NATURAL RESOURCES

LOSS ESTIMATION PILOT PROJECT FOR LAHAR HAZARDS FROM MOUNT RAINIER, WASHINGTON

by Recep Cakir and Timothy J. Walsh

WASHINGTON
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AND EARTH RESOURCES

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Loss Estimation Pilot Project for Lahar Hazards from Mount Rainier, Washington

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EXECUTIVE SUMMARY

This project was undertaken by the Washington State Department of Natural Resources, Division of Geology and Earth Resources (WADNR–DGER), in response to a Request for Proposals from the U.S. Geological Survey Volcano Hazard Program – American Recovery and Reinvestment Act (ARRA) (Award Number G10AC00057) to estimate the potential economic losses from future eruptions of Mount Rainier. Eleven major rivers drain Mount Rainier and lead to six lowland valleys with a combined population of more than 2.5 million and total assets of about $40 billion at risk from lahars. We have adapted lahar hazard zones developed by Hoblitt and others (1998) and converted to digital data by Schilling and others (2008) to the appropriate format for Hazus-MH (Hazard US – Multi Hazard), the Federal Emergency Management Agency's (FEMA) loss estimation model (FEMA, 2009b). We have assumed that structures engulfed by cohesive lahars will suffer complete loss and that structures affected by noncohesive post-lahar flooding will be appropriately presented or modeled in the Hazus-MH flood model.

The Puyallup Valley was chosen as the focus for this pilot project because it is the valley most susceptible to lahars caused by flank collapse and has the most population and property at risk. Our initial model used the Hazus default inventory, which includes generalized building types and values from census data. This model gave an estimated loss of about $12 billion for a noncohesive lahar down the Puyallup River, similar to the Electron Mudflow (Crandell, 1971). Because the Hazus-MH inventory is based on census tracts, this damage estimate includes everything in the tracts that is at least partly within the lahar hazard zone, even buildings outside the lahar hazard zone. To enhance this inventory, we acquired assessor's data from all of the affected counties and converted them into the Hazus-MH format. We then selected the data we were interested in out of the larger data set for the boundaries of the lahar hazard zones to more precisely delineate those properties actually at risk in each scenario. This refined our initial loss estimate for the Puyallup Valley to about $6 billion, with exclusion of building content values.

The results of these revised Hazus-MH models for the six lowland valleys at risk for lahars from Mount Rainier are posted on the Washington State Geologic Information Portal (http://www.dnr.wa.gov/ResearchScience/Topics/Geosciences Data/Pages/ geology_ portal.aspx).

INTRODUCTION

Mount Rainier is a potentially and recently active volcano about 20 miles southeast of the Seattle-Tacoma metropolitan area. A geologic map of Mount Rainier (Fiske and others, 1963) shows that most of the volcanic cone was constructed by multiple lava flows and breccias and a few ash deposits. In the last 10,000 years, more than 60 lahars or debris flows have traveled at least as far as 70 miles downstream (Hoblitt and others, 1998). Mount Rainier is drained by eleven rivers (Fig. 1) leading to six lowland valleys containing two major shipping ports and a substantial portion of Washington's technological and industrial infrastructure (U.S. Geodynamics Committee, 1994), placing a combined population of more than 2.5 million and total assets of about $40 billion at risk from lahars.

In part as a consequence of the vulnerability of nearby populations and infrastructure, Mount Rainier was designated as one of only two Decade Volcanoes in the U.S. by the International Association of Volcanology and Chemistry of the Earth's Interior (http://www.iavcei.org/) in 1992 as part of the International Decade of Natural Disaster Reduction. Due to the large and increasing population living and working along its lowland drainages (Fig. 2) and its multiple eruptions in recent geologic history, many geologists agree that Mount Rainier is the most dangerous volcano in the Cascade Range (Crandell, 1971; Mullineaux, 1974; Scott and others, 1995, 1998; Pringle, 2008; Sisson and Vallance, 2008).

Figure 1. Hazard zones for lahars, lava flows, and pyroclastic flows from Mount Rainier (Hoblitt and others, 1998) in the eleven river valleys draining Mount Rainier (*labeled in black*). The colored areas could be inundated if events similar in size to those of the past occurred today. Major lahars have occurred every 500 to 1,000 years and smaller flows more frequently. The hazard from lahars is not equal in all valleys. The Puyallup Valley is the valley most susceptible to lahars caused by flank collapse, owing to the weak rocks composing the upper west flank of the volcano. The zone of lahar-related flooding extends as far as Commencement Bay and the Port of Tacoma and Elliott Bay and the Port of Seattle.

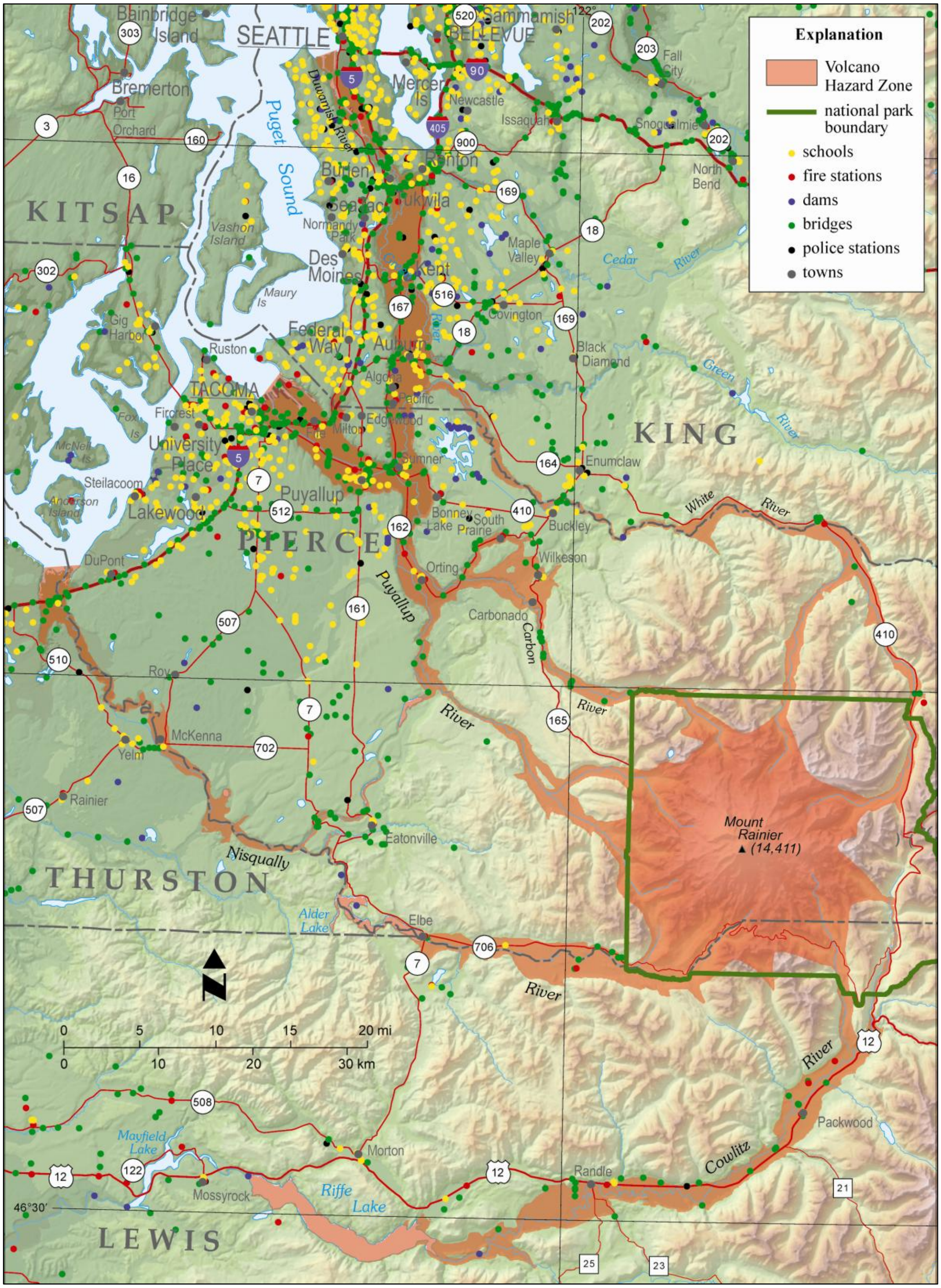

Figure 2. Lifelines and services in and near the volcano hazard zone. These clustered essential facilities are indicators of heavily populated areas in the lahar hazard zones (Hoblitt and others, 1998). Note that the major north–south transportation corridor (Interstate-5) goes through several lahar zones.

