THE FEASIBILITY OF COLLECTING ACCURATE LANDSLIDE-LOSS DATA IN UTAH

by

Francis X. Ashland

OPEN-FILE REPORT 410 March 2003
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES

The views and conclusions in this document are those of the author, and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

This open-file release makes information available to the public in a timely manner. It may not conform to policy and editorial standards of the Utah Geological Survey. Thus it may be premature for an individual or group to take action based on its contents.

Although this product represents the work of professional scientists, the Utah Department of Natural Resources, Utah Geological Survey makes no warranty, stated or implied, regarding its suitability for a particular use. The Utah Department of Natural Resources, Utah Geological Survey shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to claims by users of this product.

CONTENTS

ILLUSTRATIONS

TABLES

ABSTRACT

Whereas estimated landslide losses nationwide exceed $1.2 billion, annual landslide losses in Utah are poorly documented. This study evaluated the feasibility of collecting more accurate landslide-loss data in Utah. Currently, most local jurisdictions and state agencies do not systematically collect landslide-loss data, although some loss/cost data exist. Media reports provide unreliable and incomplete loss data. Analysis of media coverage of losses from recent damaging landslides indicates that losses may be underestimated by more than 50 percent using media-generated information. Less than 25 percent of the documented 2001-02 landslides were reported in the media, and less than half of the media reports contained loss information. Combining media reports with tax assessor's records provides somewhat more complete information. State agencies currently do not track landslide losses to utility lifelines and transportation corridors. However, some documentation regarding the costs of landslide stabilization projects exists in various agencies.

A lack of landslide-loss information in most of the state poses a serious challenge to accurate landslide-loss estimation in Utah. Statewide landslide-loss estimates would require extrapolation using data from jurisdictions where losses are reasonably well documented. Jurisdictions lacking loss data would need to be ranked based on landslide susceptibility, the amount of building inventory at risk, median property values, and other factors. Ideally, statewide landslide-loss estimation may be accomplished using a Geographic Information Systems approach.

Retrospective landslide-loss estimation was evaluated using the well-documented 1983 Thistle landslide. Whereas direct costs of the landslide were known within a year of the event, significant uncertainty in the more substantial indirect costs remained more than five years after the landslide disaster.

Obstacles to accurate landslide-loss estimation in Utah include the lack of coordinated inventorying of damaging landslides by state and federal agencies and local jurisdictions, transitory losses, damages caused by recurrent and ongoing landslide movement, the inability to differentiate damage resulting from landslides in multi-hazard areas, and trans-jurisdictional landslide losses. Another obstacle is the reluctance of government officials and homeowners to report losses because of perceived negative impacts.

INTRODUCTION

Nationwide, estimated losses from damaging landslides range from $1.2 to $2.4 billion annually (Schuster, 1996). In Utah, documented losses from damaging landslides in 2001 exceeded $3 million, including the costs to repair and stabilize hillsides along state and federal highways. The total losses caused by landslides in 2001 are, however, unknown because of the incomplete documentation of active landslides and a lack of loss data for all documented landslides that year.

This report evaluates the feasibility of collecting more accurate landslide-loss (cost) estimates in Utah. The majority of the report focuses on the current availability of landslide-loss data and uses case histories of recent damaging landslides. This report also compares the accuracy and availability of landslide-loss data from a variety of sources including media reports, county tax assessor's records, building permits, and estimates by local government officials and affected property owners. In addition, this report evaluates the potential for retrospective landslide-loss estimation using publications on the 1983 Thistle landslide, the most costly historical landslide in the United States.

SCOPE OF THIS STUDY

As part of this study, the Utah Geological Survey (UGS) performed the following:

- contacted local jurisdictions in landslide-prone areas to discuss current methods of tracking landslide losses and to assess the feasibility of more accurately estimating landslide losses,
- discussed the collection of landslide-related cost data with staff at the Utah Department of Transportation, Utah Division of Water Resources, and Utah Division of Emergency Services,
- evaluated landslide-loss information in media reports for recent landslides,
- evaluated the potential for retrospective landslide-loss estimation of well-documented, major landslide events, and
- identified potential obstacles to collecting accurate landslide-loss data.

CURRENT TRACKING OF LANDSLIDE LOSSES BY LOCAL JURISDICTIONS AND STATE AGENCIES

Landslide losses are currently not tracked in a systematic way by most local jurisdictions or state agencies affected by landslides. The methods used by local jurisdictions to track losses vary significantly as listed in table 1. In general, local jurisdictions that more systematically collected landslide-loss information were either large communities or communities that had recently been affected by either widespread or ongoing damaging landslides. State agencies also do not systematically track landslide costs.

Table 1.

Summary of current tracking of landslide costs by local jurisdictions and state agencies.

Local Jurisdiction	Department/Division	Cost Tracking System	Sources of Data	Limitations	Recent Damaging Landslides
Salt Lake City	Building Services and Inspections	Building permit-based database identifies cause of damage or distress.	Database, staff knowledge	Database incomplete. Unknown percentage of repairs without permit.	1000 E. Capitol Blvd-City Creek (1998-present) landslide
Layton	Community Development	Director began tracking landslide damage in 2001.	Staff knowledge	Data exist only for 2001 Heather Drive landslide.	2001 Heather Drive landslide, 1998 Sunset Drive landslide
Provo	Community Development Public Works/Engineering	Building distress/repair database	Database, staff knowledge	Database incomplete. Unknown percentage of repairs without permit. Hillside stabilization does not require permit.	Sherwood Hills landslide(s)
Salt Lake County	Public Works/Planning	None	None	Not applicable	Emigration Canyon landslides
Morgan County	Planning	None	None	Not applicable	2001 Frontier Drive landslide
Duchesne County	County Road	Reports documents road repair costs from landslide damage.	Report files, staff knowledge	-- -- --	1997 and 1999 Bluebell Road landslides
Weber County	Engineering	Some records on file	Building permits	Provides estimated costs for only retaining walls	1999 Eden water tank landslide

