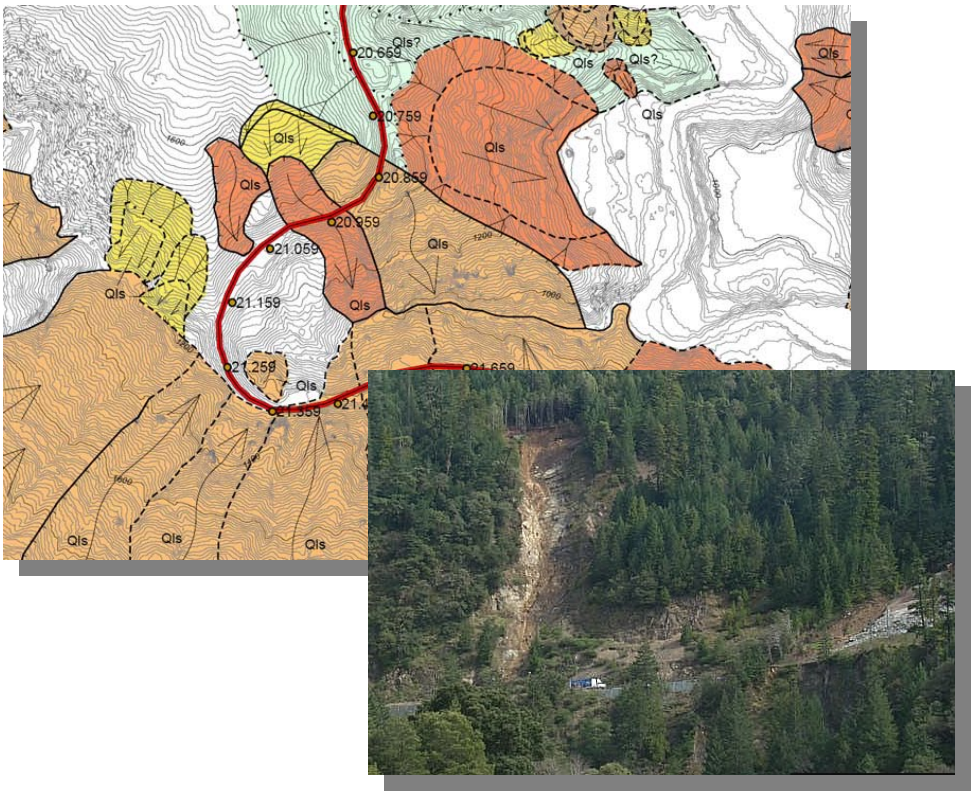
CORRIDOR-SCALE LANDSLIDE HAZARDS ASSESSMENT DEMONSTRATION PROJECT



The GeoResearch Group

Caltrans

Research & Innovation

FINAL REPORT
F/CA/TL-2006/19
SEPTEMBER 30, 2006
F-99-TL-34
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16. ABSTRACT

Each year, hundreds of landslides are mobilized along highway corridors that can affect public safety as well as the trip quality, reliability and maintenance cost of the transportation network. Modern GIS-based technologies have created new opportunities for improved assessment of landslide hazards by enabling comprehensive synthesis of vast amounts of spatial data developed from field evaluations, various remote sensing techniques, and an assortment of archival information residing with federal, state, local and private entities. Under the direction of the Caltrans GeoResearch Group in the Division of Research & Innovation, the California Geological Survey piloted the development of corridor-scale landslide hazard maps to meet the needs of various Caltrans users. The maps provide a comprehensive inventory of landslide activity along a selection of highway corridors, and are presented at a scale and in a format that is meaningful to engineers, planners, and maintenance staff. This big-picture perspective will benefit planning of route improvements and lead to more effective landslide risk mitigation measures.

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INTRODUCTION

Each year, hundreds of landslides are mobilized along highway corridors that can affect public safety as well as the trip quality, reliability and maintenance cost of the transportation network. Modern GIS-based technologies have created new opportunities for improved assessment of landslide hazards by enabling comprehensive synthesis of vast amounts of spatial data developed from field evaluations, various remote sensing techniques, and an assortment of archival information residing with federal, state, local and private entities.