The most likely hazards at Mount Rainier are debris avalanches, lahars, and floods (Crandell and Mullineaux, 1967; Crandell, 1973; Scott and others, 1992; U.S. Geodynamics Committee, 1994), as well as hazards that occur during eruptions, such as tephra, ballistic projectiles, pyroclastic flows and surges, lava flows, volcanic gases, lateral blasts, and glacial outburst floods (Hoblitt and others, 1998). Debris avalanches, lahars, and floods can also occur during dormant periods (Hoblitt and others, 1998). Iverson and others (1998) noted that lahars are likely to pose the greatest hazard at the mountain. Hoblitt and others (1998) characterized lahars from Mount Rainier as cohesive and noncohesive. Cohesive lahars form when debris avalanches originate from water-rich, hydrothermally altered parts of the volcano. They are cohesive because they contain relatively large amounts of clay derived from chemically altered rocks. Noncohesive lahars, in contrast, contain relatively little clay. Mount Rainier's noncohesive lahars are triggered whenever water mixes with loose rock debris, such as the mixing of pyroclastic flows or pyroclastic surges with snow or ice. Relatively small debris avalanches, unusually heavy rain, or abrupt release of water stored within glaciers can also initiate lahars.

The Osceola Mudflow (a cohesive lahar) occurred about 5,600 years ago and is the largest lahar to have originated at Mount Rainier in the last 10,000 years (Crandell, 1971; Dragovich and others, 1994; Hoblitt and others, 1998). The Osceola Mudflow was at least ten times larger than any other known lahar from Mount Rainier, and its deposits cover an area of about 212 square miles in the Puget Lowland, extending at least as far as the Seattle suburb of Kent and the Port of Tacoma. Orting, Buckley, Sumner, Puyallup, Enumclaw, and Auburn are partly or completely situated on its deposits, as well as on more recent debris flows.

The Electron Mudflow is another fairly large lahar that occurred in about A.D. 1502 or 1503 (Pringle, 2008). According to Hoblitt and others (1998) and Sisson and Vallance (2008), the Electron Mudflow was derived from a slope failure on the west flank of Mount Rainier and has not been correlated with an eruption. It was more than 100 feet thick at the community of Electron and as much as 20 feet thick at Orting.

About 1,200 years ago, a large noncohesive lahar associated with volcanism at Mount Rainier filled the valleys of both forks of the White River to depths of 65 to 100 feet and flowed more than 60 miles to Auburn (Hoblitt and others, 1998). This noncohesive lahar was generated by huge quantities of meltwater that mixed with rock debris.

Another lahar of similar origin, named the National Lahar, occurred less than 2,200 years ago. It inundated the Nisqually River valley to depths of 30 to 130 feet and flowed all the way to Puget Sound. More than a dozen lahars of this type have occurred at Mount Rainier in the past 6,000 years (Hoblitt and others, 1998). Hoblitt and his co-authors noted that "circumstances conducive to future debris avalanches and lahars—substantial volumes of hydrothermally altered rock, substantial topographic relief, great volumes of ice, and the potential for renewed volcanism—are all present at Mount Rainier; thus, lahars are a greater threat to communities downvalley from Mount Rainier than any other volcanic phenomenon."

In their recent vulnerability studies, Wood and Soulard (2009) developed a composite lahar-exposure index to help emergency managers understand spatial variations in community exposure to lahars, and results suggested that Puyallup has the highest combination of high numbers and percentages of people and assets in lahar-prone areas. Risk education and preparedness needs will vary based on who is threatened by future lahars, such as residents, employees, tourists at a public venue, or special-needs populations at a dependent-care facility. Emergency managers must first understand the people they are trying to prepare before they can expect these people to take protective measures after receiving an official lahar warning or recognizing natural cues.

Emergency response and mitigation planning practices relating to a large lahar flow from Mount Rainier are the key activities that significantly reduce the high losses of economies and lives in communities around the volcano. Digital information from the most up-to-date database should be provided to facilitate the most reliable loss estimations. A database such as that generated in this study and published through the Washington State Geologic Information Portal (Appendix) will be an effective tool for emergency response and mitigation practices. This information can be easily accessed and used by county emergency management offices and nonprofit organizations within the lahar-prone counties.

Our pilot project investigated whether a multi-hazard loss estimation environment such as Hazus-MH can be used to efficiently generate reasonable and reliable estimates. We used the lahar hazard estimation tool LAHARZ (Schilling, 1998; Iverson and others, 1998; Schilling and others, 2008), a semi-statistical program for ArcInfo that can easily be adopted in Hazus-MH (with the caution that generating lahar-zone polygons may require geologic information and generalization of the polygons). The lahar zones defined by the USGS and other researchers can also be transferred into Hazus-MH, although they are combined into an overall hazard map for each lahar case. We ran LAHARZ on individual lahar scenarios in order to separate them in our loss estimate. The transferred hazard zones must be further investigated for possible behaviors of the lahar flows, depending on river geometry and geomorphological and hydrological properties, so that fragility curves/damage functions can be accurately prepared. Although we mention a few examples of development of these functions in the Lahar Flow Assumptions section, further structural engineering, fluid flow, hydrologic, and geomorphic studies are required for better describing lahar flow behaviors and their effects on the various structures (residential, commercial, roads, bridges, etc.).

LAHAR HAZARD ASSESSMENT AND VERIFICATION OF HAZARD ZONES FOR MAJOR DRAINAGES

Mount Rainier, a dormant volcano, is the highest peak in the Cascade Range and carries a larger load of glacier ice than any other mountain in the contiguous U.S. The mountain's large ice mass and great topographic relief pose geologic hazards during both future eruptions and time periods without eruptive activity. The lahar hazard was defined by field investigations and construction of cross sections (Scott and Vallance, 1995; Scott and others, 1995). Four cases of lahars, with generally different modes of origin, were identified for Mount Rainier (Hoblitt and others, 1998):

- **Case M:** a low-probability and high-consequence lahar. The Osceola Mudflow is an example in this category.
- **Case I:** flows that have occurred once every 500 to 1,000 years during the last 5,600 years. The annual probability of such a flow originating somewhere on Mount Rainier is thus about 0.1 to 0.2 percent. Most Case I flows have reached some part of the Puget Lowland. The Electron Mudflow, which reached the Puget Lowland about 600 years ago via the Puyallup River, is the most recent example.
- **Case II:** flows that have a typical recurrence interval near the lower end of the 100- to 500-year range. The annual probability of such a flow is therefore close to 1 percent for the volcano as a whole. For planning purposes, Case II flows are analogous to the 100-year flood commonly considered in engineering practice. Some Case II flows have inundated flood plains well beyond the volcano, and a few have reached the Puget Lowland. Case II flows have a fairly low clay content. The most common origin for this class of flows is melting of snow and glacier ice by hot rock fragments during a volcanic eruption. An example is the National Lahar, which occurred about 2,000 years ago in the Nisqually River valley.
- **Case III:** flows that are fairly small but have recurrence intervals of 1 to 100 years for the volcano as a whole. This class of flow includes small debris avalanches as well as lahars. Case III flows are not eruptively triggered. They are largely restricted to the slopes of the volcano and rarely move beyond the National Park boundary.

Vallance and others (2003) subsequently used LAHARZ to model debris flows from Mount Rainier caused by hydrologic events, which include Case III events and some Case II events. The largest events in their models extended about 15 miles outside the national park boundaries in places, but not as far as any large communities.