State Agency	Cost Tracking System	Sources of Data	Limitations
Department of Transportation	None	Major project contracts, staff knowledge	Contract costs overlap into successive calendar years. Landslide damage repairs contained within maintenance budgets.
Division of Water Resources	None	Major project contracts, staff knowledge	Landslide-related costs not readily discernable in contracts. Losses to water facilities tracked mostly by private companies.
Division of Emergency Services	None	Reports for federally declared disasters	None since 1983 Thistle landslide

Salt Lake City

Salt Lake City is Utah's largest city and state capital. Few landslides exist within the city limits, but certain hillside areas on the north and east sides of the city have been affected by historically active landslides. Damaging landslides occurred in the City Creek area northeast of the capitol building in the early- to mid-1980s and late-1990s. Losses caused by landsliding in Salt Lake City have included:

1. home equity losses,
2. hillside stabilization costs,
3. building repair costs, and
4. utility repair and replacement costs.

Mr. Harvey Boyd, Deputy Director of Salt Lake City Building Services and Inspections, indicated that hillside stabilization and building repair costs are typically recorded in a database along with a building permit number. Landslide repair and stabilization costs are identified in the database. Mr. Boyd indicated, however, that not all property owners obtain permits for such work. In addition, the city has in the past exempted property owners from obtaining a permit, if the costs of the repair or stabilization work are excessive, to reduce the overall expense to the affected individual. In these cases, the lack of a permit prevents the cost data for some of the most expensive repairs from being included in the database because the current tracking system is permit-referenced.

One recent example is the cost of hillside stabilization for a residential lot threatened by the 1998 Capitol Boulevard-City Creek landslide (figure 1). A line of drilled piers was installed in the crown of the landslide to protect a nearby house from enlargement of the active landslide directly downslope. Whereas typically these measures would have required a city permit, the city exempted the property owner from applying for one. The basis of the city's decision was to eliminate the expense of the permit from the cost to stabilize the property, which was about $250,000, the most significant documented landslide-related cost in Salt Lake City in the late-1990s. However, because no permit was required, the costs and details of this project are not in the city's database.

Mr. Boyd also indicated that numerous landslide-related repairs likely go undocumented in the City Creek area of Salt Lake City. He speculated that many homeowners are reluctant to admit that their properties are being affected by landsliding, and thus do not apply for building permits. The costs of these repairs are therefore undocumented. Building inspectors make periodic visits to properties in the City Creek area to identify potential problems or building distress. Currently the field inspection information is not included in the city database unless the information relates directly to a permit number. Salt Lake City is in the process of implementing a new database system that will incorporate the field inspection information, facilitating the recognition of landslide-related damage and distress. The new data, however, will not include a cost estimate.

Layton City

Layton is the largest city in Davis County, with an estimated population over 58,000. In 1998 and 2001 damaging landslide movement affected several residential hillside areas in Layton. In August 2001, movement of the Heather Drive landslide destroyed three houses (figure 2) and forced the relocation of three others, and total losses exceeded $1 million (Giraud, 2002). During this landslide, Mr. J. Scott Carter, Community Development Director, compiled accurate and comprehensive loss-estimate data that included the following:

1. home equity losses,
2. losses to mortgage companies,
3. emergency response costs,
4. landslide investigation costs, and
5. costs to relocate buried utilities.

Mr. Carter provided this loss-estimate data to the media, as well as to state and Layton City officials.

Prior to the Heather Drive landslide, Layton City officials did not systematically document such losses. The UGS (Giraud, 1999a; Ashland, 2003) estimated losses from the 1998 Sunset Drive landslide, which destroyed one house, using media reports and information from Layton City officials. Mr. Carter has individual knowledge of certain other landslide-related losses in Layton, but the Davis County tax assessor's records and media reports are the only written documentation.

Provo City

Provo is the largest city in Utah County as well as the third largest in Utah. Landslide deposits underlie several areas along the east side of Provo. The Sherwood Hills subdivision sits atop a large complex of landslide deposits that has undergone local damaging movement in the early- to mid-1980s and mid- to late-1990s. Two houses in the subdivision have been destroyed by landslide movement since the mid-1990s (figure 3). Landslide movement has also caused local building distress requiring repair and hillside stabilization and damaged roads and underground utilities. Losses in the Sherwood Hills subdivision attributable to landslides include the following:

1. home equity losses,
2. losses to mortgage companies (destroyed houses),
3. hillside stabilization costs,
4. building repair costs,
5. costs to repair and replace roads and utilities,
6. lot-specific landslide investigations costs (property owners),
7. subdivision-wide landslide investigation costs (Provo City), and
8. losses in tax revenues from distressed and destroyed properties.

Figure 1. *Damage caused by movement of Capitol Boulevard-City Creek landslide to rear of lot at 1000 E. Capitol Boulevard, Salt Lake City in 1998.*

Figure 2. *Damage to one of three houses destroyed by movement of the Heather Drive landslide, Layton in 2001.*

Figure 3. Damage to a house caused by movement of upper part of the Sherwood Hills landslide in Provo. House was condemned in January 2000.

The Provo City Engineer and Chief Building Official are both familiar with specific losses in the Sherwood Hills subdivision and elsewhere in Provo. Documented building distress is recorded in a database by city building inspectors. Possible geologic causes of any distress are recorded by a code, but landsliding is not currently differentiated from other geologic processes that might cause distress. Whereas the costs of repairs are included in the database, certain costs such as hillside stabilization costs that do not require a city permit are not. Building permit records also do not differentiate between landslide repairs and standard remodeling. Mr. Chuck Hugo, Chief Building Official, estimates that a large percentage of repairs are made by property owners without obtaining a building permit.

