

Washington Geological Survey GIS Statewide Landslide Database—From Design to Implementation

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Introduction

The Department of Natural Resources, Geology and Earth Resources Division (DGER), also known as the Washington Geological Survey, actively identifies, assesses, and maps geologic hazards using modern geotechnical and geophysical methods. Our hazard maps are critical for land-use and emergency-management planning, disaster response, and building-code amendments. As our population grows, there is increasing pressure to develop in hazardous areas; thus, delineating these areas is imperative. In response to the Washington State Growth Management Act's mandate to use the 'best available science,' our geologists meet with local governments and citizens in at-risk communities to educate about geologic hazards and ensure these hazards are taken into account when planning for growth management and for disasters. The DGER is also a first responder to natural disasters, helping to staff the State Emergency Operations Center at Camp Murray and documenting damage in the field. Besides volcanic and earthquake hazards, Washington is also prone to landslides triggered by intense rainfall or earthquakes. Landslides kill more people and cost more overall each year than other natural disasters combined (Bell, 1999). Nationally, landslides account for over 2 billion dollars of loss annually and result in an estimated 25 to 50 deaths a year (Schuster, 1996; Spiker and Gori, 2000; Schuster and Highland, 2001). Additionally, according to Washington State legislative mandate RCW 43.92.

" . . . the geological survey must conduct and maintain an assessment of seismic, landslide, and tsunami hazards in Washington. This assessment must include the identification and mapping of volcanic, seismic, landslide, and tsunami hazards, an estimation of potential consequences, and the

likelihood of occurrence. The maintenance of this assessment must include technical assistance to state and local government agencies on the proper interpretation and application of the results of this assessment."

DGER has designed and is implementing a GIS-based, statewide landslide database at both 24K and 100K scales (Figure 1), which is accessible on our ArcIMS site for download as an Arc Coverage file located at <http://wigm.dnr.wa.gov/>.

Data Assembly

Over many years, various landslide databases have been created in different divisions of the Washington Department of Natural Resources (DNR) to meet a variety of purposes. In 1999, the Division of Forest Practices created the first GIS statewide inventory of landslides (Boyd and Vaugeois, 2003). This database incorporated previously mapped landslides of all scales. The DGER has been involved in various projects, from mapping landslide hazards in Cowlitz County in response to the Aldercrest-Banyon landslide, to hazard response such as the Nisqually earthquake in 2001 and the December 3, 2007, storm that caused significant landslide-related damage. However, each of these datasets and databases was intended to meet particular goals. The statewide database includes an assessment of the reliability of database entries and uses the appropriate attributes from these previous databases, with a notation indicating where the data were obtained. An additional database is linked to the statewide database to provide information on the economic impact of landslides when the data are available. This secondary database is intended for mitigation and development planning purposes.



Washington Geological Survey GIS statewide landslide database - from design to implementation



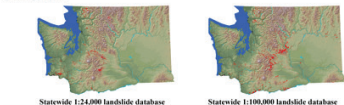
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Introduction

The Department of Natural Resources, Geology and Earth Resources Division (DER), also known as the Washington Geological Survey, actively identifies, and maps geologic hazards using modern geospatial technology. The DER has been successful in identifying and mapping geologic hazards that pose a threat to the state's economy, and building-code amendments. As our population grows, there is increasing pressure to develop and build in areas that are geologically hazardous. The DER has been successful in convincing state AR mandates to use the "best available science," our geologists work with local governments and citizens to assist them in decisions to evacuate geologic hazards and ensure these hazards are taken into account while planning for future development. The DER has been successful in convincing the state legislature to fund the staff the State Emergency Operations Center at Camp Murray and downsizing that facility in the field. Besides mapping geologic hazards, the DER also monitors and reports on seismicity in the state, including earthquakes. Landslides kill more people and cost over \$2 billion each year than other natural disasters combined (FEMA, 1999). Nationally, landslides caused over 52 million dollars of loss annually and result in an estimated 100 deaths each year (FEMA, 1999). The DER has been successful in convincing the state legislature to fund the Washington State Geological Survey WSGLAS 4392. "The geological survey must conduct and maintain a program of research, mapping, and monitoring of geologic hazards, including, but not limited to, seismicity, identification and mapping of volcanic, landslide, and tsunami hazards, an estimation of potential consequences of such hazards, and the development of hazard maps and other products that are useful to the state and local government agencies in the proper interpretation and analysis of the results of that research." DER has designed and is implementing a GIS-based, statewide landslide database in both 2D, 3D

