CSCE Annual Conference
Growing with youth – Croître avec les jeunes

Laval (Greater Laval)
June 12 – 15, 2019

ER²- FLOOD: A WEB APPLICATION FOR RAPID FLOOD RISK ASSESSMENT

McGrath, H[1,*]., Gibb, N. [2], Smirnoff, A. [2], Proulx-Bourque, JS[1], Bourgon, JF[1], Abo El Ezz, A. [2], Nastev, M.[2]
[1] Natural Resources Canada, Canada Centre for Mapping and Earth Observation
[2] Natural Resources Canada, Geological Survey of Canada
[*] heather.mcgrath@canada.ca

Abstract: Many different models exist for natural hazard simulations, but due to their technical complexity and data requirements, their use is generally restricted to domain experts. As a result, there is often a lag in the communication of risk to the emergency management community. Rapid Risk Evaluator (ER^2) is a web-based application that removes this impediment, putting risk assessment tools directly into the hands of the end users. The ER^2-Flood prototype has been developed using open source software and Canada wide datasets, and it is envisioned it will be available for nationwide use. In this first iteration of ER^2-Flood, the Height Above Nearest Drainage (HAND) model was used along with user-specified location to simulate the spatial extent and depth of the flooding across the study area. The negative impacts considered include total count of buildings affected, economic losses, social impact (i.e. population displaced), and disruptions to the transportation network. The prototype is currently being tested for the Gatineau area, using the 2017 flood as a base-case for validation. Preliminary results are similar to those obtained by other risk assessment programs (e.g. Hazus-MH); however, ER^2-Flood has a considerably shorter runtime, requires no user-provided data, and is more automated and intuitive.

1 PROJECT OVERVIEW

ER^2-Flood is presented as a prototype web-based application for the evaluation of negative impacts to flooding. The application is designed for use by the emergency management community to simulate flood events and evaluate the impacts to the community, including economic losses, transportation disruption and population displaced. Many more sophisticated tools are available, however, the value in ER^2-Flood is that minimal user expertise is required to simulate flood events, no user data is necessary, and it provides rapid results from different flood scenarios.

2 CASE STUDY LOCATION

The city of Gatineau, Quebec was selected as a case study for the ER^2–Flood prototype. Gatineau is located along the northern bank of the Ottawa River, across from Ottawa. It is the fourth-largest city in Quebec with a population of 276,245, based on the 2016 Census (Statistics Canada, 2018). Since the 1970s, the Canadian Disaster Database has recorded five major flood events in the Gatineau region, with total recovery costs exceeding $61 million (Public Safety Canada, 2018). The 2017 Gatineau flood provided values and metrics to calibrate the ER^2–Flood model (i.e. the spatial extent of the flood, population evacuated, and damage estimates).

3 METHOD

Flood risk assessment relies on three primary inputs: (1) the flood event, (2) the population and building inventory data, and (3) the vulnerability parameters. For ER^2-Flood to run rapidly and with limited user input requirements, this information is pre-populated.

3.1 Flood Event

Modeling the extent of a flood is typically a time and data intensive process. However, simplified flood models relying solely on digital terrain models (DTM) have been shown to be substantially faster and capable of producing results that closely correspond to more sophisticated models (McGrath et al., 2018; Teng et al., 2017). It should be noted, however, that these simplified models do not consider flow velocity and thus are not suitable for modelling flash floods or tsunamis, and they perform best in areas with well defined flow channels and floodplains.

In ER^2-Flood, the height above nearest drainage (HAND) model was selected as the most suitable simplified flood model (McGrath et al., 2018). The HAND model pre-computes a GeoTIFF with height values normalized to the nearest drainage outlet (Nobre et al., 2011). The base elevation data used for computing the HAND model is elevation points from the High Resolution Digital Elevation Model (HRDEM)—CanElevation series, which is derived from LiDAR (Natural Resources Canada 2017a, b). The steps required to derive the HAND model include: sink filling, flow direction calculations, and computing the vertical distance to the nearest drainage point (Kastens, 2008; McGehee et al., 2016; McGrath et al. 2018; Zheng et al. 2018). The pre-processing steps take a significant amount of time, but the resultant HAND model can simulate flood extent and depth in a matter of seconds.

3.2 Inventory

The second major component of flood risk analysis is the local inventory data. ER^2-Flood draws upon provincial datasets from the Hazus Canada database. Specifically, the application uses population and dwelling data aggregated at the level of the dissemination block, which is an area equivalent to a city block bounded by intersecting streets (Statistics Canada, 2018). Population data includes age, ethnicity, and income. Dwelling data includes building counts, building age and building value for several building occupancy types, including residential (e.g. single detached, semi-detached, movable dwelling, apartment), industrial, and commercial (Hastings et al., 2017).

3.3 Vulnerability

In order to evaluate the negative impacts of the flood on a community, a relationship between the flood hazard and the inventory data is necessary. Depth–damage curves are the internationally accepted method of estimating the economic losses associated with flood damage and are used in ER^2. The depth–damage curves were extracted from Hazus Canada. These curves represent the average damage (losses) as a function of water depth for a given building occupancy class. In addition to economic damage, population displacement was also calculated by multiplying the area population by the percent of the area inundated.

3.4 ER^2-Flood Web Implementation

The software and tools used in ER^2-Flood are entirely open source and non-proprietary. The underlying HAND model is saved as a GeoTIFF. Flask (a micro web framework) handles the client requests and initiates the computations. The damage calculations are conducted through a Python script that relies upon several libraries (e.g. pandas and numpy), as well as the inventory and vulnerability data (stored in a relational database). The results of the computations are dynamically displayed to the user using GeoServer and OpenLayers, in accordance with Open Geospatial Consortium (OGC) standards.