We converted the lahar zones for each case (Hoblitt and others, 1998; Schilling and others, 2008) to polygon forms in ArcGIS and prepared their metadata for our interactive mapping site, the Washington State Geologic Information Portal. (See later sections and Appendix for explanation of the interactive map.)

We then ran LAHARZ to verify lahar hazard zones for individual drainages and to correct artifacts in the digital elevation model (DEM). Figures 3, 4, and 5 show our LAHARZ results for the Puyallup, Puyallup-Carbon, and Puyallup-Carbon-White Rivers, respectively. We later added post-lahar sedimentation (Hoblitt and others, 1998) into Hazus-MH format to finalize the description of the zones.

Using Hazus-Multi Hazard (MH)

Hazus assesses losses by applying a hazard to an inventory of the built environment. The default inventory associated with Hazus is based on the census. Individual residential and commercial buildings are assumed to be uniformly located within census tracts and to have standard configurations. Loss estimation can be made more realistic by incorporating building data collected at the local (user-defined), county, and state levels that are more accurately located and described. The inventory data were prepared using the parcel data gathered from various county assessor offices (Appendix). We prepared this dataset in a format that can be read in the Comprehensive Data Management System (CDMS) (FEMA, 2009a), a tool developed for Hazus-MH that can be used for updating inventory data for areas within Mount Rainier's lahar inundation zones. The CDMS enables users to update and manage state- and county-wide Hazus datasets, which are used to support hazard and risk analyses in Hazus-MH.

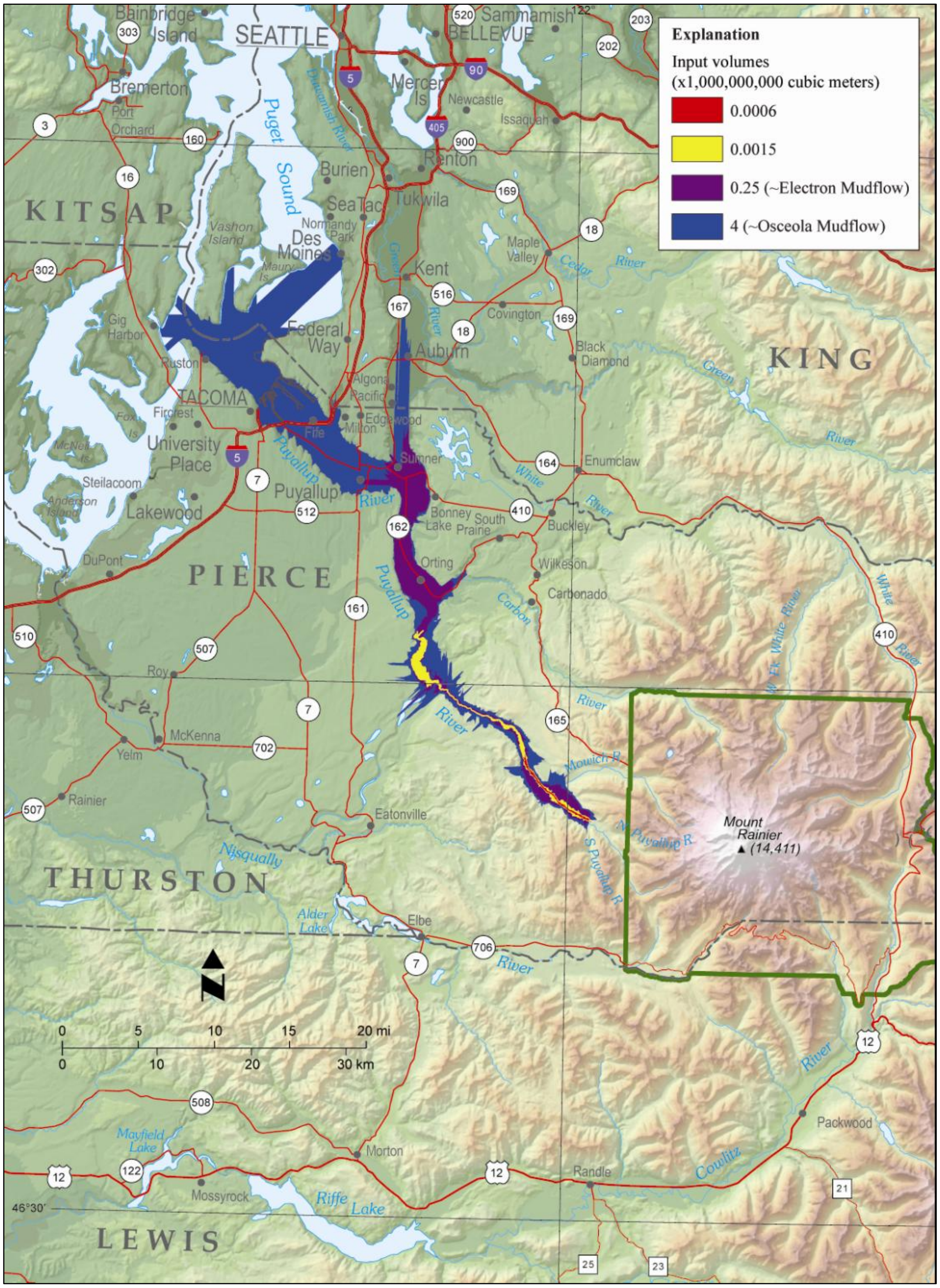

Figure 3. Results of our LAHARZ runs for the Puyallup River. For each user-specified lahar input volume, LAHARZ calculates a cross-sectional area and a planimetric area (shown here) (Iverson and others, 1998; Schilling and others, 2008). The input volumes reported in Iverson (1998) are representative of the various lahar types (Osceola, Electron, and National Mudflows, Case M, Case I, and Case II, respectively).

