PEDESTRIAN TRAVEL-TIME MAPS FOR PERRYVILLE, ALASKA: An anisotropic model to support tsunami evacuation planning

by

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ABSTRACT

Tsunami-induced pedestrian evacuation for the community of Perryville is evaluated using an anisotropic modeling approach developed by the U.S. Geological Survey. The method is based on path-distance algorithms and accounts for variations in land cover and directionality in the slope of terrain. We model evacuation of pedestrians to exit points located at the tsunami hazard zone boundary. Pedestrian travel-time maps are computed for two cases: i) travel to an existing evacuating shelter and ii) travel to either the evacuation or an alternative shelter. Results presented here are intended to provide guidance to local emergency management agencies for tsunami inundation assessment, evacuation planning, and public education to mitigate future tsunami hazards.

Photo by Dmitry Nicolsky

INTRODUCTION

Subduction of the Pacific plate under the North American plate has resulted in numerous great earthquakes and has the highest potential to generate tsunamis in Alaska (Dunbar and Weaver, 2015). The Alaska–Aleutian subduction zone (figure 1), the fault formed by the Pacific–North American plate interface, is the most seismically active tsunamigenic fault zone in the U.S. Refer to Suleimani and others (in press) for an overview of the tsunami hazard in the Perryville area.

The most recent earthquake that triggered a significant tsunami in Perryville occurred on March 27, 1964; for this event, tsunami waves were as high as 3.0 m (10 ft), respectively (Lander, 1996). An in-depth analysis of the tsunami hazard in Perryville and estimation of the tsunami hazard zone in the community is provided by Suleimani and others (in press). According to the tsunami modeling results, individuals in many residential buildings and around the airport may face a challenge when evacuating due to long walking distances to designated assembly areas.

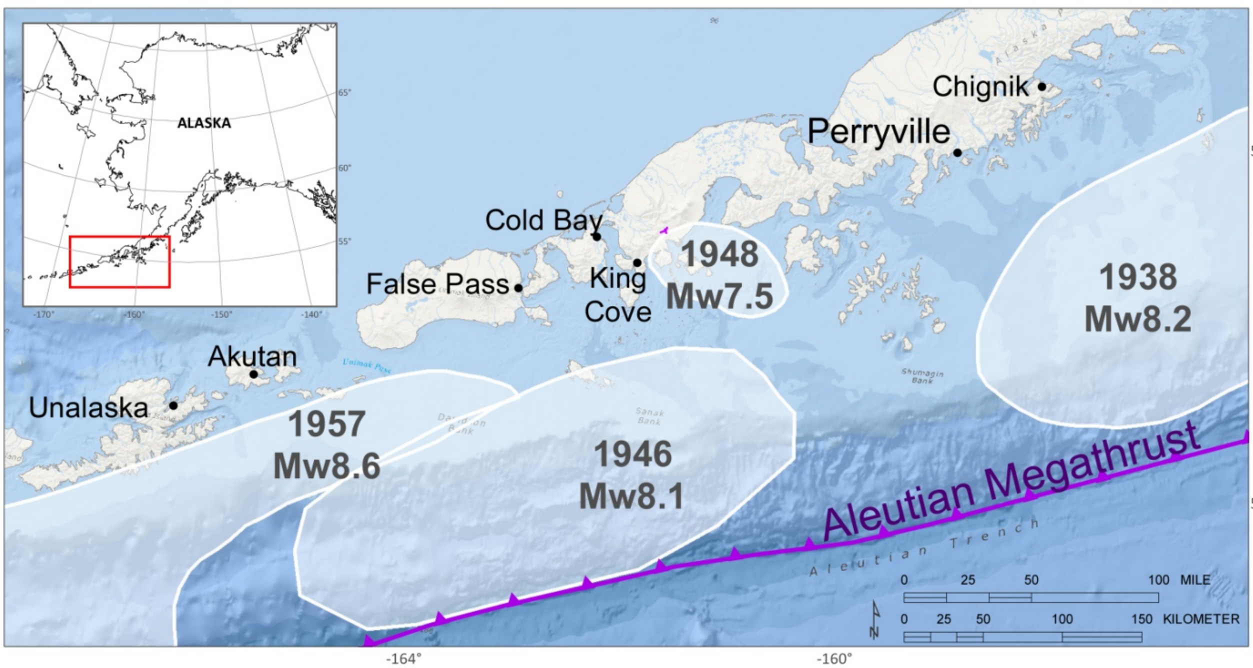

Figure 1: Map of the eastern Aleutian Islands and the southern tip of the Alaska Peninsula, identifying major active faults (dark purple lines) and the rupture zones of the 1938, 1946, 1948, and 1957 earthquakes (light shaded areas).

