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DGER NEWS

DIVISION OF GEOLOGY AND EARTH RESOURCES
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Evaluating GIS Methods for Determining the Pre-Movement Slope Gradient of Deep-Seated Landslides

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Division of Geology and Earth Resources

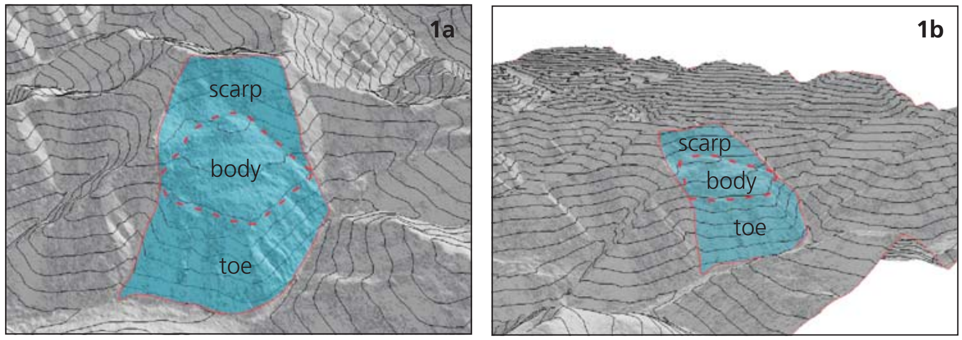


Figure 1. Three-dimensional views of a deep-seated landslide (blue shaded area) showing the different gradients of the scarp body and toe. 1a. Oblique aerial view straight on the deep-seated landslide. 1b. Oblique aerial view of the deep-seated landslide from the side. The base elevation data in these images is lidar and the contour interval is 50 ft.

Introduction

Under the Landslide Hazard Zonation (LHZ) Project, DGER geologists are working to identify potentially unstable slopes on lands regulated by the Department of Natural Resources (DNR) Forest Practices Division. Among the products generated during an LHZ analysis are detailed reports, a tabular landslide inventory data, and two maps—a landslide inventory map and a landform-based hazard map. These products are used as screening tools by DNR foresters and other land managers in evaluating areas for timber harvest.

The first step in the process is for the geologist to gather a variety of available images and elevation data, including stereo air photos, orthophotos, USGS 7.5-minute topography, and lidar (light detection and ranging), which are used to evaluate the watershed. Landslides are identified on air photos and lidar (where available) and then digitized into a geographic information system (GIS) with reference to orthophotos. Limited field work is used to check the remotely sensed inventory.

Once the information is in the GIS, it can be analyzed in various ways. One piece of data routinely collected is the slope gradient at which the landslide initiated. This value is very important for use in landform hazard mapping, land-use planning, and future landslide modeling studies. It is one of the landslide descriptive values determined for each landslide mapped by the LHZ Project and recorded with the landslide inventory.

For small (less than one acre) shallow (slide planes less than 10 ft deep) landslides, digital topography from either USGS topographic maps or lidar provides the data to derive a slope map and simply evaluate the small landslide initiation area to estimate original slope gradient.

For larger deep-seated landslides, it is much more difficult to identify where to measure the pre-slide slope gradient, since they have distinctively different areas of scarp, body, and toe (Fig. 1). Measurements on the scarp and toe will yield slope gradients that are different than the pre-slide surface, and measurements on the body of the slide will typically return shallow gradients. Depending on the location, it may also be difficult and extremely subjective to estimate pre-slide slope gradient on slopes adjacent to the landslide in question. In this context, I evaluated several different GIS methods for estimating the pre-movement slope gradient of deep-seated landslides.

GIS Methods

Using either digital USGS or lidar topographic data and derived slope maps, there are several methods by which pre-movement slope gradients of deep-seated landslides can be estimated. They vary greatly in complexity, precision, and repeatability.

Analyst-Chosen Method. The least time-consuming, least repeatable, and potentially least precise method is to choose some spot on the landslide that you feel is representative of the pre-landslide slope and record the gradient at that spot.

Centerline Method. A second, more reproducible method is to draw a line connecting the highest elevation part of the landslide with the presumed lowest elevation of the affected slope, in essence reconstructing the pre-landslide slope at the centerline of the feature (Fig. 2), and then calculate the gradient of the centerline.

