seismic mitigation upgrades are a government project, anything data published to the public eye would usually focus on success and progress rather than setbacks, resulting in the bias in our own maps because we use government progress reports to determine the overall safety of each school. Another source of error is the fact that data may not be up to date. For example, Laurier Annex and Chief Maquinna Annex have both been shut down but has still been included in government datasets for schools in Vancouver, so we had to go in and remove certain schools that did not apply on our own project.

Most disaster support hubs are located in community centres. Although we determined which areas require additional hubs, we did not take into account the possible venues for such places. At those locations, there may not be an available building or space for proposed hubs. However, for less densely populated areas that have proposed additional hubs, these hubs can act more as support "stations", where local citizens can get access to resources and information. Uncertainty also lies in the fact that UBC and the Musqueam First Nations Reserve are not represented on these maps. This is due to the lack of information in our neighbourhood contour layer and population data. The City of Vancouver also did not consider putting any hubs at those locations. Citizens living in those areas may have to report to their closest hub and there may not be enough space to accommodate them.

Further Research and Recommendations

Although in an overview, Vancouver seems to be safe to an extent during an earthquake, further research in earthquake assessment can always be done. Our project aimed to focus on a few aspects of social safety in earthquake analysis: schools, safety hubs and population. Our findings made it possible to interpolate areas Vancouver should set up new disaster support hubs based on population and school locations. In other cases, looking at hospitals or shopping malls is just as critical for Vancouver's earthquake plan. Again, our project proposed new changes to Vancouver's current safety plan, but in order for these changes to take place, future research must be made in financial, political and social scopes to ensure that a placement of new support hubs is feasible. In the end, a city should never cease to prepare and plan for incoming natural disasters because there is no such thing as over prepared. Education is also a very important aspect of earthquake preparedness, and we must continue to educate ourselves and others to be as safe as possible.

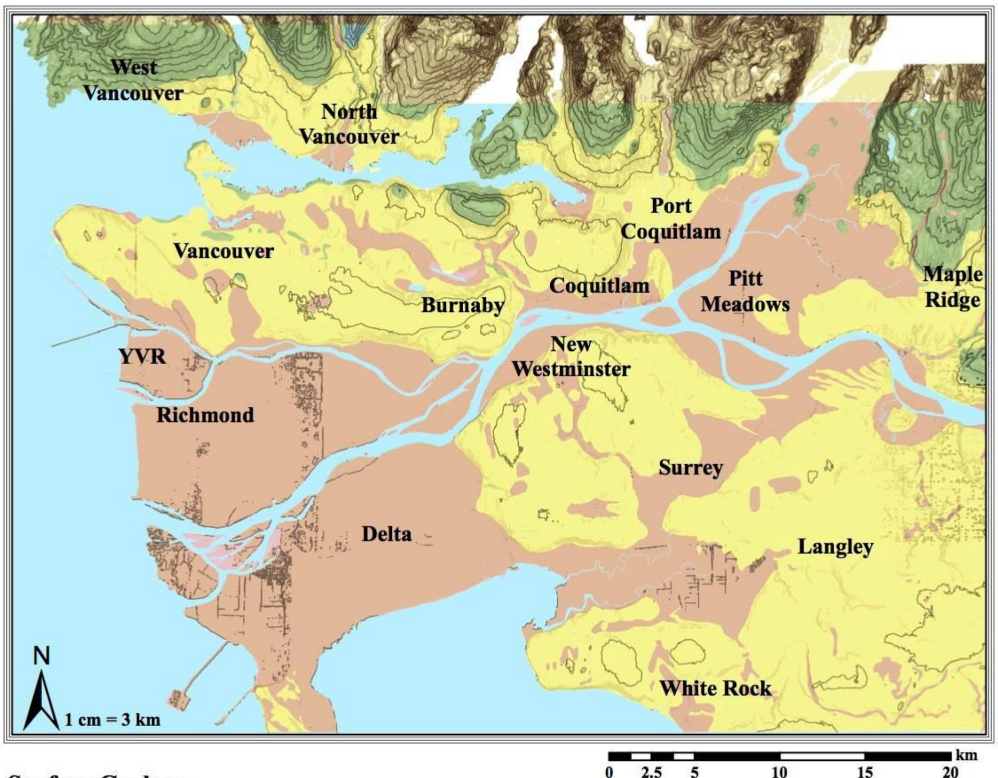
Concluding Points

Earthquake awareness and preparedness has been heavily emphasized in recent years for the Vancouver Area. With reference to the surface geology of BC's lower mainland, our project focuses on aspects that determine how safe the City of Vancouver will be when an earthquake occurs. We found that many schools within the local boundary area have been upgraded, however, the majority are still vulnerable. With attention to where existing disaster support hubs are located, we have also determined where additional stations can be placed. Although large scale natural disasters are difficult to predict, citizens of Vancouver can take comfort in knowing that the City is putting efforts towards promoting safety and sanction in the event of such impacts.