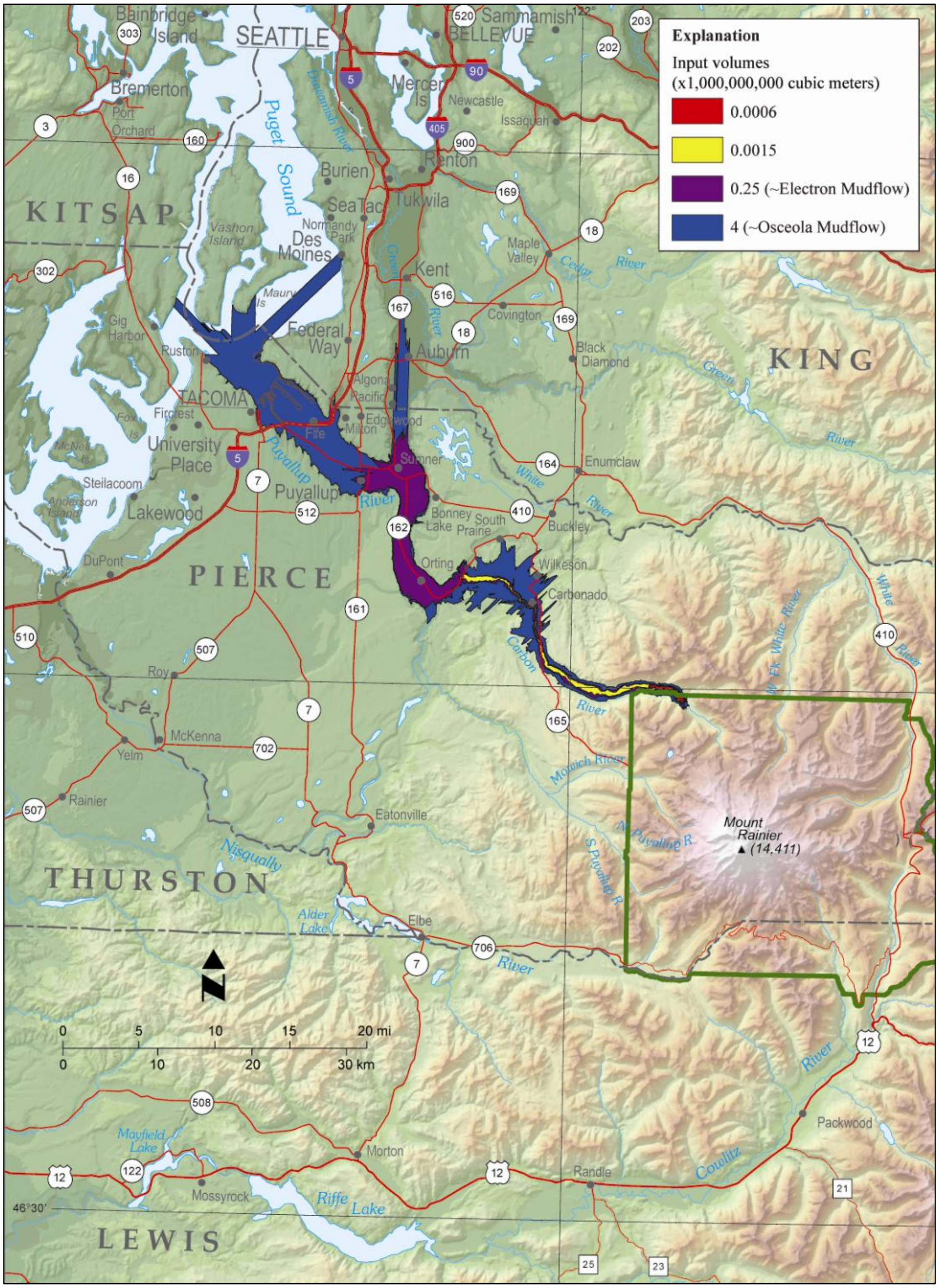

Figure 4. LAHARZ results for the lower Puyallup and Carbon Rivers. The input volumes are the same as in Figure 3.

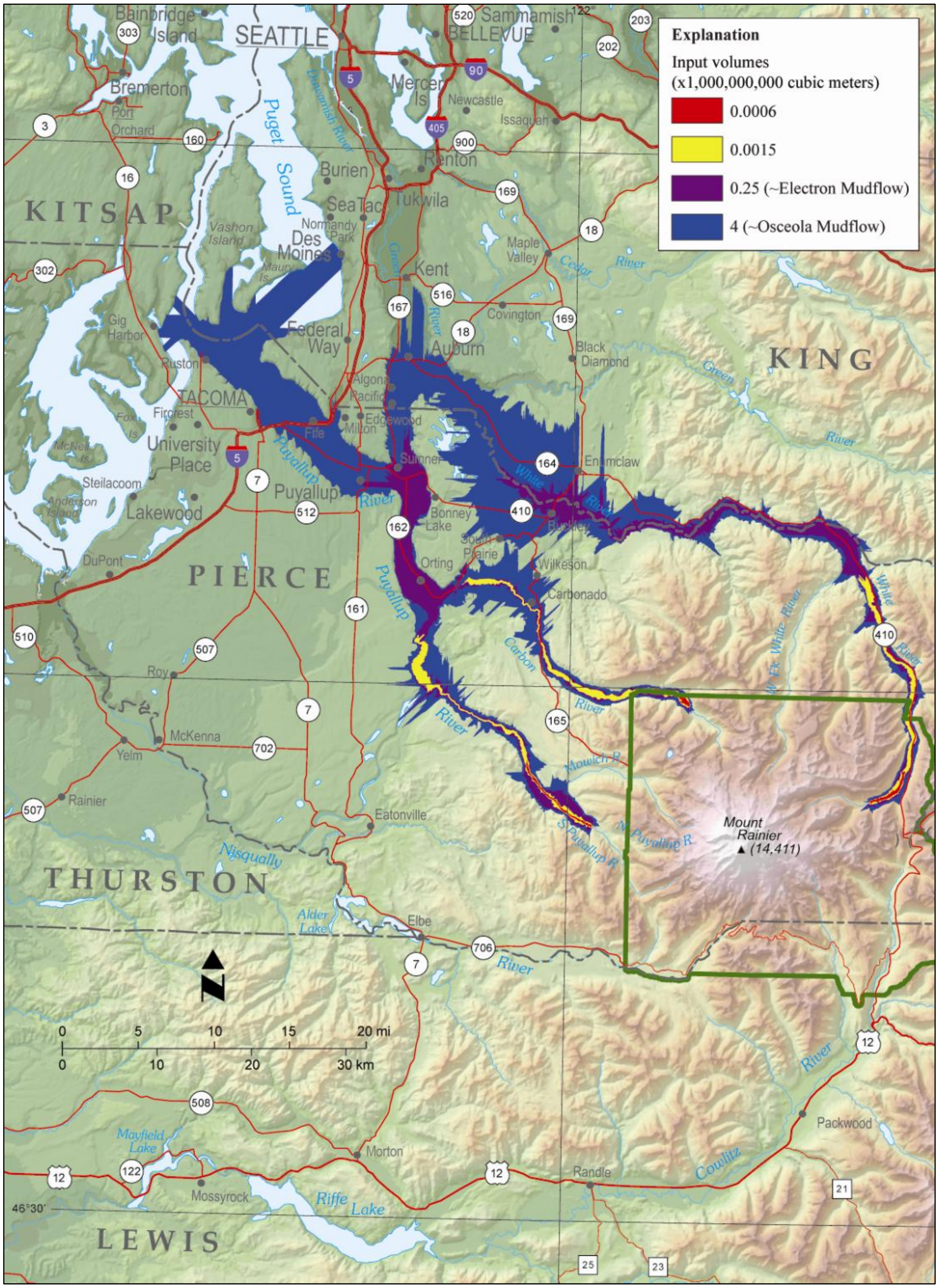

Figure 5. LAHARZ results for the Puyallup, Carbon, and White Rivers. The input volumes are the same as in Figure 3.

Once data are imported into the statewide datasets, the CDMS allows Hazus-MH users to query, sort, export, and print information. Hazus-MH can then be re-run, with specified parameters, for flood and earthquake models to arrive at direct and indirect loss estimations.

Since most of the lahar zones are expected to have 100 percent damage to properties in the path of a cohesive lahar, we chose to use parcel data directly for evaluation of the properties at risk. (See Fig. 7 for results from each drainage.) However, the flow of noncohesive lahars and post-lahar events may be described as flood-like flow, thus running the Hazus-MH flood model will more appropriately analyze the condition.

Specific scenarios based on different volumes of lahars were developed using the LAHARZ tool (Schilling, 1998; Iverson and others, 1998). This type of specific scenario generation is needed to assess in more detail the different sections of the Carbon and Puyallup Rivers, the only two undammed drainages of the eleven main drainages of Mount Rainier that reach the lowlands. This assessment should also be coordinated with county emergency management officials to better understand their needs and help them prepare for a volcano hazard event.

We arranged a series of meetings and workshops with potentially affected jurisdictions to define and model expected lahar events. Additional meetings will be held to introduce the new Mount Rainier Lahar Hazards interactive mapping site on the Washington State Geologic Information Portal (http://www.dnr.wa.gov/Research Science/Topics/GeosciencesData/Pages/geology_portal.aspx) (see Appendix). We have given a preliminary demonstration to the Mount Rainier Working Group (MRWG), who suggested that this tool be used at their next workshop for concerned communities (government, business, education, residential, etc.) in and around the lahar zones. They recognized that this interactive mapping site will provide a base for further information needed for lahar hazard emergency response and mitigation plans. For example, lahar evacuation maps can be posted on this interactive mapping site for better emergency evacuation education and outreach.

We transferred our collected inventory data into Hazus-MH, including lahar hazard zones and essential facilities (ES), general building stocks (GBS), utilities (Util), transportation (TP), and high potential loss facilities (HPLF). Inventory data that come with Hazus-MH software are called a Level 1 database. We updated this database with more accurately characterized and located data. The result was a Level 2 database.

Figure 6 shows the Puyallup River lahar hazard zone that was transferred into Hazus-MH as a study region. This permitted a calculation of direct losses (in dollars) using the Hazus-MH default inventory data. The resulting estimate for assumed total damage to buildings inside the zone was approximately $12.6 billion, and the parcel land value was $6.4 billion. We later modified the boundaries of the zones based on USGS hazard estimations, then recalculated the likely damages in dollars for each zone. Results are shown in Figure 7.