Under the direction of the Caltrans GeoResearch Group (GRG) in the Division of Research & Innovation, the California Geological Survey (CGS) piloted the development of corridor-scale landslide hazard maps to meet the needs of various Caltrans users. The project team delivered a variety of mapping products, identifying the location and severity of the landslide threat along selected highway corridors. This information is displayed at a scale and in a manner meaningful to both Caltrans planners and designers. User guidelines and region-specific mitigation strategies were developed for a variety of geologic, climatological, and environmental conditions. The maps and guidelines can provide planners, designers and responders with a readily accessible and fully synthesized resource summarizing the geologic setting of a corridor from a broad perspective. This, in turn, will have immediate, positive, and long-term impact on planning, maintenance, and emergency response strategies for these corridors.

THE NEED FOR RESEARCH

Caltrans expends approximately $22 million annually in managing landslides along an estimated 1200 miles of landslide prone highways. This represents a significant portion of the estimated $106 million annual landslide costs for U.S. highways for repairs and maintenance. California is one of the many states along the Pacific Coast, the Rocky Mountains, and the Appalachian Mountains with high costs associated with landslides. An average of 200 landslides and 10 road closures occur per year along California highways that require clean up and/or mitigation. Impacts of landslides include not only road closures with the resulting traffic delays and economic effects, but also can produce adverse environmental impacts ranging from view degradation to water-quality issues.

Landslide hazards often go unrecognized until it is too late and costs have already been incurred. Seemingly inadvertent alterations to roadway or drainage systems associated with routine maintenance or minor alignment alterations can reduce stability and even initiate conditions that trigger a slide. Furthermore, the extent of landslide hazards is generally not recognized, and the focus tends toward recently active slides. Although Caltrans' geo-professionals can identify slide risks if alerted, the vast majority of routine corridor planning and maintenance activity does not

involve their input. Therefore, a simple and direct means of communicating the broad context of landslide-hazards to all levels of staff was needed.

Figure 1 – 1997 Mill Creek Landslide

Figures 1 and 2 illustrate the value of broader context regarding landslide hazards. In the Winter of 1997 the Mill Creek Landslide closed down State Route 50 and dammed the American River for several hours. The landslide caused significant damage to many homes and roadways in that area as shown in Figure 1. State Route 50 was closed for almost a month which severely impacted travel and the South Lake Tahoe region's economy. The map in Figure 2 was prepared by the CGS as part of the emergency response and recovery from the 1997 incident, and now serves as a planning and maintenance document for developing long-term mitigation strategies. Note that the yellow areas in Figure 2 represent additional landslide features. Recognizing the value of this product, Caltrans geotechnical engineers solicited assistance from the GRG to

develop product standards using experience gained from slide mapping of selected highway corridors within a variety of climatological and geological settings.