Data assembly

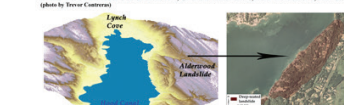
Through the years various landslide databases have been created in different divisions of the INRM to meet a variety of purposes. In 1999, the Division of Forest Practices created the first GIS statewide inventory of landslides (Blevy and Vangelis, 1999). This database incorporated previously mapped landslide data from Tallahassee, FL, and the Division of Forest Practices, and was used to assess the potential for landslides in Florida. The DGER has been involved in various projects, from mapping landslide hazards in Collier County in response to the Aldercrest-Banyan landslide, to hazard response as in the Nisqually earthquake in 2001 and the December 3rd storm 2007. However, each of these datasets and databases were intended to meet particular goals. The statewide database assesses the reliability of other database entries and uses the appropriate attributes from the previous databases to populate the statewide project, with a notation indicating where the data were obtained. As a result, the database is not linked. This statewide database is provided information on the estimated impact of landslides when that data is available. This secondary database is intended for mitigation and development planning purposes.



Statewide 1:24,000 landslide database



Landslides on the south side of Little Hill, Chehalis Headwaters, from the Dec. 3rd, 2007 storm



Alderwood landslide near Lynch Cove, Mason County, occurred in 900AD and triggered a

Landslide Processes and Attributes

Landslide Processes

Landscape processes were modified from the Washington Department of Natural Resources, Forest Practices Division, Landscape Hazard Zonation Project Protocol (LHZ, 2004). The changes reflect gaps in the LHZ protocol, such as the additions of hyperconcentrated flows and lateral spreads, which are critical in future land use planning. Landscape processes were grouped into two categories, shallow landslides and deep-seated landslides. Shallow landslides are differentiated to shallow undifferentiated (including shallow colluvial), debris flow, debris slide (which includes debris avalanches), hyperconcentrated flows and block falls and topples. Deep-seated landslides are differentiated to lateral spreads, general deep-seated, earthflows, translational, rotational, composite and megalandslides/starstransoms.

Attributes

Landscape hazards were mapped from the Washington Department of Natural Resources (DNR), Forest Practices Division's Landscape Hazard Zonation Project (LHJ, 2004). Attributes were created for multiple reasons. The first was to establish a balance between critical information and attribute excessiveness. The second was to ensure critical information would be available for land use planning and hazard assessment, as well as for future research into landslide hazards. The third was to establish a basis by which to flag landscapes that have caused or potentially could cause damage. Emphasis was placed on landslide triggers, such as slope, gradient, and structure. When available, landslides were hyperlinked to pictures and websites, allowing land managers and emergency responders to further assess future hazards. This will also allow the public to better understand landslide dangers within Washington State.

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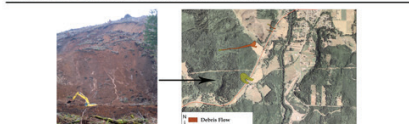
Converting Existing Data into a GIS Database

Existing

The inventory of existing landfile datasets and databases is shown in Washington State. The most comprehensive landfile database is the 1999 Division of Forest Practices GIS statewide inventory of landfiles (Brod and Vaugoois, 2003). This database combines the 1:100,000 scale geologic mapped landfiles with various other datasets, from scales at 1:24,000 to 1:12,000. The majority of datasets at a scale of 1:24,000 to 1:12,000 are from DNR studies of various departments. The rest of the datasets are from county or tribal records, or from independent mapping projects. Polygons were entered as a separate geologic polygon layer for each project. The 1:100,000 scale geologic map polygons for each dataset have been converted, when possible, to the same extent within the Landfile Hazard Zonation Mapping Project. The remaining inventory landfile datasets are from various projects in the Washington Geological Survey. Each project is maintained in a GIS database with overlapping polygons and attributed for the specific project.