Lahar Flow Assumptions

In this loss estimation assessment, we assumed that structures engulfed by cohesive lahars will suffer complete loss. We recommend running a Hazus-MH flood model for structures affected by post-lahar flooding, although in this scenario flooding can occur multiple times, each one modifying both the topography of the basin and the contents of the lahar inundation zone. Other studies using different assumptions may be important for development of lahar damage functions (for types of lahars such as debris, concentrated/hyper-concentrated, and flood-like flows).

An important approach that may be the most relevant to our study is an investigation by Haugen and Kaynia (2008), who estimated the momentum of lahars, calculated a lateral force, and applied the Hazus earthquake model, substituting the lahar lateral force for earthquake peak ground acceleration. However, this was not validated for a range of structures, and it is not known how different types of structures would be damaged by a lahar flow.

Accurately characterizing phases of lahar flows will be the other key element of damage functions that estimate the level of damage. We think that, if it is possible, modifying and using current damage functions in Hazus-MH flood and earthquake models will be a better way to roughly construct damage functions for a future Hazus-MH lahar flow model. Determining phases of lahar flows is currently an active research topic and requires extensive study of fluid dynamics, hydrology, and geomorphology in vulnerable drainage areas. Tom Pierson, Richard Iverson, and others of the USGS Cascades Volcano Observatory (CVO, oral commun., 2011) advised us to use a conservative approach, that is, total building damage inside the lahar hazard zones.

RESULTS

Our preliminary results showed that Level 1 Hazus-MH, which uses only the default inventory data, provides an approximate and overly conservative loss estimate for a large lahar in the Puyallup River lahar zone. Because the Hazus-MH data are based on census tracts and blocks, this estimated damage includes everything in the census tracts or blocks, even buildings outside the lahar hazard zone. To correct this, we acquired assessor's data from all of

Table 1. Values of properties at risk (2011 parcel-based) in the Puyallup River lahar zone. Figure 7 shows the total value of the types of properties listed in Table 1 within major drainages of Mount Rainier.

Puyallup River	**Values**
Agricultural	$150,884,650
Commercial	$2,891,489,050
Educational	$429,095,650
Forest timber land	$78,892,800
Government	$230,764,500
Industrial (heavy + light)	$3,657,854,650
Native American land	$87,427,550
Church + nonprofit organization	$130,797,250
RES1 (single-family dwelling)	$3,548,966,565
RES2 (mobile home)	$163,633,300
RES3 (multi-family dwelling)	$111,433,550
RES3B (fourplex)	$31,976,550
Townhouse/condo	$159,342,850
Apartment	$732,187,500
Temporary lodging	$110,731,150
Nursing home	$62,331,100
Right of way	$16,959,950
Tideland	$4,026,650
Vacant	$408,637,250
Wetland	$264,300
Total =	$13,007,696,815

the affected counties and converted these data into Hazus-MH format. We then clipped the data to the boundaries of the lahar hazard zone to more precisely delineate those properties actually at risk in each scenario (Fig. 6).

We refined the calculations based on updated parcel data received from King, Pierce, Thurston, and Lewis Counties. We then generated a lahar_parcel layer with its metadata file. Lahar_parcel layer preparation and information about the parcels and processing steps are explained in the Appendix. Table 1 gives examples of values of exposed properties for the Puyallup River lahar zone as roughly determined from the LAHARZ runs.

Final results of these models for the major drainages of Mount Rainier have been posted to the Washington State Geologic Information Portal as the Mount Rainier Lahar (Volcanic Mudflow) Hazards interactive map (http://www.dnr.wa.gov/ResearchScience/Topics/GeosciencesData/Pages/geology_portal.aspx). The Appendix gives further details about how to use the portal site.

CONCLUSIONS

Our Hazus-MH analysis and recent studies on community exposure to lahar hazards from Mount Rainier (Wood and Soulard, 2009) indicate that development of damage functions specific to lahar hazards will be needed. Our efforts in this project are based on updating the Hazus database at the county level so that mitigation and emergency response plans can be realistically applied. We anticipate that with an enhanced database environment, lahar hazards elsewhere can be easily marked and transferred into Hazus-MH. These lahar inundation zones can be used as specific project areas to calculate loss estimation models in Hazus-MH. Results and plans from these studies can be used in the Hazus-MH environment, which is the most comprehensive and advanced platform for direct and indirect loss estimations based on earthquake, flood, and hurricane models.

Our final assessments for at-risk assets are based on 2011 parcel data gathered from lahar-prone Pierce, Thurston, King, and Lewis Counties surrounding Mount Rainier (Fig. 7). The most significant accomplishment of this project is the interactive mapping site on the Washington State Geologic Information Portal (http://www.dnr.wa.gov/Research Science/Topics/GeosciencesData/Pages/geology_portal.aspx). The portal site provides supportive data for emergency response/mitigation planning activities. We posted our main results and associated data layers and named the interactive mapping site “Mount Rainier Lahar (Volcanic Mudflow) Hazards – Properties at Risk”. We strongly believe that the Hazus-MH disaster models can be an effective guide for development of the lahar hazard fragility curves/damage functions. Using the Hazus-MH tool will help develop better emergency response, mitigation plans, and community preparation for lahar-prone areas.