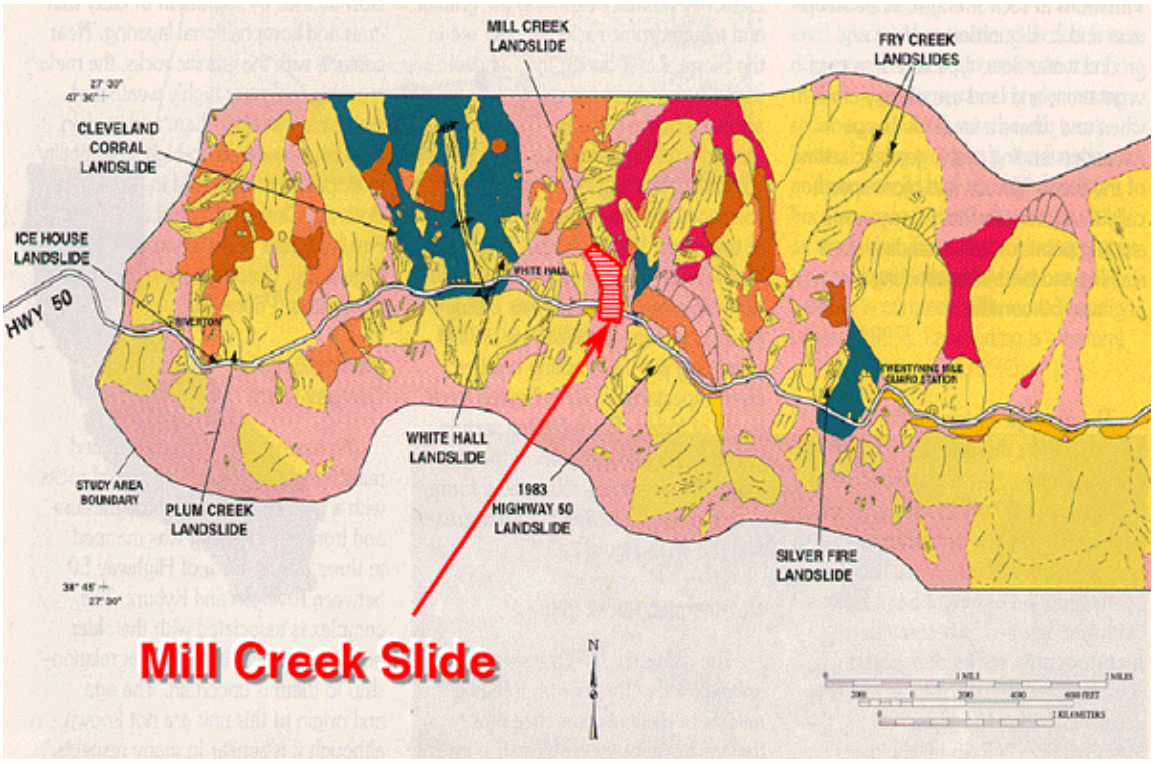

Figure 2 – Landslide Hazards along the Highway 50 Corridor

SCOPE OF THE RESEARCH PROJECT

The GRG established a major inter-agency agreement with CGS to serve as the technical lead for this project so as to leverage their prior experience, extensive archives, geology expertise, and GIS capabilities. The CGS maintains geologic archives for the State of California, thus providing unique access to tremendous information resources, including relatively obscure reports, maps, aerial photography, remote sensing data, and records compiled by a variety of organizations. CGS staff have compiled information from these diverse sources and performed extensive field verification surveys to ensure the veracity of their synthesis.

To assure that the CGS work met Caltrans' user needs, the GRG established a Project Advisory Panel (PAP), consisting of Caltrans geo-professionals and various District representatives to help guide the project. Initially, the PAP helped assemble a list of over 1200 miles of slide-prone highway corridors based on Caltrans' project experience. The PAP also aided prioritization of 187 route miles along seven corridors in five Districts for mapping under this research-funded demonstration project. Selection criteria included route importance, diversity of Districts, and

assuring that a representative variety of geologic and climatological environments were considered. Highway corridors selected for the project are shown in Table 1.

Table 1 – Corridors Selected for the Pilot Study

District	County	Rte	Segment	PM Limits	Distance (mi)
1	DN	101	Wilson Creek to Cresent City	12 to 27	15
1	MEN	101	Leggett to Red Mtn. Creek	90 to 98	8
1	HUM	299	Blue Lake to Willow Creek	8 to 39	31
4	SON	1	Bodega Bay to Fort Ross	10 to 34	24
5	MON	1	Big Sur to Point Lobos	44 to 70.42	27
5	MON	1	County Line to Big Sur	0 to 44	44
5	SLO	1	San Carpoforo Creek to County Line	71.4 to 74.3	3
7	LA	5	Jct Route 126 to Gorman Creek	55 to 80	25
8	RIV	60	Redlands Blvd to Junction Route 10	20 to 30	10

Work on the project began in December 1999 and was completed in June 2006 at a cost of $777,000. Early on in the project, District 5 Planning recognized the value of the research products generated by this study. As a result they contributed an additional $460,015 to have more mapping done within their district as well as perform other landslide hazard related studies associated with the Big Sur Coast Highway Management Plan.