Other Local Jurisdictions and Statewide Estimates

Most other jurisdictions generally lack the staff or procedures for documenting landslide losses. In these jurisdictions, the only landslide-loss information is personal knowledge of local government staff members. The likelihood that the costs of major landslide damage will be documented increases in areas where landslides are relatively rare. In Duchesne County, the county road department has been able to document costs to repair roads damage by landslides and rock falls because of the small number of recent events. In most other jurisdictions, building permitting procedures do not identify landslide repairs or document costs. In some cases potential landslide-related costs are not documented because of a lack of rigorous code enforcement due to inadequate government staff or resources. Due to the general lack of uniform loss documentation by most local governments, significant changes in procedures would be required before accurate statewide landslide-loss estimates could be achieved in Utah. The state, most likely the UGS, would need to coordinate and facilitate implementation of landslide-loss documentation procedures, but cooperation of all jurisdictions is unlikely.

The extent and total dollar value of landslide losses in a jurisdiction depends mainly on landslide susceptibility, the extent of hillside development, and property values. Landslide-loss information is lacking in most of the state and thus estimating statewide losses would require extrapolation using data from jurisdictions where losses are reasonably documented. Jurisdictions lacking loss data would need to be ranked based on landslide susceptibility, the amount of building inventory at risk, median property values, and other factors. Ideally, statewide landslide-loss estimation may be accomplished using a Geographic Information Systems approach.

Utah Division of Water Resources

The Utah Division of Water Resources funds water projects including the repair and replacement of dams and canals damaged by landslides. Table 2 describes the status of landslide-loss information available from the Utah Division of Water Resources. Dr. Ben Everitt, a geologist with the division, has individual knowledge of specific landslide problems, but the division does not systematically compile landslide-loss data for dams, canals, and other water-delivery facilities. The division also funds and performs geological and geotechnical investigations of certain facilities, such as an ongoing

landslide investigation for the Recapture Dam. Contracts for these investigations are filed with the division, but differentiating landslide investigations from other geotechnical investigations would require thorough evaluation of the contract and related documents. Dr. Everitt indicated that additional costs could be inferred for dam safety investigations of dams on landslides. However, the exact additional costs are unknown. Losses from landslide damage to canals are substantial, but are not tracked by the division. Most canals are privately owned, and are not required to report losses or repair costs to any government agency.

Table 2.

Status of landslide-loss data available at the Utah Division of Water Resources.

Type of Data	Limitations
Staff knowledge	Limited to specific projects
Contracts	Do not directly specify whether work is landslide-related
Feasibility reports (for proposed projects requesting funding)	Loss data may be part of documentation; tracking of annual losses to canals and water-distribution facilities is the responsibility of private companies

Utah Department of Transportation

The Utah Department of Transportation constructs, maintains, and upgrades Utah's state and interstate highways. As part of this responsibility, the department repairs road damage caused by landslides, and takes various measures to reduce landslide damage or stabilize cut slopes. Ms. Leslie Heppler, a geologist with the Geotechnical Division, and division engineers have individual knowledge of specific landslide problems along Utah highways, but the department does not systematically compile landslide-loss data. Ms. Heppler has individual knowledge of costs associated with recent major landslide stabilization and repair projects. Contracts for this work are also filed with the department. However, the costs of most minor landslide repairs (removal of rock-fall debris, periodic cleaning of ditches and catchments, pavement repair, placement of roadside barriers, etc.) are included within the annual maintenance budgets. In general, annual highway maintenance costs attributable to landslide damage are undocumented.

Utah Division of Emergency Services

The Utah Division of Emergency Services (DES) coordinates emergency management activities in the state. As part of this responsibility, DES staff occasionally document geologic hazards or request such documentation by other state or federal agencies such as the UGS or Natural Resources Conservation Service, respectively. Dr. Fred May, former State Hazards Mitigation Officer, indicated that the division generally only documents losses associated with federally declared disasters or in preparation for

substantiating that a disaster qualifies for federal assistance. No landslide-caused federally declared disasters have occurred since 1983 in Utah.

THE AVAILABILITY OF LANDSLIDE-LOSS ESTIMATES IN MEDIA REPORTS

Although media reports exist for many newsworthy landslides, media coverage of damaging landslides in Utah is inconsistent and sporadic. Table 3 lists the nine documented active/damaging landslides in Utah in 2001 and 2002, the potential and estimated actual costs, and the number of news articles covering each event. Media reports exist for only two of these landslides, most notably the 2001 Heather Drive landslide (see case history below). The absence of media reports for most landslides suggests that media coverage is an unreliable information source for preparing accurate landslide-loss estimates. Whereas the losses at most of these landslides remain undocumented, estimated losses at the 2001 Frontier Drive landslide (figure 4), for which no media reports exist, total nearly $752,000. In general, homeowners and local jurisdictions do not encourage media attention and in many cases prefer to avoid it. The only landslides in 2001-02 covered by the media were either large and newsworthy (Heather Drive landslide) or were brought to the attention of the media by the UGS (Capitol Blvd-City Creek landslide) to highlight scientific investigations.

Table 3.
Active landslides of 2001 and 2002, potential and estimated losses, and number of media reports.