In this report, we employ the pedestrian evacuation modeling tools developed by the U.S. Geological Survey (USGS) (Wood and Schmidtlein, 2012, 2013; Jones and others, 2014) to provide guidance to emergency managers and community planners in assessing the amount of time required for people to evacuate out of the tsunami-hazard zone. An overview of the pedestrian evacuation modeling tools, required datasets, and the step-by-step procedure used is provided in Macpherson and others (2017, this series). The maps of pedestrian travel time can help identify areas in Perryville on which to focus evacuation training and tsunami education.

COMMUNITY PROFILE

The community of Perryville (55°54'49''N, 159°09'04''W), population 113, is on the south coast of the Alaska Peninsula (fig. 1). It is 805 km (500 mi) southwest of Anchorage, and 443 km (275 mi) southwest of Kodiak. Perryville is an Alutiiq community and a federally recognized tribe and maintains a subsistence lifestyle. Commercial fishing provides cash income. According to DCCED (2015), the community was founded in 1912 as a refuge for Alutiiq people driven away from their villages by the eruption of Mt. Katmai. Captain Perry of the ship "Manning" transported people from the Katmai area to Ivanof Bay and later to the new village site. The village was originally called "Perry", but the "ville" was added to conform to the name of the area's post office, established in 1930. Perryville is also accessible only by boat and aircraft. Scheduled and charter flights are available from King Salmon. As in many other coastal communities, much of the economic activity and infrastructure is on or near the coast—a potential tsunami inundation area. Refer to Community Development Plans (DCCED/DCRA) for a review of the history, economy, and infrastructure of Perryville.

TSUNAMI HAZARD

Tsunami hazard assessment for Perryville was performed by numerically modeling several hypothetical scenarios (Suleimani and others, in-press). The worst-case scenarios for the Perryville area are thought to be thrust earthquakes along the Alaska Peninsula with magnitudes ranging from M_w 9.0 to M_w 9.3. The maximum predicted wave in Perryville can reach 21 m (69 ft) and could cause widespread damage and flooding. The numerical simulations estimate that the first wave might arrive at the community within 45 to 60 minutes. Significant wave activity could continue for at least 12 hours after the earthquake.