MAPS AND PRODUCTS

The CGS, PAP, and GRG developed general reporting and display standards. GIS-based maps prepared at 1:12,000 scale were selected as the optimal means for compiling and archiving available data and interpretations. GIS-based maps represent a major step forward from the hand-drawn generation of maps (e.g. Figure 1), since each landslide can be represented spatially in a map display and also assigned informational attributes in separate data tables. Attributes selected by the PAP for map display include landslide type (i.e. rock slide, debris slide, debris flow, earth flow), activity (active or historic, dormant-young, dormant-mature, dormant-old), and confidence of interpretation (i.e., definite, probable, questionable). Additional attributes assigned to all slides include the interpreted depth of slide, azimuth of movement, geologic unit, lithology, and data sources. Significant landslides are assigned additional information including size, recency of movement, probable rate of movement, and possible consequences for the highway. A corridor-specific report is also generated for each route, summarizing geologic setting and key landslide features. These reports and PDF versions of the maps are included in the Appendices to this report.

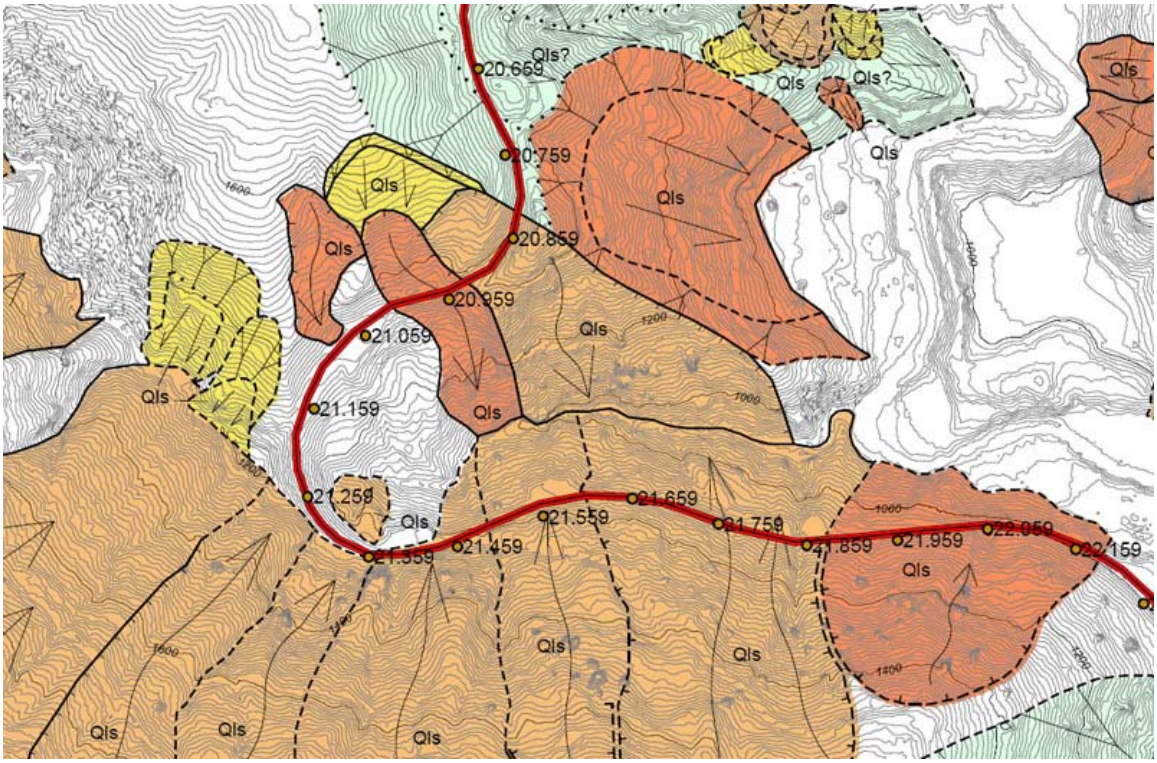

Figure 3 – Example of Landslide Hazard Map

Draft summary reports and map plates in pdf format will be made available for download via the Caltrans internet. Figure 3 shows an example of what the landslide hazard maps look like. GIS files for each mapped corridor can be found on a DVD attached to this report.