Landslide	Year(s) Active	Estimated Losses	Specific or Potential Losses (Costs)	Media Reports
Capitol Blvd.- City Creek	2001, 2002	na	Home equity losses, movement monitoring, infrastructure relocation/repair	1 (2001)
4229 Southridge Ct.	2002	na	Home equity loss, landslide investigation, slope repair	none
I-80 Milepost 131.15	2002	na	Highway maintenance, damage to biostabilization measures	none
I-80 Lambs Canyon exit	2001, 2002	na	Highway maintenance	none
Sherwood Hills – Mile High and Windsor Drives	2001, 2002	na	Home equity losses; repairs to roads, utilities, and houses	none
Truman Drive	2002	na	Home equity loss, landslide investigation, slope repair	none
Green Hollow-High Mountain View Circle	2001, 2002	na	Home equity loss, landslide investigation, slope stabilization	none
Frontier Drive	2001	$751,500	Home equity loss, landslide investigation, slope stabilization	none
Heather Drive	2001	$1,092,000	Home equity loss, landslide investigation, slope stabilization, emergency response	20 (2001-2002)

Figure 4. *Damage to the rear of a lot caused by movement of the Frontier Drive landslide, Mountain Green in 2001. Losses and stabilization costs of this landslide exceeded $750,000.*

THE POTENTIAL USE OF MEDIA REPORTS AND TAX ASSESSOR RECORDS TO ESTIMATE LANDSLIDE LOSSES

The 2001 Heather Drive landslide in Layton, Utah destroyed three houses and forced the relocation of three others. The damaging landslide movement generated considerable media coverage by local newspapers and television. Twenty newspaper and television website articles on the landslide that cover a period between August 20, 2001, and April 5, 2002, were reviewed to determine the completeness of the landslide-loss data (table 4). Eleven of these articles are subsequent to August 29, 2001, the date by which most of the landslide damage had occurred. In this section, landslide-loss data from media reports are compared to detailed cost estimates by Layton City and to estimates based on county tax assessor's records.

Table 4.
Extent of media coverage of losses caused by the Heather Drive landslide.

Description	Number
Total news articles	20
Total with loss data	9
Articles with itemized loss information	5
Articles after August 29, 2001	11
Total post-8/29/01 articles with loss data	7

On August 30, 2001, Layton City provided the local media with an estimate of the landslide losses of around $1 million. A subsequent refinement of this estimate was included in a UGS report (Giraud, 2002) on the landslide and subsequently cited (directly or indirectly) in three newspaper articles. Table 5 summarizes Layton City's landslide-loss estimate as of late April 2002.

Table 5.
Heather Drive landslide losses estimated by Layton City.

Description	Estimate
Home equity losses	$590,000
Mortgage company losses	$450,000
Layton City's emergency response	$28,000
Utility relocation	$24,000
Total	**$1,092,000**

County tax assessor's records allow estimation of some of the losses to residential properties on the landslide. Table 6 summarizes the loss estimates using these records. A significant difference exists between the total estimated property losses using the county tax assessor's records ($690,910) and the property losses estimated by Layton City ($1.04 million). The estimate based on the county tax assessor's records is only about two-thirds the more detailed estimate made by Layton City. The differences likely are due to the following:

1. county-assessed property values may not accurately reflect pre-landslide market value and underestimate home equity losses, and
2. losses to mortgage companies in Layton City's estimate included interest due on the principal.

Table 6.
Inferred property losses from the Heather Drive landslide based on county tax assessor's records.

Description	Recorded Value
House and lot – 1369 E.	$154,040
House and lot – 1393 E.	$218,880
House and lot – 1417 E.	$111,700
Lot – 1381 E.	$37,990
Lot – 1423 E.	$34,240
Lot – 1431 E.	$32,000
Lots – 1456 Tartan Way	$102,060
Total	**$690,910**

Several newspaper articles itemized certain landslide losses resulting from the 2001 Heather Drive landslide. Table 7 summarizes these losses that total about $520,000. Thus, newspaper articles documented specific details for only about half of the total losses estimated by Layton City. In addition, differences exist between newspaper accounts and county tax assessor records for specific losses such as the value of the 1369 E. and 1393 E. properties destroyed by the landslide. Also, certain losses, such as reduced tax revenues and charitable contributions to the affected families, are not included in Layton City's landslide-loss estimate.

By combining landslide-loss data from the county tax assessor's records with specific loss information reported in newspaper articles, a more complete list of losses associated with the Heather Drive landslide is obtained that can then be compared with the detailed loss estimate compiled by Layton City. Table 8 summarizes the combined landslide-loss estimates using both the county tax assessor's records and specific landslide-loss information in newspaper articles.

Table 7.

Summary of itemized Heather Drive landslide-loss information in newspaper articles.

Description	Reported Cost
House and lot – 1369 E.	$175,000
House and lot – 1393 E.	$200,000
Helical anchors – 1369 E.	$80,000
Charitable contributions to families	$21,000
Layton City emergency response	$19,800
Landslide investigation	$14,000
County tax revenue losses	$10,000
Total	**$519,800**

Table 8.

Heather Drive landslide-loss estimate using county tax assessor's records and itemized loss information in newspaper articles.

Description	Reported Cost
House and lot – 1369 E.	$154,040
House and lot – 1393 E.	$218,880
House and lot – 1417 E.	$111,700
Lot – 1381 E.	$37,990
Lot – 1423 E.	$34,240
Lot – 1431 E.	$32,000
Lots – 1456 Tartan Way	$102,060
Helical anchors – 1369 E.	$80,000
Charitable contributions to families	$21,000
Layton City emergency response	$19,800
Landslide investigation	$14,000
County tax revenue losses	$10,000
Total	**$835,710**

Table 9 compares the available estimates of landslide losses caused by the 2001 Heather Drive landslide and shows the variation between the detailed landslide-loss estimate compiled by Layton City and the other estimates. The total losses based on specific information in newspaper articles, county tax assessor's records, or a combination of these sources range from about 45 to 77 percent of the total losses estimated by Layton City. The table shows that the exclusion of certain losses (county tax revenues, charitable contributions) in Layton City's estimate accounts for only a small fraction of the difference. As stated above, specific information on losses in newspaper accounts is incomplete and thus the ratios shown in table 9 are solely for this case and are included for comparison purposes only. County tax assessor records show only the losses to the affected residential property, may poorly reflect equity losses, do not show interest due to mortgage companies, and exclude other losses. The comparison

shows that in the absence of a detailed audit of landslide losses as was performed by Layton City, information from newspaper articles and county tax assessor's records can also be used to estimate landslide losses. However, in this case, the total losses were significantly underestimated using these two sources.