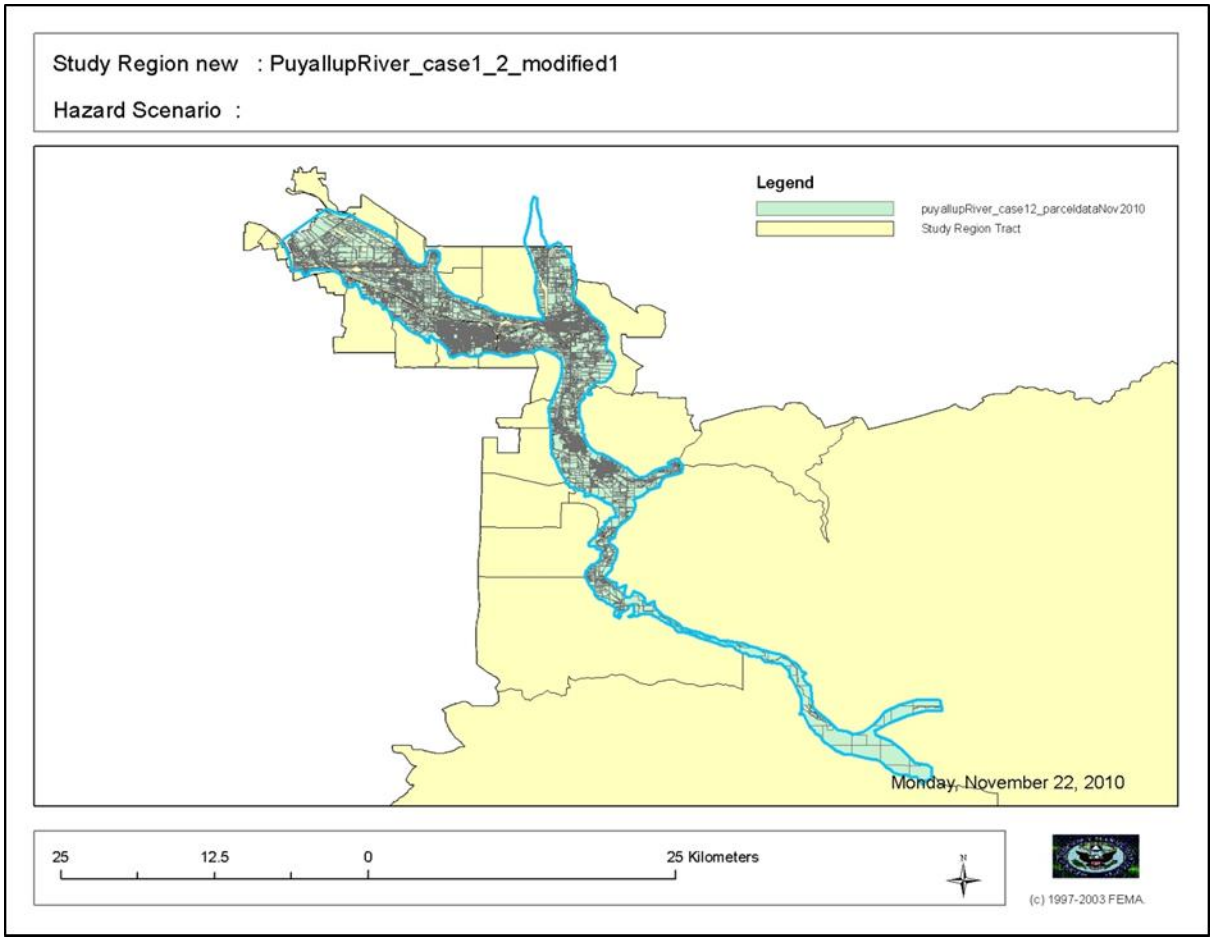

Figure 6. Puyallup River lahar zone (blue-bounded polygon) and census tracts selected when lahar zone is imported into Hazus-MH. Small polygons inside the lahar zone show the parcel data coverage clipped for the zone.

We expect that these pilot project results will inspire similar applications in other lahar-hazard areas and lead to future development of a volcano hazard module (models such as lahar, tephra/ash fall, etc.), in addition to earthquake, flood, and hurricane modules, in the Hazus-MH environment.

FUTURE WORK

Further research projects are needed to investigate fragility curves/damage functions specific to various volumes of lahar flows and their flow behaviors. Because lahars have multiple flow behaviors (debris flow, mudflow, etc.) and there are uncertainties in terms of rheological characteristics of mixtures and transitions from debris flow to hyper-concentrated stream flow, Webby and Forster (2002) proposed a simplified hydrological model for lahar hazard assessments. Their method roughly determines the lahar flow behaviors and uses “one-dimensional shallow water wave equations incorporating a single energy dissipation parameter” (equivalent to Manning’s channel roughness coefficient for turbulent water flows, n). They also tested a lahar simulation for a potential collapse scenario of New Zealand’s Ruapehu Crater Lake outlet barrier (Hancox and others, 1997, 1998), which is consistent with their suggested model. They then verified and tuned their models by using the 1953 and 1975 lahar events.

After running LAHARZ and approximately estimating the lahar hazard zones, a simplified hydrological method, such as that used for Ruapehu Crater Lake may be adapted to further characterize flow behaviors in the lahar hazard zones. Collaborations between USGS–CVO scientists and National Institute of Building Sciences–FEMA engineers should lead to construction of a Hazus-MH lahar model that can be applied for all lahar hazards from other volcanoes.

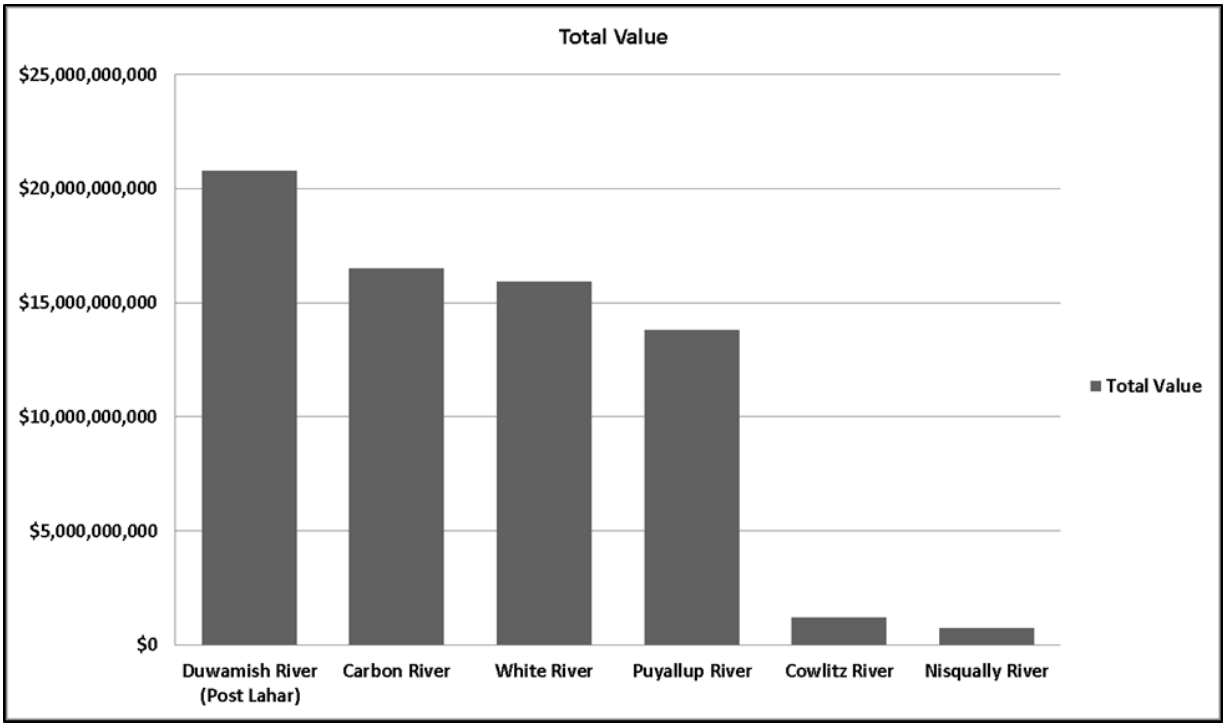

Figure 7. Total value of property at risk in lahar zones in the six major drainages of Mount Rainier. Total value is the sum of parcel value, building value, and content value. Data preparation and processing steps are explained in the Appendix. (See Figure 2 for possible combinations of pathways.) Combined total value for the six drainage systems is about $40 billion.

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Appendix. Washington State Geologic Information Portal

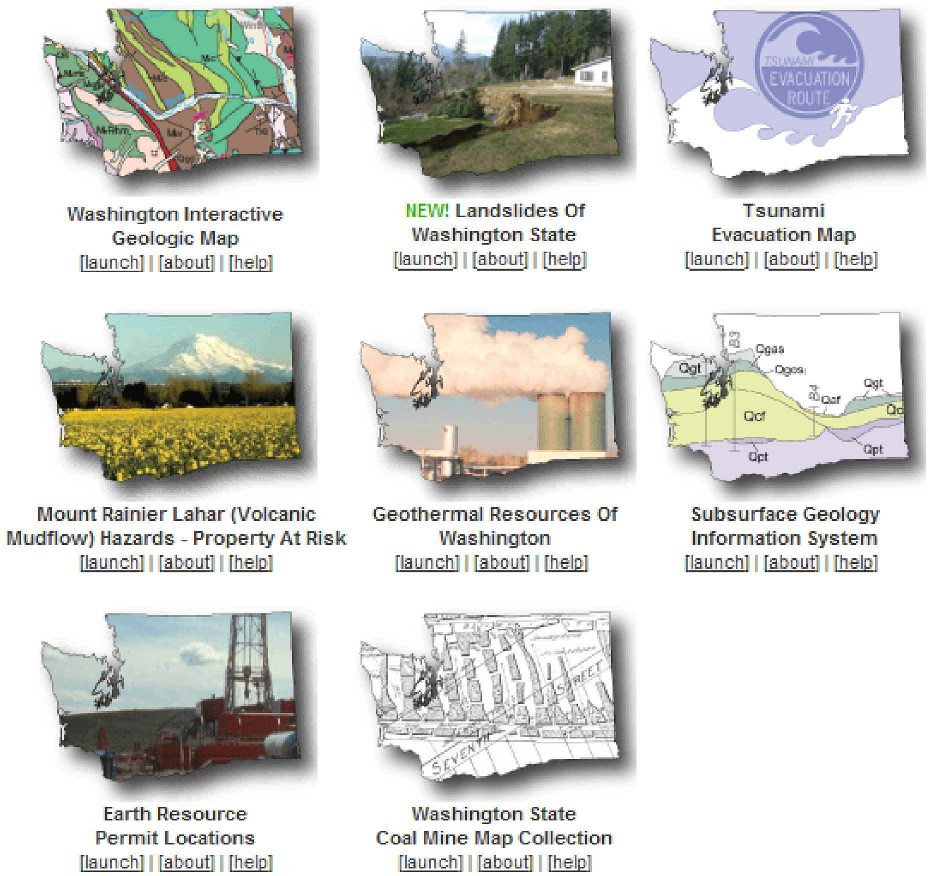

Figure A1. Part of the initial screen of the Washington State Geologic Information Portal (http://www.dnr.wa.gov/ResearchScience/Topics/GeosciencesData/Pages/geology_portal.aspx), showing icons for interactive theme maps. "Mount Rainier Lahar (Volcanic Mudflow) Hazards – Properties at Risk" is on the left in the middle row.