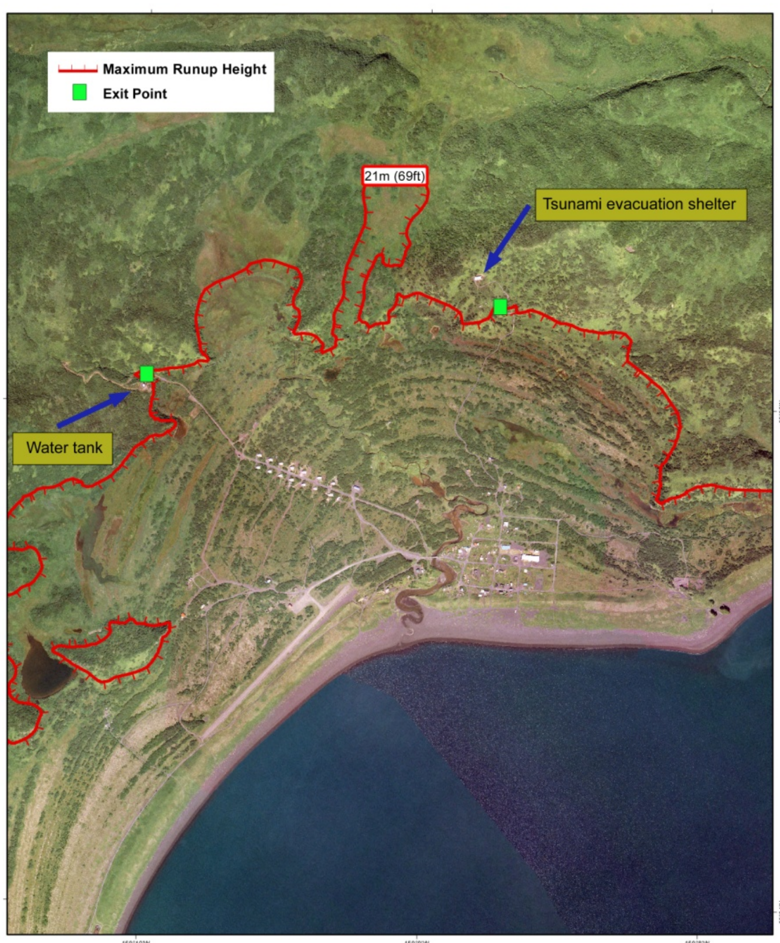

Figure 2: Map of Perryville depicting the tsunami hazard zone (red line with hatch marks toward the potential inundation zone).

The estimated extent of inundation in Perryville is shown by the hatched red line in figure 2. Much of the economic activity and infrastructure for the area including the airport, schools, City Hall and the Office of Public Safety are within the tsunami hazard zone.

The hydrodynamic model used to calculate propagation and runup of tsunami waves is a nonlinear, flux-formulated, shallow-water model (Nicolsky and others, 2011), that has passed the appropriate validation and verification tests (Synolakis and others, 2007; NTHMP, 2012). We emphasize that although the developed algorithm has met the benchmarking procedures, there is still uncertainty in locating an inundation line. Refer to Suleimani and others (in press) for an in-depth discussion of the uncertainty in the modeled tsunami hazard zone. For example, the accuracy is affected by many factors on which the model is based, including suitability of the earthquake source model, accuracy of the bathymetric and topographic data, and the adequacy of the numerical model in representing the generation, propagation, and runup of tsunamis.

PEDESTRIAN EVACUATION MODELING

Pedestrian evacuation modeling and prediction of population vulnerability to tsunami hazards were successfully applied to coastal communities in Alaska by Wood and Peters (2015). Also refer to Wood and Schmidtlein (2012, 2013) for an overview and limitations of the anisotropic, least-cost distance (LCD) approach to modeling pedestrian evacuation. We stress that the LCD focuses on the evacuation landscape, using characteristics such as elevation, slope, and land cover to calculate the most efficient path to safety. Therefore, computed travel times are based on optimal routes, and actual travel times may be greater depending on individual route choice and environmental conditions during an evacuation.

Recently, Jones and others (2014) developed the Pedestrian Evacuation Analyst Extension (PEAE) for ArcGIS, which facilitates development of pedestrian travel-time maps. A brief overview of the PEAE and a step-by-step procedure to compute the pedestrian travel-time maps for Alaska coastal communities are provided in Macpherson and others (2017, this series). Note that the data required for the PEAE include: the tsunami hazard zone, exit points or assembly areas, digital elevation model (DEM) of the community, and land-cover datasets. In the following subsections we describe the compilation of the datasets required to compute the travel-time maps, the scenarios we considered, and the modeling results for Perryville.

We visited Perryville in 2017 to gain knowledge of the physical setting and local specifics. We investigated several routes and recorded the time required to walk them.

DATA COMPILATION AND SOURCES

All original datasets were projected to NAD83 Alaska State Plane Zone 6 m to allow us to compute the final evacuation times in meters per second. Original data sources are summarized in Table 1.

- **Tsunami Hazard Zone:** A hazard-zone polygon for PEAE was created using the approximate tsunami hazard zones (Suleimani and others, in press) as a boundary.
- **Assembly areas:** An assembly area may be an important building, or a place that has been agreed upon by the community as a gathering place in times of emergency, or could be just flat land that is out of the hazard zone. We chose two assembly areas: the first area is the existing tsunami evacuation shelter—where people usually go in case of the imminent tsunami hazard; the second area is the water tank, northwest of town. All assembly areas are shown by blue arrows in figure 2, while the exit points are marked by green rectangles.
- **Exit points:** Locations at the tsunami hazard zone boundary on the roads leading toward the assembly areas.
- **Digital Elevation Model:** The DEM employed in this study is consistent with the tsunami DEM used by Suleimani and others (in press) to compute the tsunami inundation. The original source for topographic elevations is the National Geophysical Data Center (NOAA), with a spatial resolution of about 21 × 13 m (69 x 41 ft). Note that the tsunami DEM was re-sampled using the PEAE tool to set the analysis cell size at 1 m (3.3 ft) resolution to improve the accuracy of the travel-time maps.
- **Land Cover:** A land-cover layer was created using the high-resolution imagery from Digital Globe world imagery (ESRI) and verified by GINA BDL WMS (http://www.alaskamapped.org/bdl/) including building footprints and water features. Roads and trails were added using high-resolution imagery and verified by data extracted from the Open Street Map API (https://www.openstreetmap.org).