Appendices

Map of the geology of Vancouver:

Greater Vancouver Area: Vulnerability to Earthquake Damage Based on Geology



Surface Geology

TYPE AND VULNERABILITY

- **Bedrock in mountains- Low Vulnerability**
- **Ice Age sediments in uplands- Medium Vulnerability**
- **Modern sediments in lowlands- High Vulnerability**
- **Water**
- **Contours *100 m***

Vulnerability levels were estimated based on the geology of the locations. Bedrock is the most stable and secure material whereas modern sediments are the most susceptible to shifting and change in the event of an earthquake.

In The Event of an Earthquake:

1) DROP — Drop to the ground (before the earthquake knocks you down)

2) COVER — Take cover, by getting under a sturdy desk or table

3) HOLD ON — Grab the legs of the desk or table, and hold on until the shaking stops

For more information, visit: http://vancouver.ca/home-property-development/earthquake.aspx

Data Source: UBC Geography Department G Drive
Date: 4/5/2017

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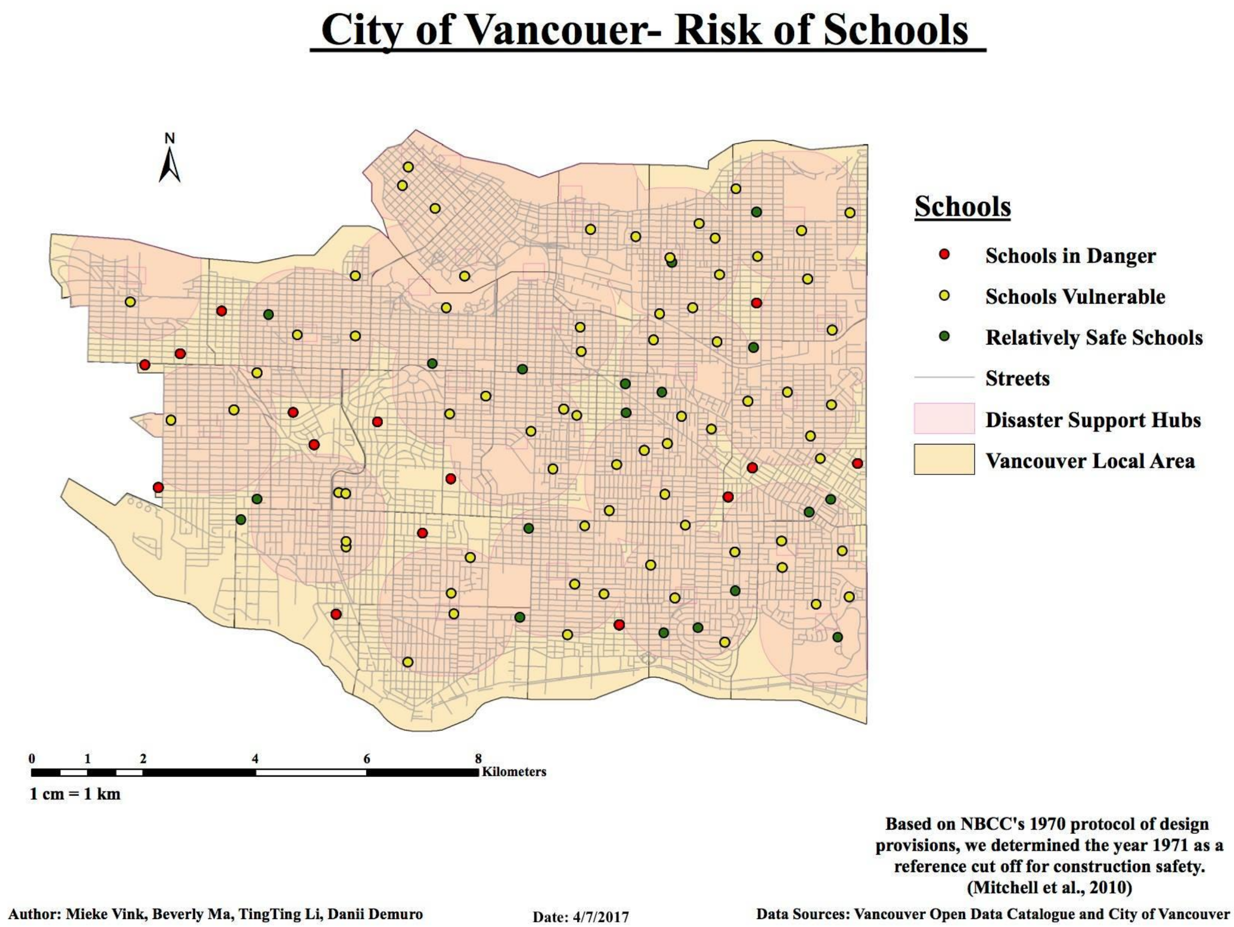
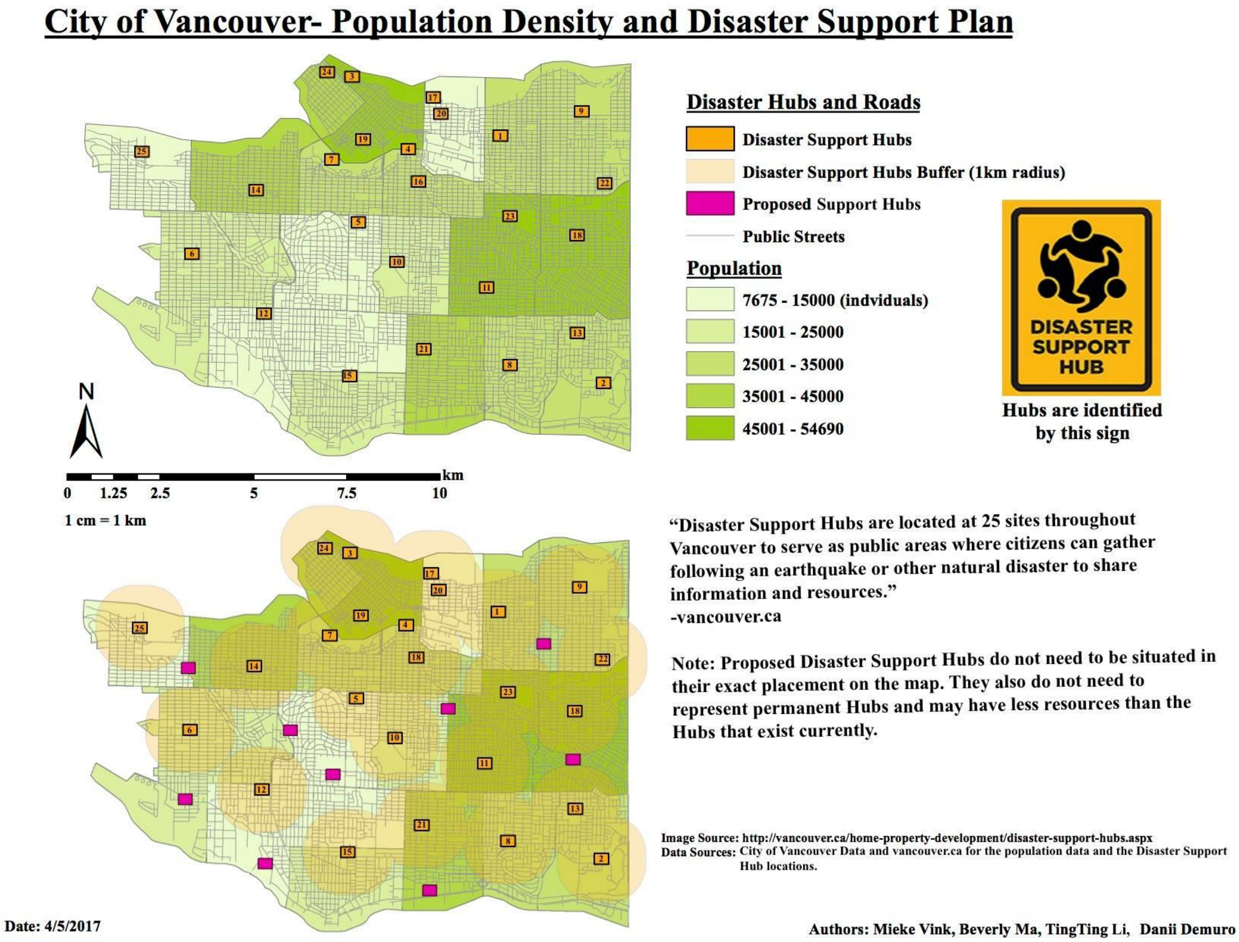
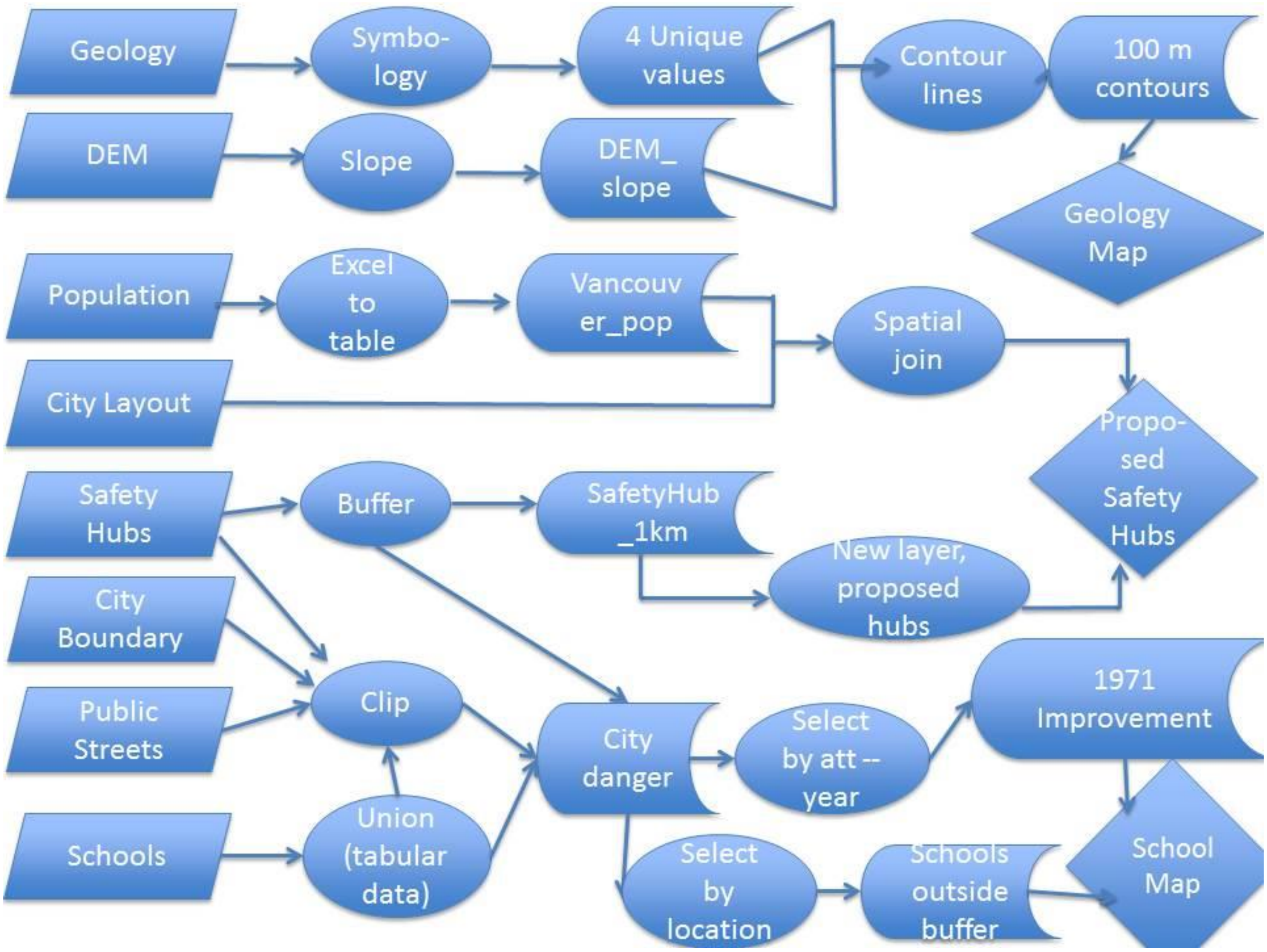
Map of Vancouver schools and their relative danger:



Map of Disaster Support Hubs and new proposed Hubs



Flow chart showing each layer/input in the process to create our 3 maps:



Sources:

Our data was collected and downloaded from a variety of databases and servers including:

- Geography Servers > Courses > FraserLowlands (lithology of Greater Vancouver)
- Open Data Catalogue Vancouver -> Streets, Local area boundary, Schools
- City of Vancouver -> Disaster Support Hubs, School building dates
- Statistics Canada -> Population tabular data

References

Mitchell D., Paultre P., Tinawi R., Saatcioglu M., Tremblay R., Elwood K., ... DeVall R. (2010). Evolution of seismic design provisions in the national building code of Canada. *Canadian Journal of Civil Engineering, 37(9,)* 1157-1170.

(2017). *Progress Report-Seismic Mitigation Program.* Retrieved from BC Government: http://www2.gov.bc.ca/assets/gov/education/administration/resource-management/capital-planning/seismic-mitigation/progress_report.pdf