Average-Gradient Method. A third method is to calculate the average gradient across the landslide polygon. Using this method, the steeper and shallower areas of the deep-seated landslide effectively average each other out. The benefit of this method is that this task can be performed very easily using GIS and is entirely reproducible using the same set of mapped landslides. The drawbacks are the difficulty in conceptualizing how the GIS is reconstructing the pre-landslide slope and that there is no simple way to customize the process for specific landslides.

Fit-Plane Method. The fourth method is to fit a plane through the landslide to approximate the pre-landslide slope (Fig. 3) and to calculate the gradient of this plane. This method is very time consuming, requiring many steps within GIS, but has the benefit of being easy to conceptualize, analyst customizable, and relatively repeatable.

Comparison of Methods

I used the "fit-plane" method as the standard or control against which to compare the other methods. This method

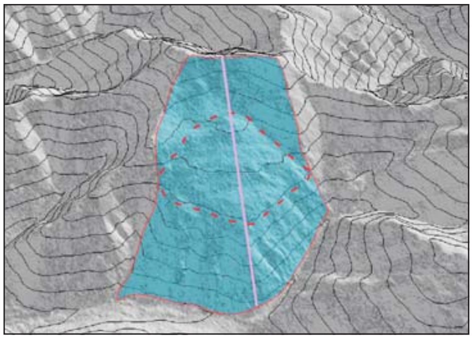
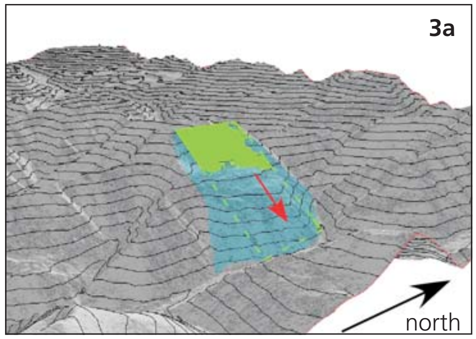


Figure 2. Three-dimensional view of a deep-seated landslide showing the presumed pre-landslide slope at the centerline of the feature (purple line).



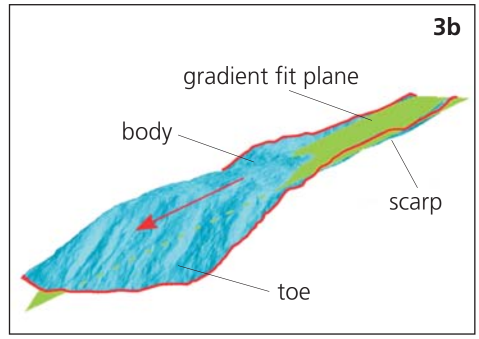


Figure 3. Three-dimensional view of a deep-seated landslide showing the plane (in green) fit through the landslide to approximate the pre-landslide slope. 3a. View of the landslide from the southeast in the context of the surrounding terrain. 3b. View of the landslide from the north with the surrounding terrain removed.

was selected as the control because I was able to customize it to many different landslide types, and conceptually it captured the pre-landslide slope best. To do the comparison, I analyzed the pre-landslide slope gradient for 68 deep-seated landslides mapped by Lorraine Powell (2005) in the Cabin Creek watershed administrative unit (WAU) using the four methods described above. I used a paired sample t-test (a statistical test used to determine whether there is a significant difference between the average values of the same measurement made under two different conditions) to compare the different gradient results from each method to the control fit-plane method. Assuming that the fit-plane method is a good choice for the control, the paired sample t-test showed whether or not a given method returned results that are statistically different from the fit-plane method, and, on average, how much the method either over- or under-estimated the gradient.

Results and Conclusions

Not surprisingly, the gradient difference between the fit-plane method and the analyst-chosen subjective representative gradient was statistically extremely significant, and, on average, the analyst overestimated the pre-landslide slope gradient by 24 percent. Reconstructing the pre-landslide slope at the centerline of the deep-seated landslide was also statistically different from the fit-plane method. However, this method only slightly underestimated the gradient compared to the fit-plane method, by about 2 percent on average. The best-performing method was to calculate the average gradient across the entire landslide feature. This method returned gradient results that were not statistically different from the fit-plane method and only underestimated the gradient by 0.5 percent on average.