Table 1. Data sources of the input layers required for the Pedestrian Evacuation Analyst Extension.

Layer in PEAE	Data Sources
Tsunami Hazard Zone	Suleimani and others (in press)
Assembly areas	1. Existing tsunami evacuation shelter; 2. Water tank (northwest of town)
DEM	Carignan and others (2014)
Land Cover	Digitized from imagery
Buildings	Digitized from GINA BDL & Digital Globe imagery
Roads	Digitized from imagery and confirmed through Open Street Map
Water	Digitized from GINA BDL & Digital Globe imagery
Imagery	Digital Globe imagery

EVACUATION SCENARIOS

We model the pedestrian evacuation time for two scenarios. We emphasize that the assumed base speed of the evacuee is set according to the “slow walk” option (0.91 m/s, 3 ft/s, or 2 mph) in the PEAE settings. Note that this is a very conservative speed and many residents should be able to evacuate twice as fast (1.52m/s “fast walk”, if not 1.79m/s “slow run”) as the modeled rate. However, soil liquefaction, darkness, freezing rain, ice and snow on the road can also significantly impact the walking pace. Additionally, in the case of severe weather conditions or a thick snow cover, the evacuation might be confined to well-traveled roads and paths. We therefore assume that pedestrians will travel to the closest road and then stay on roads to leave the hazard zone.

Scenario 1. **Evacuation to the existing evacuation shelter by roads only**

Pedestrian evacuation from roads and paths in the tsunami hazard zone **along the roads and paths** to the outer boundary of the hazard zone.

In addition to examining pedestrian evacuation to the existing tsunami shelter located on the eastern side of the creek, we consider an evacuation scenario where the additional assembly point is setup near the water tank, on the western side of the creek. We assume that individuals travel to the nearest assembly point located on the either bank. The exit points (figure 2) are chosen on (or immediately outside of) the boundary of the tsunami hazard zone on a likely evacuation route.

Scenario 2. **Evacuation to the nearest assembly area by roads only**

Pedestrian evacuation from the tsunami hazard zone **using the roads and paths** to the nearest assembly area. We assume two assembly areas (the existing tsunami shelter and near the water tank) around the boundary of the tsunami hazard zone.

MODELING RESULTS

We apply the methodology outlined in Macpherson and others (2017, this series) to compute the travel times produced by the four scenarios. The pedestrian travel-time maps are shown on Sheets 1–2 corresponding to Scenarios 1–2.

Scenario 1 predicts that evacuation to the exit point located on the road leading to the evacuation shelter could be achieved in about 30 minutes from the school and City Hall. Walking times from the western side of the creek are higher; the evacuation from the airport area can take as much as 45 minutes. The first wave can start to arrive in 30 minutes and hence some evacuees located on the western side of the creek might not evacuate in time. Especially if the bridge connecting the two sides of the community collapses due to the ground failures of fine-grained material on both sides of the creek.

The community water tank located on the western side of the creek can also function as an assembly point for the community. The computations for Scenario 2 reveal that walking times to the exit point are significantly decreased for the western part of the community. In particular, pedestrian travel time from the airport decreases from 45 to 28 minutes. Although, the water tank could be used as a potential assembly area, the road leading to it needs to be maintained and clear of snow, ice and debris.

SOURCES OF ERRORS AND UNCERTAINTIES

The modeling approach described in this report will not exactly represent an actual evacuation; like all evacuation models, the LCD approach cannot fully capture all aspects of individual behavior and mobility (Wood and Schmidtlein, 2012). The weather conditions, severe shaking, soil liquefaction, infrastructure collapse, downed electrical wires, and the interaction of individuals during the evacuation will all influence evacuee movement. Refer to Wood and Schmidtlein (2012, 2013), Jones and others (2014), and Macpherson and others (2017, this series) for an in-depth discussion of the limitations of the LCD approach in estimating the travel times to safety.