ESTIMATE OF BENEFITS RESULTING FROM THIS RESEARCH

There are a number of quantifiable benefits that have resulted from the research project. Furthermore, substantial benefits could be realized through broader implementation of these map products into Caltrans practice. An evaluation of the benefits based upon costs for two aspects of landslide hazard management are presented here.

First, the maps provide a valuable resource for Caltrans staff that saves time, and can result in cost savings. The new maps represent a comprehensive synthesis of all the geologic and landslide hazard information available for a region. In preparing the maps, CGS had to identify, review, and synthesize geologic and landslide hazard map data from multiple sources that were not always consistent or accurate. This activity can be a substantial effort and to date had been carried out by Caltrans staff on a project by project basis. A typical data gathering effort for a single project would require spending a day gathering, reviewing, and compiling this data, costing an estimated $80,000 annually.

(1 person)(1 day)($50/hr)(8 hr)(200 landslides/yr) = $80,000 per year

Second, the new maps provide a tool for Caltrans to be more proactive in mitigating landslide hazards before they happen. Currently, most of the costs are associated with clean-up and construction efforts. Smaller landslides that close a roadway for a couple of days can cost approximately $100,000 to $200,000 to clean up the slide debris and perform minor roadway or embankment repairs. Larger landslides can result in a month or more of road closures and can cost upwards of $3 million for clean up and repairs typically involving construction of larger retaining walls or other structures. In contrast, many landslide failures could be mitigated through relatively lower cost means such as dewatering, with typical costs in the $150,000 range. Considering that Caltrans deals with approximately 10 road closures per year, with perhaps two of them major slides, approximately $7.6 million is spent in response to landslides failures.

(2 large slides/yr)($3,000,000)	= $6,000,000 per year
(8 small slides/yr)($200,000)	= $1,600,000 per year

TOTAL	= $7,600,000 per year

If the maps had been used to identify and mitigate, say, one of the large and four of the small landslides statewide, the cost savings would be approximately $3,050,000 annually.

(mitigate 5 slides/yr)($150,000)	= $750,000 per year
(avoid 1 large slides/yr)($3,000,000)	= - $3,000,000 per year
(avoid 4 small slides/yr)($200,000)	= - $800,000 per year

TOTAL SAVINGS	= - $3,050,000 per year

Add to this the cost savings from data synthesis described earlier ($80,000), and the annual savings is estimated to be $3.1 million. Considering the cost of the research project ($1.2 million) and the potential annual savings over the course of the next ten years, a benefit-cost factor of 26 is calculated. That is, for every dollar spent on the research, an estimated $26 could be saved.

($3.1 million/yr) / (($1.2 million)/(10 yrs)) = 26 per year

The overall economic benefits and costs, direct and indirect, to the traveler are difficult to quantify, however, the reduced congestion resulting from mitigating landslide failures are

significant. For example, the previously mentioned Mill Creek Landslide had an estimated impact of over $1 million per day over the month that it closed the highway.

SUMMARY & RECOMMENDATIONS

This project developed a standard methodology for integrated archive and display of landslide hazards along a highway corridor to aid in risk assessment. Caltrans staff associated with the demonstration routes are encouraged to use and distribute these maps/reports (and web-based tools in the future) as resources to inform planning decisions, communicate with other agencies/public, and to guide maintenance practices for long-term proactive landslide hazard mitigation. Caltrans staff responsible for the other 1000-plus miles of slide-prone corridors are encouraged to examine these demonstration products, evaluate their utility, and decide whether similar mapping might warrant prioritization of future non-research budget resources.

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