MOUNT RAINIER LAHAR (VOLCANIC MUDFLOW) HAZARDS – PROPERTIES AT RISK

The most significant accomplishment of this project is the interactive mapping site on the Washington State Geologic Information Portal (http://www.dnr.wa.gov/ResearchScience/Topics/GeosciencesData/Pages/geology_portal.aspx) (Fig. A1). We posted the results of this study and associated data layers to the portal and named the interactive theme map "Mount Rainier Lahar (Volcanic Mudflow) Hazards – Properties at Risk". It is explained below in a series of screen shots (Fig. A2). The interactive mapping site provides supporting data for emergency response/mitigation planning activities of end users (emergency managers, planners, etc.).

Mount Rainier Lahar Hazards Theme

This theme (Figs. A2 and A3) shows hazard zones for lahars coming from Mount Rainier, as determined by the U.S. Geological Survey. Lahars are mudflows or debris flows emanating from a volcano and typically flowing along river valleys. Lahars are similar in consistency to unset liquid concrete and can be extremely destructive. This map theme shows land parcels at risk of being affected by lahars; it provides information on the value of the land, structures, and content of each parcel. This theme also shows areas that could be affected by lava flows and pyroclastic flows, as well as areas at risk for post-eruption erosion, sedimentation, and flooding. The following information layers are available:

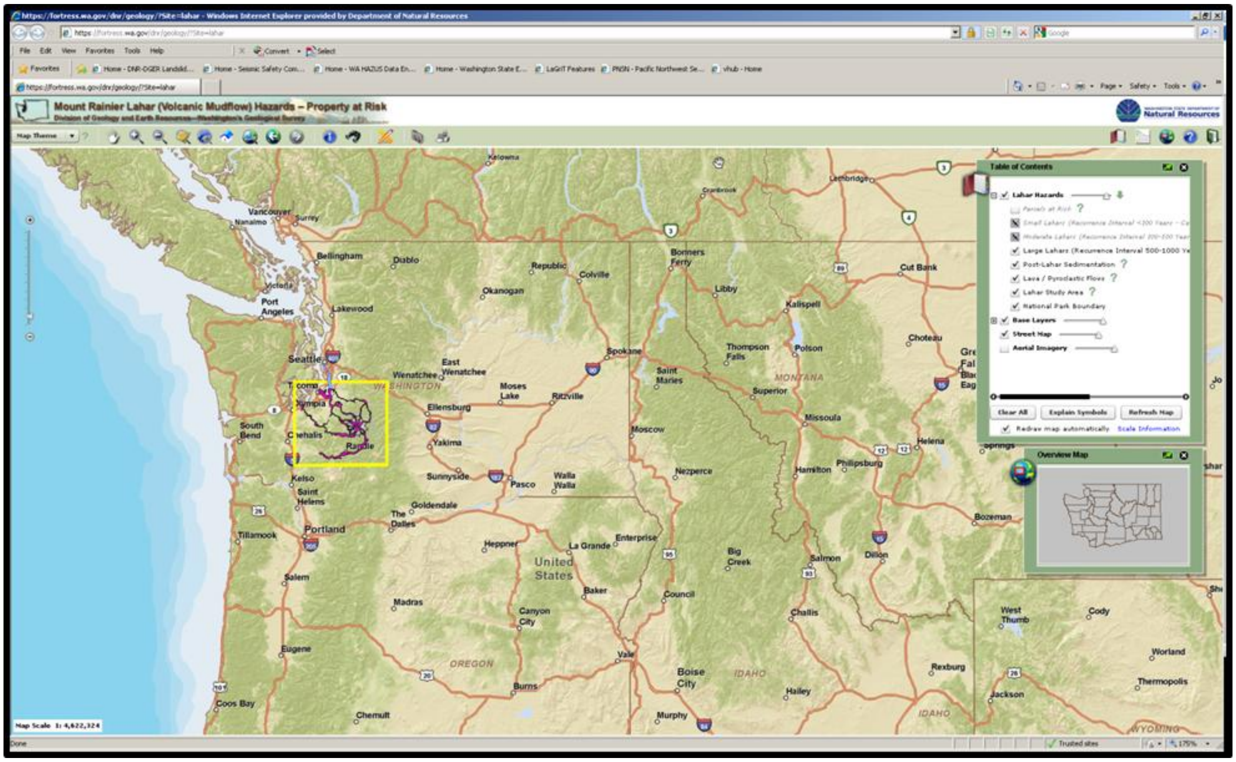

Figure A2. Screen shot of the Mount Rainier Lahar Hazards theme (within yellow square) on the Washington State Geologic Information Portal. Zoom in for a closer look.

Layer: Small Lahars (Recurrence Interval <100 Years – Case III)

This layer shows areas that could be affected by moderately large debris avalanches or small noncohesive lahars, all of noneruptive origin. The time interval between Case III lahars at Mount Rainier is about 1 to 100 years.

Layer: Moderate Lahars (Recurrence Interval 100–500 Years – Case II)

This layer shows areas that could be affected by relatively large noncohesive lahars, which are commonly caused by the melting of snow and glacier ice by hot rock fragments during an eruption, but they can also have a noneruptive origin. The time interval between Case II lahars from Mount Rainier is near the lower end of the 100- to 500-year range, making these flows analogous to the so-called "100-year flood" commonly considered in engineering practice. The National Lahar is an example of a Case II lahar.

Layer: Large Lahars (Recurrence Interval 500–1000 Years – Case I)

This layer shows areas that could be affected by cohesive lahars that originate as enormous avalanches of weak, chemically altered rock from the volcano. Case I lahars can occur with or without eruptive activity. The time interval between Case I lahars on Mount Rainier is about 500 to 1,000 years. The Electron Mudflow is an example of a Case I lahar.

Layer: Post-Lahar Sedimentation

This layer shows areas subject to post-lahar erosion and sedimentation and the ongoing potential for flooding. At Mount St. Helens, nearly $1 billion was spent during the first 10 years after the 1980 eruption to mitigate flood hazards.