Table 9.
Comparison of Heather Drive landslide-loss estimates using different sources.

Source(s)	Estimated Losses	Ratio[1] (percent)	Notes
Layton City	$1,092,000	na	Excludes charitable contributions, tax revenue losses, and losses at 1456 Tartan Way
	$1,040,000	na	Losses to residential property only
County tax assessor records	$690,910	66	Losses to residential properties only
Newspaper articles	$519,800	48	Specific information on losses
Newspaper articles	$488,800	45	Specific information on losses excluding charitable contributions and tax revenue losses
Combined tax records and newspapers	$835,710	77	More accurate estimate used
Modified combined	$804,710	74	Excludes charitable contributions and tax revenue losses

[1]Relative to appropriate Layton City estimate.

THE FEASIBILITY OF RETROSPECTIVE LANDSLIDE-LOSS ESTIMATION

The 1983 Thistle landslide (figure 5) in Utah County is North America's most costly individual landslide (Schuster, 1996) and an ideal case history for evaluating retrospective landslide-loss estimation. Numerous published accounts (Kaliser, 1983; Anderson and others, 1984; University of Utah, 1984; Schuster, 1985, 1996; Duncan and others, 1986; Kaliser and Fleming, 1986; Kaliser and Slosson, 1988; Kaliser, 1989; Slosson and others, 1992) exist of the landslide event. Reported direct and indirect costs were evaluated to examine the variation and reliability of loss estimates for this major and well-documented landslide event.

Table 10 summarizes the published direct and indirect cost estimates for the 1983 Thistle landslide. Direct costs include the replacement of the railroad line and highway destroyed by the landslide, losses to the town of Thistle, and costs to stabilize and investigate the stability of the landslide. Indirect costs include lost revenue to the Denver & Rio Grande Railroad from loss of the rail line, lost coal-mining revenues from mines isolated from their market, and economic losses to local communities isolated by the loss of the transportation routes.

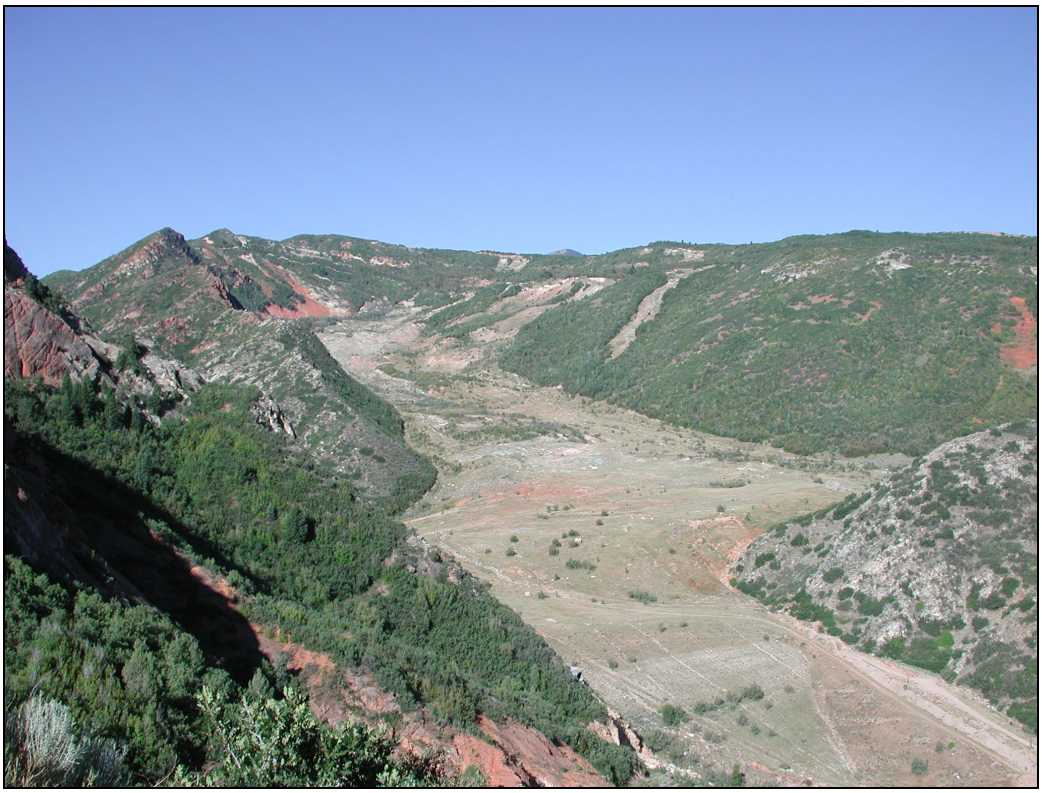

Figure 5. *View of the Thistle landslide, Utah County. Direct costs associated with movement in 1983 exceeded $200 million. The landslide also reactivated in 1997 and 1998.*

Table 10.

Comparison of direct and indirect cost estimates for the 1983 Thistle landslide.