Converting Data

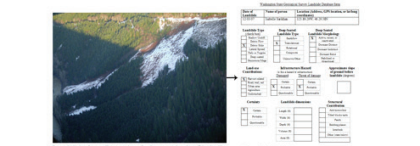
A dataset is converted into the Washington Geological Survey's landslide database by importing the polygons and relevant attributes into the database. In the case of the Division of Forest Practices Landslide Database, landslides of the scale of 1:25,000 were separated from the scale of 1:250,000 and 1:500,000. This was completed by overlying the existing coverage with the 1:25,000 scale map. The polygons were then separated into the two scales. The polygons of the 1:25,000 scale were then entered into a new layer, allowing the polygons to be filtered. Errors in attributes were noted in this process to insure quality of data. The layered polygons were then entered into the Washington Geological Survey's landslide database and the original data were deleted. The original data were then entered into the Washington Geological Survey's landslide database and the original datasets will be preserved online for download, allowing the previous studies' unique attributes to be preserved. Each dataset within the Washington Geological Survey contains a unique code allowing the user to easily determine which dataset is being used. The user can also download the data in a format that is more easily managed and is more easily manageable levels and by allowing the user to explore unique attributes of specific studies.



Landslide covering SR 6 east of Pu. El from the Dec. 2007 storm. Credits by Nelson M. Soto

Emergency Response

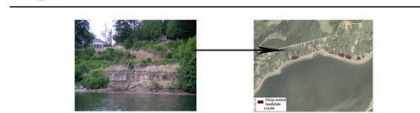
An important aspect of land-use hazard reduction is real-time monitoring and emergency response (Spilker and Gerl, 2003). In addition to hazard response, DGER intends to provide an on-line data collection form to encourage Washington citizens to document all types of landslides to keep the database up to date and detailed. This form will request information regarding the size and type of landslide, material type, economic damage, etc. While not all citizens will be able to assess all aspects of landslides, this form will help keep DGER geologists informed about potentially very large or very damaging events which would require field assessment. A landslide database form will require DGER geologists to participate in educational forums for the public. The legislative mandate RCW 3.90 which states "it is the intent of the legislature that there be an effective State Geological survey that can produce essential information that provides for the health, safety, and economic well-being of the citizens."



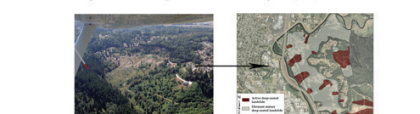
Landslide from December 3rd storm in the Chehalis headwaters.

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Deep-seated landslide along coastal bluff in Mason County, 2006. (photo by Isabelle Serikhan)



Reactivation of portion of larger slide #271. Declared federal landslide disaster area in 1998. 138 homes affected, 128 total or partial losses. (photo by Karl Wegmann)

Figure 1. Page-size version of DMT'08 poster showing the DGER statewide landslide database (see full-resolution image at http://namdb.usgs.gov/Info/dmt/docs/DMT08_Sarikhan.pdf).

Landslide Processes and Attributes

Landslide Processes

The classification of landslide processes was modified from the Washington Department of Natural Resources, Forest Practices Division, Landslide Hazard Zonation (LHZ) Project Protocol (Washington State Department of Natural Resources, 2004). The changes reflect gaps in the LHZ protocol, such as the additions of hyperconcentrated flows and lateral spreads, which are critical in land use planning. Landslide processes were grouped into two categories, shallow landslides and deep-seated landslides. Shallow landslides are classified as shallow undifferentiated (including shallow colluvial), debris flow, debris slide (which includes debris avalanches), hyperconcentrated flows and block falls, and topples. Deep-seated landslides are classified as lateral spreads, general deep-seated, earthflows, translational, rotational, composite, and mega-landslides/sturzstroms.