Layer: Lava / Pyroclastic Flows

This layer shows areas that could be affected by pyroclastic flows, pyroclastic surges, lava flows, and ballistic projectiles in future eruptions. During any single eruption, some drainages may be unaffected by any of these

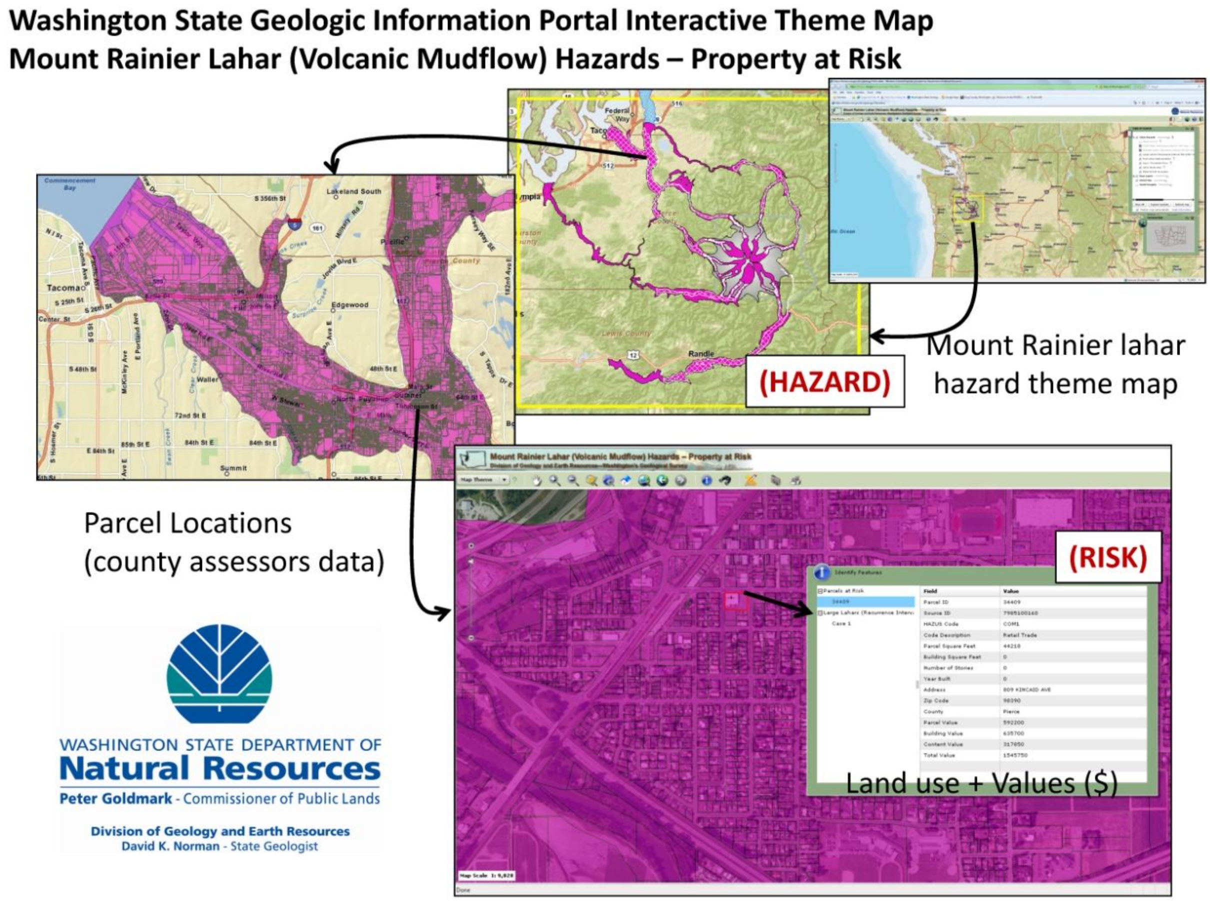

Figure A3. Inside the Mount Rainier Lahar Hazards theme, progressing from small scale to large scale, showing a table accessible with the "identify" tool.

phenomena, while other drainages are affected by some or all phenomena. The average time interval between eruptions of Mount Rainier is about 100 to 1,000 years.

Layer: Parcels at Risk

This layer provides select parcel data for analysis of financial loss due to the destruction of property in different volcanic scenarios outlined in the Case I, Case II, and Case III lahar inundation layers. It represents parcel data gathered from and compiled by various county entities in King, Lewis, Pierce, and Thurston Counties. The parcels provide assessor's data describing location, size, value, and building use for assessed parcels. This layer has been clipped to encompass only the data representing Mount Rainier lahar hazard zone Cases I, II, and III. In some instances, contents value has been estimated or calculated with the formula used in Hazus, the loss estimation model of the Federal Emergency Management Agency (FEMA). The Hazus model is a tool for mitigation and recovery planning and analysis. For more information on Hazus, go to http://www.fema.gov/plan/prevent/hazus/.

Interactive Mapping Tools for Emergency Response and Mitigation Planning

We expect that the interactive mapping tools shown in Figure A4 and the data layers listed in the previous section will be used by emergency responders and mitigation planners. These tools are also being considered by the Mount Rainier Working Group for use in their workshop (in planning stage) during hands-on exercises for various scenarios. In addition, this interactive mapping site will be adoptable for other datasets (that is, lahar evacuation maps) for lahar emergency response practices, and additional data can be added onto the current database and made available for public use. Finally, other WADNR–DGER portal databases (geology, earthquakes, active faults, subsurface, geothermal, oil and gas, etc.) can be used in the same mapping environment, which allows users to bring in other geologic information for specific hazardous areas and lahar hazard scenarios.

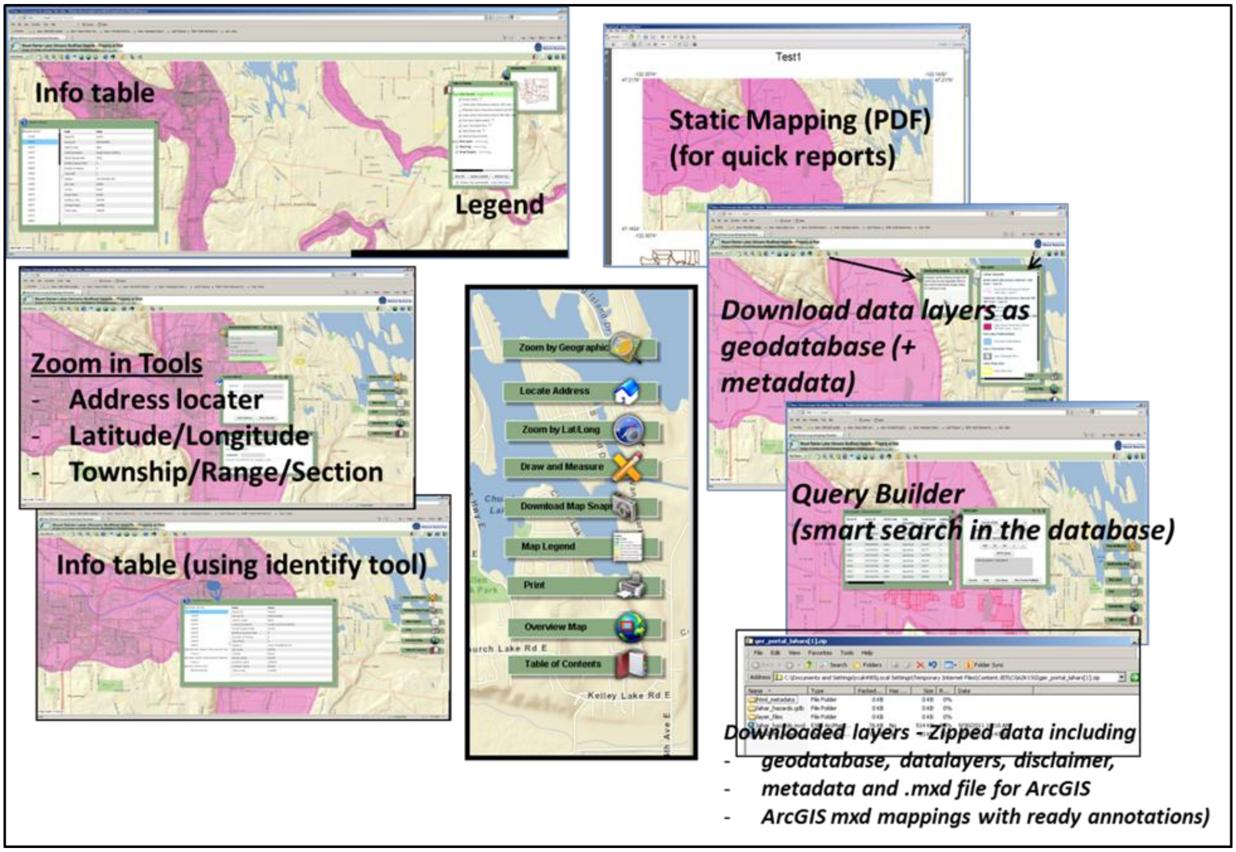

Figure A4. Tools available in the Mount Rainier Lahar Hazards theme (interactive mapping site) that can be used for planning emergency response and mitigation.