Estimated Cost	Cost Type	Literature	Source cited
$200+ million	Direct	Kaliser, 1983; Duncan and others, 1986	Kaliser, 1983
$200 million	Direct	Schuster, 1985, 1996; Kaliser and Fleming, 1986; Slosson and others, 1992	University of Utah, 1984
$250+ million	Unspecified	Christenson and others, 1987	None
$337 million	Combined	Kaliser and Slosson, 1988; Kaliser, 1989	Stephens, 1984

Four reports (Schuster, 1985, 1986; Kaliser and Fleming, 1986; Slosson and others, 1992) list the direct costs at about $200 million. Three of these (Schuster, 1985, 1996; Kaliser and Fleming, 1986) cite the University of Utah (1984) report as the source of the direct cost estimate, while Slosson and others (1992) credit the estimate to Fleming and Schuster (1985). Three reports (Kaliser, 1983; University of Utah, 1984; Duncan and others, 1986) indicate that direct costs exceeded $200 million, but do not provide specific direct cost estimates. Duncan and others (1986) cite the Kaliser (1983) publication as the source of the estimate. Christenson and others (1987) indicate the cost of the landslide exceeded $250 million, but do not specifically indicate whether the figure refers to direct or combined direct and indirect costs. Kaliser (1989) indicates that the combined direct and indirect costs of the 1983 Thistle landslide were about $337 million and provides some details on the specific costs that account for the majority of the estimated costs. The earliest reported estimates (Kaliser, 1983) of direct costs associated with the 1983 Thistle landslide preceded completion of some of the major transportation lifeline relocation projects. While later reports were published following completion of most of the work related to relocation of transportation lifelines, most cite direct cost figures from earlier published reports.

Indirect costs of the 1983 Thistle landslide were not readily available directly after the event and remain difficult to assess even today. The University of Utah (1984) report indicated that indirect costs were pervasive in Utah's economy, but did not provide specific estimates. Kaliser and Slosson (1988) reported the combined direct and indirect costs reached about $337 million, but added that comprehensive knowledge of the indirect costs of the 1983 Thistle landslide was still lacking at the time of their report five years following the event. By subtracting the estimated $200 million in direct costs reported in the University of Utah (1984) report from the estimated combined costs of $337 million in the Kaliser and Slosson (1988) report, total indirect costs can be inferred to be about $137 million. However, Kaliser (1989) reported indirect costs of at least $122 million from lost coal mining revenues alone. In addition, Schuster (1996) reported railroad revenue losses of about $81 million. These two indirect costs total $203 million and exceed the inferred indirect costs based on the estimated combined cost of Kaliser and Slosson (1988).

Certain costs associated with the 1983 Thistle landslide still remain unrealized. The abandonment of the Sanpete line of the Utah railway in 1983 disrupted coal shipments from the Wasatch Plateau mining areas to various markets. Following abandonment of the line, some coal was transported by truck to a railroad loading facility in Juab County.

The possibility of constructing a replacement railroad that avoids the Thistle area is currently being considered (Oberbeck, 2002). Ultimately, if the railroad line is built, at least part of the cost, estimated at about $70 million (Oberbeck, 2002), could be associated with the 1983 Thistle landslide.

This analysis of retrospective landslide-loss estimation using the 1983 Thistle landslide as a case history indicates the following:

1. Direct cost estimates became available within a year of the event, but later estimates relied considerably on the initial estimates and were not updated with more recent and accurate cost data.
2. Indirect cost estimates were difficult to obtain for several years following the landslide.
3. Even five years after the event, uncertainties existed in the indirect cost estimates.
4. Certain costs may still be unrealized more than two decades following the event.

POTENTIAL OBSTACLES TO ACCURATE LANDSLIDE-LOSS ESTIMATION

Estimating the Number of Damaging Landslides

While some recent landslides in the Wasatch Front area of Utah have been well documented (Ashland, 2003), significant uncertainty exists regarding the number of damaging landslides that occur each year. Currently, no coordination exists between local jurisdictions and state and federal agencies to share information on damaging landslides on an annual basis. Thus, the knowledge of any one agency or jurisdiction concerning statewide landslide losses is limited. In addition, rarely is loss data shared by private companies that operate critical lifelines that might be impacted by landslides. The uncertainty in the relation between the number of documented damaging landslides and the actual number of such landslides prevents a basis for estimating statewide losses.

Transitory Losses: the 1998 Sunset Drive Landslide, Layton

In 1999, estimated costs associated with the 1998 Sunset Drive landslide (figure 6) in Layton included the losses in equity and mortgage payments of two houses damaged by the landslide (table 11). One house was eventually demolished and the estimated loss proved to be real. However, the second house that had been abandoned at the time of the initial loss estimate was subsequently reoccupied by a new homeowner. If some equity loss is assumed for the second house, in this case 25 percent ($50,000), then the post-1999 direct losses total only $306,000 or about 67 percent of the 1999 estimate.

Figure 6. *Two houses damaged by movement of the Sunset Drive landslide, Layton in 1998. House on the right was subsequently condemned and demolished.*

Table 11.
Estimated direct losses at the Sunset Drive landslide.

Description of Loss	Estimated Losses (dollars)	Source of Loss Estimate
House at lot 105 (demolished)	$200,000	Deseret News, April 21, 1998
House at lot 104 (abandoned)	$200,000[1]	Deseret News, April 21, 1998
Demolition of house at lot 105	$ 10,000	Standard Examiner, October 20, 1998
Geotechnical slope-stability investigation	$ 40,000	Deseret News, October 15, 1998
Relocation fees for family at lot 105	$ 6,000	Standard Examiner, September 10, 1998
Subtotal Value of Direct Losses (as of March 1999)	***$456,000***	

[1]*House subsequently re-occupied and thus loss may be overestimated.*

Damage Caused by Recurrent or Ongoing Movement: the Sherwood Hills Landslide, Provo

Recurrent or ongoing movement at very or extremely slow rates results in widespread, but typically limited damage in the Sherwood Hills subdivision, Provo. The cumulative effects of movement, sometimes over several years, locally results in damages that require repair or result in severe distress. Assigning the costs of landslide damage to a specific calendar year may be difficult where movement and the resulting damage occurs gradually over two or more years. Landslide movement typically triggers in the fall and early winter and continues into the spring of the following year. Thus, landslide movement that triggered in one year causes damages that become severe enough to be documented in the following year.