Attributes

The types of landslide attributes were modified from the Landslide Hazard Zonation (LHZ) Project Protocol (Washington State Department of Natural Resources, 2004). Attributes

were created for multiple reasons. The first was to establish a balance between recording the critical information and defining an excessive number of attributes. The second was to ensure critical information would be available for land use planning and hazard assessment, as well as for future research into landslide hazards. The third was to establish a basis by which to identify landslides that have caused or potentially could cause damage. Emphasis was placed on landslide triggers, such as slope, gradient, and structure. When available, landslides were hyperlinked to pictures and websites, allowing land managers and emergency responders to further assess future hazards. This will also allow the public to better understand landslide dangers within Washington State.

Converting Existing Data into a GIS Database

The inventory of existing landslide datasets and databases is sparse in Washington State. The most comprehensive landslide database is the 1999 Division of Forest Practices GIS statewide inventory of landslides (Boyd and Vaugeois, 2003). That database combines the 1:100,000-scale Division of Geology and Earth Resources digital maps of landslides with various other datasets of scales from 1:24,000 to 1:12,000.

The majority of datasets at a scale of 1:24,000 to 1:12,000 are from DNR studies by various departmental divisions. The rest of the datasets are from county or tribal records, or from other types of mapping projects. Polygons were originally entered as a single layer (with no overlapping polygons) and were separated to represent overlapping polygons. Every dataset has been converted, when possible, to the attribute-set within the Washington Geological Survey's Protocol.

For each selected dataset, the polygons and relevant attributes are incorporated into the Washington Geological Survey's landslide database. In the case of the Division of Forest Practices Landslide Database, landslides of the scale of 1:100,000 were separated from the scale of 1:24,000 and 1:12,000. This was done by overlaying the DGER 1:100,000 geologic map's landslide polygons and removing those polygons. The polygons were then hand-merged into single polygons and pasted into a new layer, allowing the polygons to be layered. Errors in attributes were noted in this process, to ensure data quality. The layered polygons were then entered into the Washington Geological Survey's landslide database and relevant attributes were inserted into the database.

The original landslide datasets will be preserved online for download, allowing the previous studies' unique attributes to be preserved and compared to those in the Washington Geological Survey's landslide database. Each dataset within this statewide database contains a unique code that allows the user to easily determine the source dataset for each landslide. This approach increases the usefulness of the database by linking it to the source information, thereby keeping the statewide database to a manageable size.

Emergency Response

An important aspect of landslide hazard reduction is real-time monitoring and emergency response (Spiker and Gori, 2000). In addition to hazard response, DGER intends to provide an online data collection form to encourage Washington citizens to report landslides of any size, in order to help maintain a comprehensive database. This form will request information regarding the size and type of landslide, material type, economic damage, etc. While not all citizens will be able to assess all aspects of landslides, this form will help to keep DGER geologists informed about potentially very large or very damaging events which would require field assessment. A landslide database form will require DGER geologists to participate in educational forums for Washington citizens, according to legislative mandate RCW 43.92.900 which states, "*It is the intent of the legislature that there be an effective State Geological Survey that can produce essential information that provides for the health, safety, and economic well-being of the citizens.*"

Public Accessibility

ArcGIS is a specialized tool to which the general public generally does not have access. Therefore, in order to educate the general public, we have developed an ArcServer system that allows easy data acquisition and navigability of landslide features. Additionally, the landslide information will be accessible by KML/Z files, allowing the general public to access this layer of information on simplified spatial visualization programs (such as Google Earth). We also may provide RSS and GeoRSS feeds and corresponding Mapplets (Haefner and Venezky, 2007), for continuous updates during emergency events.

Not only will the public be able to use the information within the database for community planning or hazard mitigation, but an accessible database will bring the public's attention to the high landslide hazard in the Pacific Northwest. Hopefully, a more aware public is a better prepared public!

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