Statistical comparison of these methods shows that subjectively choosing a representative gradient can dramatically overestimate the pre-movement slope gradient. This probably happens because analysts tend to choose representative areas that are on or close to the scarp of deep-seated landslides. In addition, this method is not repeatable, and for that reason alone, it should not be used. The comparison also shows that it is preferable to use the average gradient across the entire landslide GIS polygon for evaluating pre-movement slope gradients of deep-seated landslides. This is the least time consuming and most reproducible GIS method. The main drawback of the average gradient method is that it is not customizable for individual landslide features.

For questions or more information on this process, contact Eric Bilderback at 360-902-1476 or eric.bilderback@wadnr.gov.

References

Landslide Hazard Zonation Technical Committee; Upslope Processes Science Advisory Group of the Cooperative Monitoring, Evaluation and Research Committee, 2005, Landslide Hazard Zonation Project Protocol, Version 2.0: Washington Forest Practices Division, 41 p. [www.dnr.wa.gov/forestpractices/lhzproject/lhz_protocol_v2_final.pdf]

Powell, L. P., 2005, LHZ—Landslide inventory—Final A-1 map Cabin Creek watershed: Washington Department of Natural Resources, 1 sheet, 1:24,000. [http://www.dnr.wa.gov/forestpractices/lhzproject/completed/index.html] ■

GEOLOGIC MAP OF WASHINGTON WINS INTERNATIONAL DESIGN AWARD

DGER's "Geologic Map of Washington State" (GM-53) has won both Best Map of 2005 and Best Geologic Map in the Avenza 2005 MAPublisher Map Competition. (MAPublisher software allows maps developed in a geographic information system [GIS] to be imported into a high-end graphics program, linking the spatial attributes and data to the graphic interface.) This competition draws entries from all over the globe, and we are very proud to have our map selected as the overall winner.

A spokesperson for Avenza said, "We received many entries in various categories. The judging process was extremely difficult due to the high quality of maps we received from MAPublisher users throughout the world." All winning submissions, as well as notable entries in each category, are posted on the Avenza website at http://www.avenza.com/MPcomp/2005/ .

The Geologic Map of Washington State was compiled by geologist and geographic information systems specialist J. Eric Schuster, and Geologist-editor Jaretta M. Roloff did the design and layout.

The map was compiled from previously published 1:250,000-scale geologic quadrant maps of Washington. The level of detail was simplified by combining the 1:250,000 units into units that have broader lithologic and age ranges and deleting small polygons. In the 'Key to Geologic Units', small index maps of the State of Washington accompany each unit symbol and brief unit description. These index maps show the color of the map unit as well as its distribution.

To prepare the map, digital versions of the 1:250,000 quadrant maps were merged and simplified in ESRI's ArcInfo and ArcGIS, and the plate was then laid out using Avenza MAPublisher and Adobe Illustrator.

The 55.5 x 36-inch full-color map comes with at 44-page pamphlet. It comes flat or folded. The flat map is printed on coated white stock and is suitable for framing. GM-53 may be purchased ($10.15 flat; $10.84 folded) from the Washington State Department of Printing at http://www.prt.wa.gov/ or downloaded from http://www.dnr.wa.gov/geology/pubs/gm53.htm. ■

Editor's Corner: Help the Public Find Your Report

> If a report cannot be found, does it exist? And if that unfindable report was produced with public money, has that tax money just been thrown away?
>
> *—Connie Manson*

That's the question, isn't it? Assuming you are proud of your report, map, or other publication and want it to be professional looking, easily located, correctly identified, and available in the future, you need to do the following for maximum effectiveness:

1. Set up the title page (and cover) so that it is accurately and consistently citable. Necessary items are: title, author(s), publisher, series and number (as appropriate), and date of publication.
2. Print and distribute sufficient copies.
3. Post the PDF on the web.