Differentiating Landslide-Related Damage from Other Causes

Multi-hazard areas exist throughout Utah and complicate attempts to identify and quantify landslide damage. Other hazards that cause distress and damage to buildings, roads, and utilities include expansive and collapsible soils, piping, frost heave, and shallow ground water. Other causes of building distress include poorly compacted fill soils and poor preparation of footing and slab subgrade soils, settlement of excessive fills, and the use of inferior building materials and construction practices.

In several landslide areas, differentiating landslide-related damage from damage due to other causes posed a significant challenge for local and state officials. At the Sherwood Hills landslide prior to 1998, local officials attributed the majority of distress to causes other than landsliding, including settlement of excessive fills, expansive soils, and poor construction practices and foundation preparation. Appreciation of the landslide origin of the building distress in Sherwood Hills only followed detailed landslide

investigations and analysis of GPS survey and inclinometer data. In 1998, building distress in the Springhill subdivision in North Salt Lake could not be unequivocally attributed to landsliding based solely on geologic reconnaissance of the problem area (Giraud, 1999b). Subsequent geotechnical investigation including data from inclinometers (Terracon, 1998) was required before the cause of the distress was directly attributable to landsliding.

Trans-jurisdictional Landslide Losses

In some cases, lifelines may cross jurisdictional boundaries, including state lines, such that landslides on one side of the boundary create losses on the other. For example, the West Cache Canal in northern Utah and southern Idaho delivers about 95 percent of its irrigation water to Utah. Landslides in the upstream Idaho section of the canal have caused damages and disrupted the delivery of irrigation water. In 1995, landslide-induced failure of the canal caused estimated losses of about $875,000 (West Cache Irrigation Company, 1996) including the $125,000 cost to repair the canal. Most of the agricultural losses, about $712,500 of a total $750,000 in losses, were the result of reduced crop yields on Utah farms lacking critically needed irrigation water.

CONCLUSIONS

Currently, landslide losses in Utah are poorly documented. Most local jurisdictions and state agencies contacted as part of this study do not systematically track such losses. Databases in which landslide-related costs may be contained are commonly referenced to building permits, and thus track only a percentage of the actual damage repair and stabilization costs from landsliding. Also building permits commonly do not identify the causes of damage or list the cost of repairs. Media reports and other potential loss data such as tax assessor records provide only partial information on actual losses. State agencies currently do not track landslide losses to utility lifelines and transportation corridors. However, some documentation regarding the costs of landslide stabilization projects exists in various agencies.

A lack of landslide-loss information in most of the state poses a serious challenge to accurate landslide-loss estimation in Utah. Statewide landslide-loss estimates would require extrapolation using data from jurisdictions where losses are reasonably well documented. Jurisdictions lacking loss data would need to be ranked based on landslide susceptibility, the amount of building inventory at risk, median property values, and other factors. Ideally, statewide landslide-loss estimation may be accomplished using a Geographic Information Systems approach.

Retrospective landslide-loss estimation appears feasible for major landslides that are well documented, but uncertainties in the loss estimates pose a problem, particularly for indirect costs. Direct cost estimates were available for the 1983 Thistle landslide within a year of the event. Later articles that had access to more recent and thus likely more accurate direct costs relied on the initial estimates, however. Uncertainties existed in

indirect costs associated with the landslide more than five years after the event, and some possible indirect costs of the landslide still remain unrealized in 2002.

Several potential obstacles to accurate landslide-loss estimation were identified as part of this study by examining recent case histories of damaging landslides in northern Utah. These potential obstacles include the lack of coordinated inventorying of damaging landslides by state and federal agencies and local jurisdictions, transitory losses, damages caused by recurrent and ongoing landslide movement, the inability to differentiate damage resulting from landslides in multi-hazard areas, and trans-jurisdictional landslide losses. In addition, homeowners and local governments are often reluctant to report losses because of perceived negative effects.

RECOMMENDATIONS FOR MORE ACCURATE LANDSLIDE-LOSS ESTIMATION IN UTAH

Better coordination between state and federal agencies, local jurisdictions, lifeline companies, and other professionals is necessary to obtain more accurate landslide-loss estimates in Utah. Table 12 provides a list of state and federal agencies that should develop a cooperative program to document damaging landsliding in the state. In addition, local jurisdictions, lifeline companies, and other professionals should also participate in documenting or reporting damaging landslides or distress and/or damage in hillside settings. Table 13 lists other possible participants.

Table 12.
List of state and federal agencies that document landslides in Utah.

Type	Agency
State	Utah Geological Survey
	Division of Water Resources
	Department of Transportation
	Division of Emergency Services
Federal	Natural Resources Conservation Service
	U.S. Forest Service (districts)
	Bureau of Land Management
	U.S. Geological Survey

To improve both the interest in and methods used to compile landslide-loss estimates, local jurisdictions need to be invited to further explore the need and ease of this effort. Certain local jurisdictions, most notably Salt Lake City and Layton City, have staff with individual interests in more accurate landslide-loss data. By providing these individuals the opportunity to share their thoughts and experience with other local jurisdictions, more interest in compiling landslide-loss estimates may develop at a local level. In addition, a proposed database that will be implemented by Salt Lake City appears suitable for accurate loss estimation at a local level. The database will identify repair costs related to

landsliding and will not be restricted by a permit-referenced system. Thus, the database will likely include more information than other databases currently used at a local level and ease access by the user to landslide-loss data.

Table 13.
List of possible participants to document damaging landslides in Utah.

