Faster Response After Landslides on Highways

Caltrans Tests Portable Field Mapping Systems

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Portable field mapping systems significantly reduced the time to deliver engineering solutions for maintenance and construction after landslides affecting highways in California, minimizing costly delays.

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Landslides can be difficult to predict, and their effects on roadways can be significant. Responding quickly and effectively is key to minimizing costs and traffic delays.

Problem

Repairs and maintenance after landslides on U.S. highways cost an estimated $106 million annually. With an estimated 1,200 miles of landslide-prone highways, the California Department of Transportation (Caltrans) spends approximately $22 million each year on managing an average of 200 landslides and 10 road closures.

An extreme example is the Mill Creek landslide, which closed State Route 50 east of Sacramento in the winter of 1997 for more than one month and dammed up the American River for several hours. Smaller landslides, however—like the one on Highway 20 in Colusa County (photo, below)—occur more often and demand more resources.

Cut slope failure on Highway 20, Colusa County.

Detailed mapping of landslides is essential for understanding slope failures and for designing effective repairs. Data from maps that show cross sections assist in slope stability analyses and in designs for effective mitigation.

Landslides usually occur without warning. Engineers must respond rapidly, develop mitigation strategies within hours or days, and direct the construction and maintenance crews to carry out the repair work and restore traffic service safely. Rigorous surveys often are needed but are difficult because of the time constraints.

Solution

The Caltrans GeoResearch Group (GRG) initiated a research project to test innovative mapping technologies. GRG acquired two field mapping systems and evaluated them during deployments on landslides from October 2001 through October 2002.

The first system relied on differential Global Positioning System (GPS) and laser ranging hardware, providing accuracy within 1 meter. The second system employed real-time kinematic GPS hardware with centimeter-level accuracy.

Each system offered its own advantages in accuracy, user interaction, system complexity, training requirements, and cost. A goal therefore was to identify equipment with a good balance of these characteristics.

In a typical field mapping system, the operator carries the GPS unit and a ruggedized computer in a backpack or beltpack. The interface with the computer is through a handheld touch screen or pen screen. The GPS antenna, mounted in the backpack or on a pole, and the GPS receiver together provide the operator's position. An optional handheld or pole-

Field mapping in progress.

mounted laser ranging device allows the operator to stand in one position and acquire the relative coordinates of surrounding points that otherwise would be difficult to obtain with the GPS (photo, above).

As coordinate points are acquired, the software generates a digital terrain model, or topographic map, in real time on the computer's display. The basic training for an operator typically requires a two- to three-hour field orientation with an experienced staff person but does not require a background in surveying.

The real-time maps provide a distinct advantage—before leaving the site, the operator can determine immediately if the map details are satisfactory. With real-time topographic map data in the field, the user also can generate map cross-sections quickly.

Other data can be incorporated into the maps, such as field notes, digital photos, and hand sketches. These data then can be used for comprehensive mapping, slope stability analysis, and earthwork calculations.

Application

Both of the field mapping systems were deployed successfully in response to more than 30 landslides. In November 2002, for example, a cut slope failed on State Route 20 in Colusa County. On an emergency contract to develop slope grading plans, Caltrans engineers used the field mapping system to survey the slope, develop cross sections, perform slope stability analyses, and provide grading recommendations. One person completed the field mapping work in less than one day and generated a topographic map before leaving the site.

Benefits

In addition to producing higher quality data and maps, the systems realize an economic benefit. The labor cost for a single operator mapping the November 2002 Colusa County landslide over the course of one day was about $300. A conventional survey would have required a crew of three surveyors for one full day; after that, one person would need two more days to process the data and generate a map; the total labor would have cost $1,500.

Assuming 200 landslides per year, the mapping system would cost $180,000 to deploy for a 3-year period (200 landslides x $300 labor x 3 years); in contrast, conventional surveys would cost $900,000 (200 landslides x $1,500 labor x 3 years). Even including the initial cost of one mapping system ($15,000) and the cost of the research project ($80,000), the potential net savings would be $625,000, or a benefit of $3.30 for every $1 spent.

The direct and indirect economic benefits and costs to the traveler are difficult to quantify; however, quicker landslide response reduces the significant cost of congestion. For example, the month-long closing of the highway after the Mill Creek landslide cost more than $1 million per day.

The GRG research demonstrated the effectiveness of portable field mapping systems with successful test deployments on rapid-response landslide projects. These systems significantly cut the time required for staff to deliver engineering solutions for maintenance and construction work, reducing the delays to traffic.

Moreover, the systems performed in many situations for which conventional surveying procedures were not feasible. In these situations in the past—before the availability of portable field mapping systems—Caltrans engineers would have relied on crude estimates of landslide geometry from tape measurements and compass bearings.

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