Title Page

Information cannot be retrieved if it is not cited properly. It cannot be cited properly without a formal title page. The title page is the most crucial piece of documentation for a publication, particularly for scientific reports of all kinds. Librarians catalog and create citations from the title page, as do authors when they are constructing a bibliography. (A citation is the bibliographic reference that appears in the "References" section of your report and serves as a road map for others to find the report you quoted.) For the sake of accurate citations, it is important that the title page states who wrote or compiled the report, who published it, and when.

Be sure the cover and title page say the same thing. Someone may edit or alter the title page and somehow the cover doesn't get the message. If there is only a cover, the cover becomes the title page by default. A CD label also functions as a title page.

Optional items on a title page or cover may include a logo, a location map, a statement of cooperation, a professional license stamp, and the contractor's name and contract number.

If the product is a map sheet only, it should have the same information as a title page. If the map is accompanied by a report with a title page, the title-page information must be repeated on the map sheet(s). In addition to the standard bar scale, maps need a ratio scale, such as 1:24,000 or 1:100,000, for cataloging purposes.

Suppose the document is intended for in-house use only. It still needs a title page. Someone in-house will want to cite the report, or it will be posted on the web, or a paper copy will fall into other hands. You can be sure that someone outside your office will want to find it or cite it.

Title

Devise a title that tells readers what, where, and when (if appropriate). It can be long—the more information you give, the more likely it is that librarians will be able to index your report properly, and people will be able to find it—but don't make it any longer than absolutely necessary. Some examples are:

The Miocene and Pliocene Ringold Formation and associated deposits of the ancestral Columbia River system, south-central Washington and north-central Oregon

Tsunami hazard map of the Elliott Bay area, Seattle, Washington: Modeled tsunami inundation from a Seattle fault earthquake

Paleontology and stratigraphy of Eocene rocks at Pulali Point, Jefferson County, eastern Olympic Peninsula, Washington

Remember to indicate both county and state (if appropriate). There are, for example, 11 Lake Smiths (or Smith Lakes) in Washington, and other states have counties with the same names as ours.

Punctuate your title. If you have a subtitle, you can choose how to attach it to the title. You may use a semicolon, a long dash, or indicate a subtitle by starting a new line and changing fonts, type size, or case. The most common mistakes in title punctuation are: not putting a comma both before and after the year in a month-day-year date, and not putting a comma both before and after the state in a city-state combination.

Is your report a revision or a final version? Only a draft or preliminary version? Let the user know!

If the report is part of a series, maintain consistency in the title format, for example:

Geologic map of the ______ 7.5-minute quadrangle(s), _______ County, Washington

Inactive and abandoned mine lands—_______ mine, ______ mining district, ______ County, Washington

Reconnaissance investigation of sand, gravel, and quarried bedrock resources in the _________ 1:100,000 quadrangle, Washington

In general, don't abbreviate—not the state or the words "county" or "mountain" or similar geographic terms. (You want people to be able to find the title when they do a search.) A possible exception is well-known abbreviations, like USGS or GIS. Some geographic names may contain abbreviations. You can check geographic names at http://geonames.usgs.gov/.

Author(s)

Be clear about authorship. Is your report an agency or division product? Is it some committee's effort, or is individual authorship appropriate? If no author is given, default is to the agency or company.

Are you Chuck Smith, Chaz Smith, Charles Smith, or Charles C. Smith? Individual authors should pick an author name and stick with it. For technical publications, this is usually "first name, middle initial, and last name".

Women need to think about this when they marry. You may want to retain your maiden name for your career, or possibly add your married name to your maiden name as in "Nancy Jones Smith".

Agency or corporate names should be exact. If you search bibliographies, it's amazing how many variations there are for the same agency. Did the name really change, or was it sloppy work on someone's part?

Don't disguise the authorship as "sponsored by", "list of participants", or some such. A simple "by" is best.

Publisher

State directly who the publisher is—that is, the agency or company that produced the report. A logo alone may imply that the agency is the publisher, but it may really be a subdivision, as in our case, where we use the Department of Natural Resources logo, but our publisher name is "Washington Division of Geology and Earth Resources".

Multiple logos may imply joint publication. If it *is* a joint publication, you need to say so on the title page. If it is not a joint publication, you may acknowledge the contributions of other agencies by listing them elsewhere—for example, on the back of the title page (logos optional).