County governments	Road departments, planners, engineers, and building officials
City governments	City engineers and building officials
Universities	Geology departments (faculty)
Lifeline companies	Questar Gas Utah Power Petroleum pipeline companies Water districts
Canal companies	Various
Geotechnical consultants	Engineers and geologists

However, a fundamental change in the documentation procedures of many local governments would be a prerequisite for implementing a database such as Salt Lake City's. The UGS would likely need to undertake a significant effort to increase awareness and educate local government officials of the benefits, if any, of making such changes. Initially, only a few jurisdictions may be willing to participate based on the level of interest expressed by officials contacted as part of this study.

ACKNOWLEDGMENTS

This research was sponsored jointly by the Utah Geological Survey and U.S. Geological Survey (award no. 01HQ-R01914), and conducted as part of the Association of American State Geologists Landslide Loss Estimation Pilot Project and performed in conjunction with similar research by the geological surveys of the states of California, Kentucky, Nebraska, Ohio, Oregon, and Pennsylvania. I am grateful to James Davis (California Geological Survey) for both conceiving of and obtaining funding for the project. Harvey Boyd (Salt Lake City), J. Scott Carter (Layton City), Ben Everitt (Utah Division of Water Resources), Leslie Heppler (Utah Department of Transportation), and Chuck Hugo and Nick Jones (Provo City) provided valuable information related to recent landslide losses and the procedures used to track them by various agencies. Alan Isaacson (University of Utah Bureau of Economic and Business Research) provided information on losses caused by the 1983 Thistle landslide.

REFERENCES

Anderson, L.R., Keaton, J.R., Saarinen, T.F., Wells, W.G., 1984, The Utah landslides, debris flows, and floods of May and June 1983: Washington, D.C., National Academy Press, 96 p.

Ashland, F.X., 2003, Characteristics, causes, and implications of the 1998 Wasatch Front landslides, Utah: Utah Geological Survey Special Study 105, 49 p.

Christenson, G.E., Lowe, M.V., Nelson, C.V., and Robison, R.M., 1987, Geologic hazards and land-use planning, Wasatch Front: Utah Geological and Mineral Survey, Survey Notes, v. 21, no. 1, p. 3-7, 10-14.

Duncan, J.M., Fleming, R.W., and Patton, F.D., 1986, Report of the Thistle Slide Committee to the State of Utah Department of Natural Resources Division of Water Rights: U.S. Geological Survey Open-File Report 86-505, 95 p.

Fleming, R.W., and Schuster, R.L., 1985, Implications of the current wet cycle to landslides in Utah, *in* Bowles, D.S., editor, Delineation of landslide, flood, and debris flow hazards in Utah: Logan, Utah Water Research Laboratory, Utah State University, p. 19-28.

Giraud, R.E., 1999a, Reconnaissance of a landslide on East Sunset Drive, Layton, Davis County, Utah, *in* McDonald, G.N., compiler, Technical reports for 1998 Applied Geology Program: Utah Geological Survey Report of Investigation 242, p. 28-35.

-----1999b, Reconnaissance of building distress and ground movement in the Springhill Circle area, North Salt Lake, Davis County, Utah, *in* McDonald, G.N., compiler, Technical reports for 1998 Applied Geology Program: Utah Geological Survey Report of Investigation 242, p. 60-75.

-----2002, Movement history and preliminary hazard assessment of the Heather Drive landslide, Layton, Davis County, Utah: Utah Geological Survey Report of Investigation 251, 22 p.

Kaliser, B.N., 1983, Geologic hazards of 1983: Utah Geological and Mineral Survey, Survey Notes, v. 17, no. 2, p. 3-8, 14.

-----1989, Water-related geologic problems of 1983 – Utah occurrences by county: Utah Geological and Mineral Survey Miscellaneous Publication 89-4, 24 p.

Kaliser, B.N., and Fleming, R.W., 1986, The 1983 landslide dam at Thistle, Utah: American Society of Civil Engineers Geotechnical Special Publication 3, p. 59-83.

Kaliser, B.N., and Slosson, J.E., 1988, Geologic consequences of the 1983 wet year in Utah: Utah Geological and Mineral Survey Miscellaneous Publication 88-3, 109 p.

Oberbeck, S., 2002, Central Utah may get rail line: Salt Lake City, Salt Lake Tribune, July 19, p. E1.

Schuster, R.L., 1985, Landslide dams in the western United States: Tokyo, Proceedings of the IVth Conference and Field Workshop on Landslides, p. 415-418.

----1996, Socioeconomic significance of landslides, *in* Turner, A.K. and Schuster, R.L., editors, Landslides - investigation and mitigation: Washington, D.C., National Research Council, Transportation Research Board Special Report 247, p. 36-75.

Slosson, J.E., Yoakum, D.D., and Shuirman, Gerard, 1992, Thistle landslide - Was mitigation possible?, *in* Slosson, J.E., Keene, A.G., and Johnson, J.A., editors, Landslides/landslide mitigation: Boulder, Colorado, Geological Society of America Reviews in Engineering Geology, v. IX, p. 83-93.

Stephens, M., 1984, 1983 rain and snowmelt floods, Utah: Unpublished report for the U.S. Army Corps of Engineers, 45 p.

Terracon, 1998, Geotechnical report, Springhill landslide, City of North Salt Lake, Utah: Salt Lake City, unpublished consultant's report, 23 p.

University of Utah, 1984, Flooding and landslides in Utah – an economic impact analysis: Salt Lake City, University of Utah Bureau of Economic and Business Research, Utah Department of Community and Economic Development, and Utah Office of Planning and Budget, 123 p.

West Cache Irrigation Company, 1996, West Cache Canal Company proposed pump station feasibility report: Newton, Utah, unpublished report, p. 10-15.