SUMMARY

Perryville poses a unique situation, as it is a small community separated in the middle by the creek. The main finding from the scenario time maps is that, because of the layout of the community, those on the western side of community would face very long walking travel times to reach the designated evacuation gathering point at the existing tsunami evacuation shelter. Adding a second evacuation assembly area at the western side of the community shortens those modeled walking times considerably.

Maps accompanying this report have been completed using the best information available and are believed to be accurate; however, the report's preparation required many assumptions. In most cases the actual walking speeds proved faster than those modeled. The information presented on these maps is intended to assist state and local agencies in planning emergency evacuation and tsunami response actions. These results are not intended for land-use regulation or building-code development.

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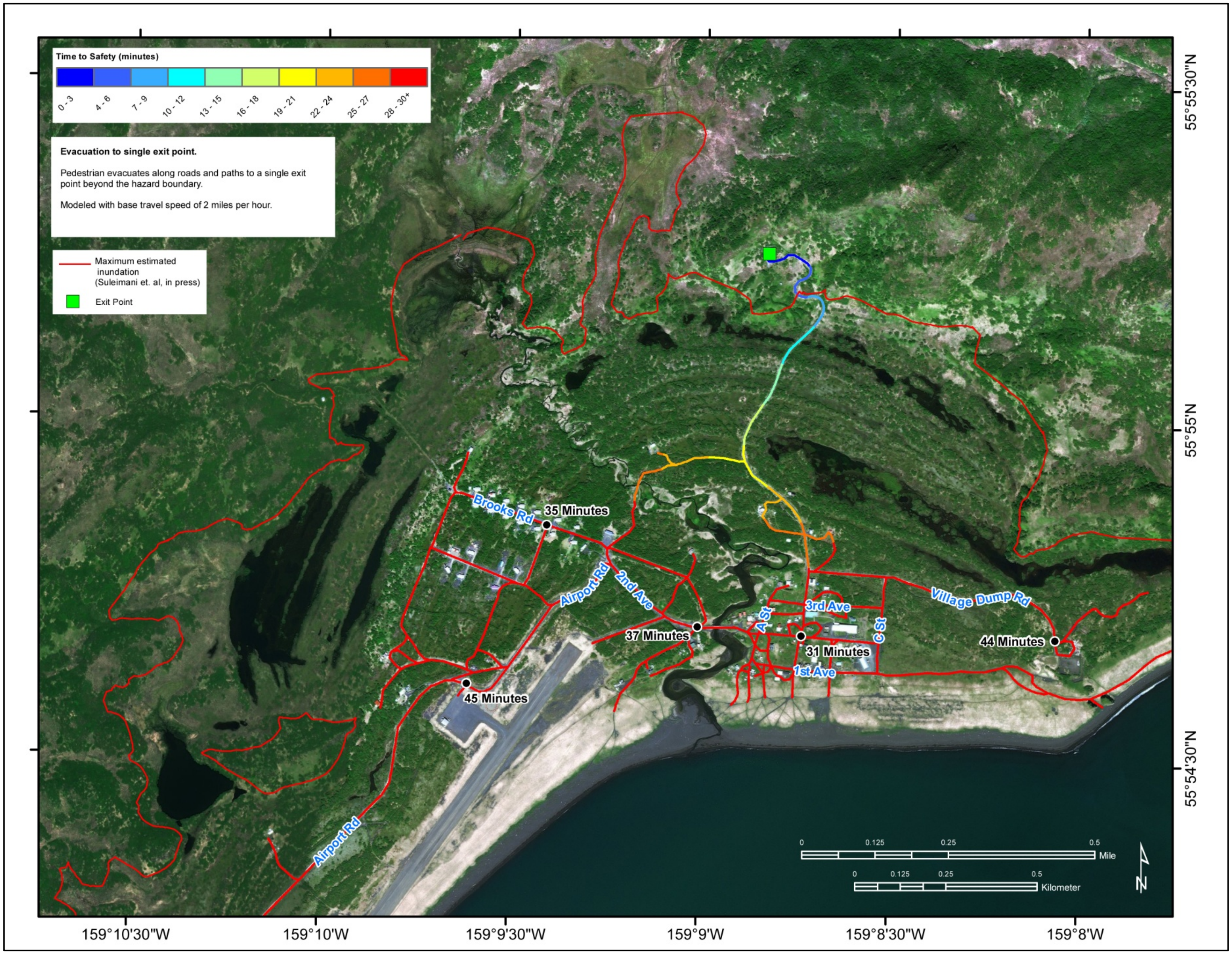
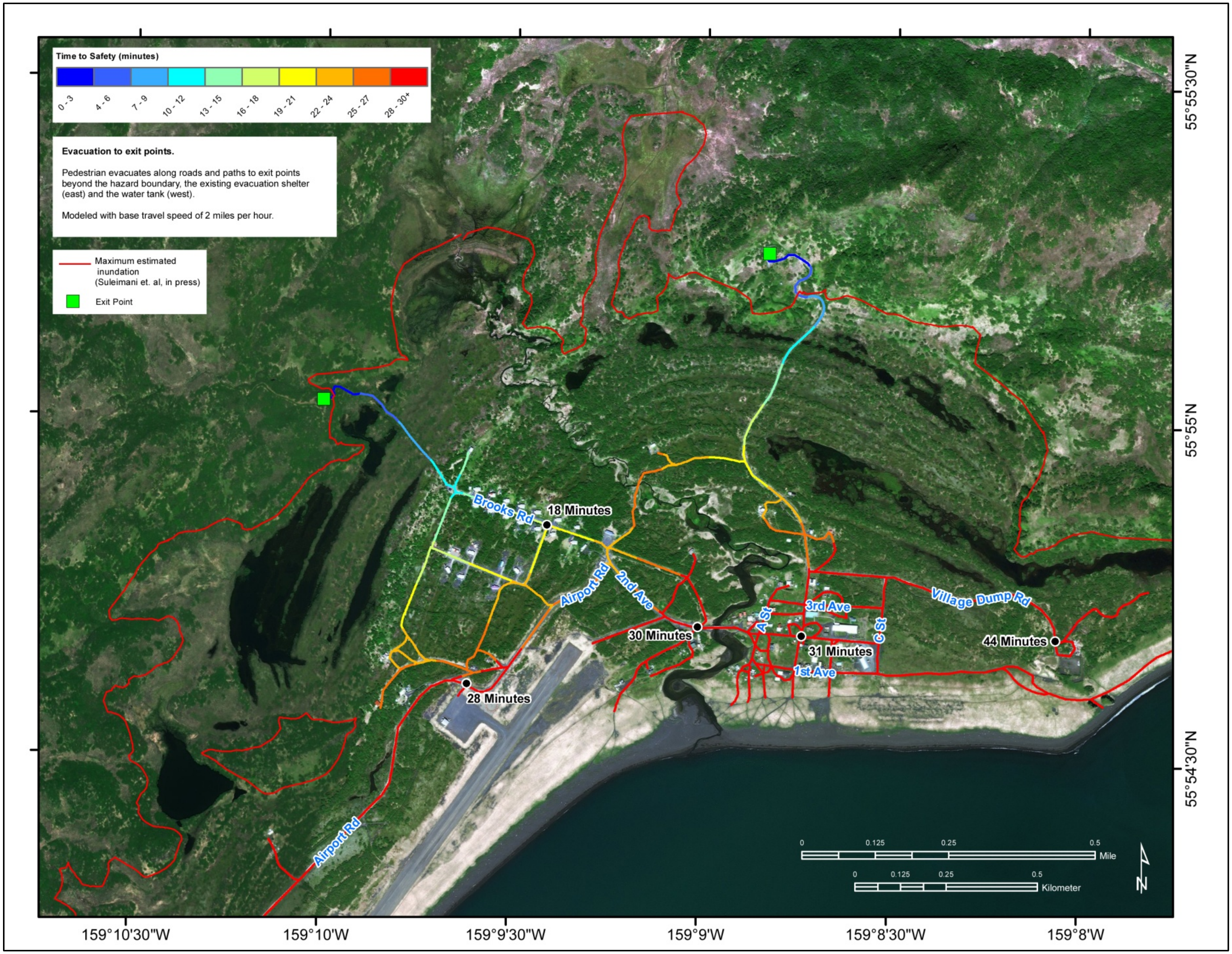


MAP SHEET 1: Travel-time map of pedestrian evacuation to the existing tsunami evacuation shelter



MAP SHEET 2: Travel-time map of pedestrian evacuation to either the existing tsunami evacuation shelter or water tank.

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