There are only two inputs required from the user: (1) the location for the reference water level, which is set by a single click on the map (Figure 1a); and (2) the flood depth at that location, which is input in the dialog box (Figure 1b). As the user adjusts the water level, the map dynamically updates to show the flood extent. The flood extent is coloured blue on the map (Figure 1b); flooded road segments and buildings are coloured orange and red, respectively.

Once the user presses "Run", a request is sent to the server and processing begins. First, the affected blocks are determined. If the inputted water level exceeds the lowest HAND value in the block, the block will be at least partially affected. Second, the negative impacts are calculated. Currently, the script computes the number of flooded buildings, the economic losses, and the number of people affected and displaced by the flood (Figure 1c, d). Testing is in progress to compare ER^2-Flood results against Hazus Canada results.

With the current version of ER^2-Flood, loss estimates are rapidly computed and displayed to the user. The web application demands very little user interaction (three mouse clicks) to run a simulation and results are obtained within minutes. For the scenario given in Figure 1, the simulation was completed in 1 min 25 s. For a similar simulation using Hazus Canada, this process would demand much more user interaction, as well as the need to find and upload appropriate flood extent files. An experienced user might require 15 minutes or more for this process using Hazus.

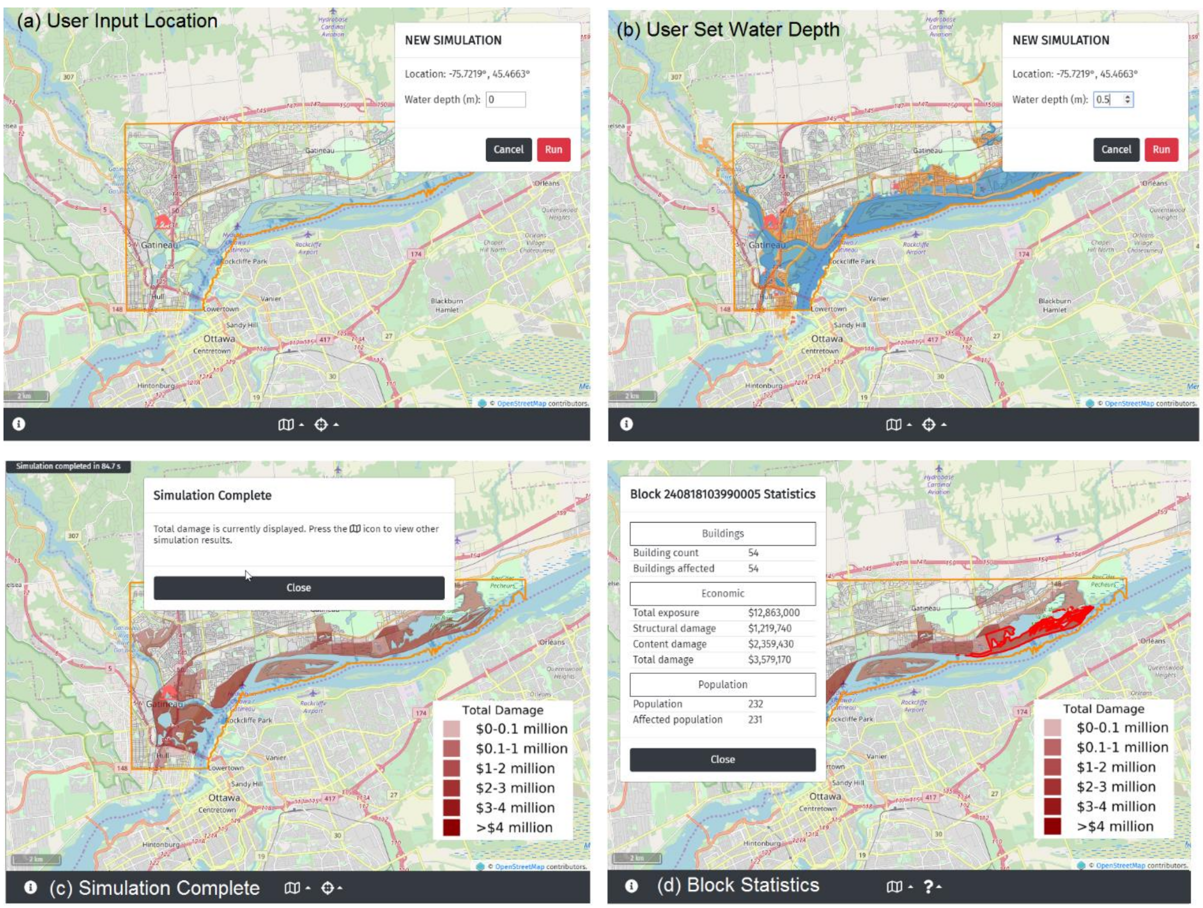

Figure 1 ER2–Flood web interface: (a) user input location; (b) user input flood level; (c) processing; and (d) results.

4 CONCLUSIONS

In this paper, a prototype web-based application for natural hazard risk assessment has been presented and the modules described. This application uses nationally available datasets and open source technology, in order to allow non-specialists to run risk assessment and visualize the negative impact associated with different flood scenarios. Testing is presently underway to determine the quality of the results when compared against existing more sophisticated risk analysis software. The initial prototype is very promising, particularly with regards to is speed and ease of use. The application provides a much-needed resource for emergency managers and the public safety community to build their understanding of their vulnerability to flood events.

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