Series

The series name and number are usually paired with the publishing agency's name:

> Washington Division of Geology and Earth Resources
> Open File Report 2005-1

The format should be consistent. Avoid the bad example of a sister agency that released Publication # 96-4, Publication No. 96-5, Publication 96-6, and Publication Number 96-8.

If you don't have a formal series, perhaps your agency should consider starting one. If you are going to be publishing a number of maps or reports of the same general type, they should probably be grouped as a series and given numbers. This aids people who want to find all of the reports of a like kind.

Date of Publication

Date of publication could be given as month and year, or only year. Do not neglect this just because there is a date in the title—for example, the date of a conference. The Washington Geology Library has several volumes of conference proceedings with only the date of the conference in the title on the title page, but we know that the actual date of publication was a year or two later.

Print Run

If you are going to the expense of printing, print enough copies for your use and more—you *will* get requests. It's a lot cheaper to print enough the first time than to reprint.

Distribution

Send at least two copies to the State Library. Also be sure to send copies to the USGS and all the major universities in the state, as well as to public libraries in the region to which the study pertains. Send copies to state agencies that might be interested in the topic, such as the Washington Geology Library (anything on Washington geology, tsunamis, earthquakes, volcanoes, and landslides), Department of Transportation (maps and engineering geology), the Department of Ecology (hydrology), and the Department of Natural Resources (watersheds and biology). And don't forget the databases, such as GeoRef, that people might use to find your report.

Addresses for the libraries we send to most frequently are listed below. The ones with e-mail addresses will take an electronic instead of a paper copy if it can be easily printed out—that is, not require a plotter.

The Web

Post your publication on your website. Remember to add the title, authors, and key words to the file properties dialogue box attached to the file so that people can find it with a search. Try to keep the publication in the same place on your website for as long as it will be useful, which in the case of geology publications can be a long time.

Posting on a website constitutes publication, even if it's not formal publication. If the information is in web format, the website is presumed to be the publisher and no title page is needed. But if the information is posted as a Word document or PDF, it is a report, and a title page (or the map equivalent) is definitely needed. And don't forget page numbers—they are needed for proper cataloging and citation.

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by Jaretta M. Roloff and Lee Walkling, based on material developed by Connie J. Manson and Katherine M. Reed

USGS EARTH SCIENCE INFORMATION CENTER NEWS

CDROM Media Discontinued

The USGS Center for Earth Resources Observation and Science (EROS) has discontinued the media choice of CDROM for digital line graphs (DLGs), digital raster graphics (DRGs), and digital orthophoto quarter quadrangles (DOQQs). The digital orthophoto quadrangle (DOQ) County CDs were discontinued as a product.

FTP and DVD media options will still be available for individual DLGs, DRGs, and DOQQs through Earth Explorer. Full national coverage of the most recent DOQQs is available from the Seamless Data Distribution System (SDDS) at http://seamless.usgs.gov/, which also offers 24K and 100K decollared DRGs for 90 percent of the nation. These may all be downloaded at no charge.

New Access to Historical Air Photos

Earth Explorer has released three new views of the historical aerial photo collections:

Aerial Photos - Non USGS Agencies
Aerial Photos - USGS
Aerial Photos - USGS Photo Reference Mosaics

Prior to the release, access to the 69,000 photo mosaics was limited to USGS business partners and Earth Science Information Centers. The public may now browse digitized photo mosaics and order imagery.

To date, over 2.25 million frames have been digitized, creating a nationwide baseline for the conterminous U.S. that includes completed National Aerial Photography Program (NAPP) and National High Altitude Photography (NHAP) collections.

Check out Earth Explorer at http://earthexplorer.usgs.gov.

DEM Distribution Discontinued

Changes have been made to the National Map, the online, interactive map service at http://nationalmap.gov/. The tiled, individual digital elevation models (DEMs) in the layers consisting of national elevation data (NED) have been replaced with seamless data. DEMs will be disabled from search, access, and ordering through Earth Explorer and the USGS anonymous FTP. NED may be downloaded, at no charge, from the SDDS. The older DEM and DLG data may still be obtained as a custom order. For more information on any of these products, contact custserv@usgs.gov. ■

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