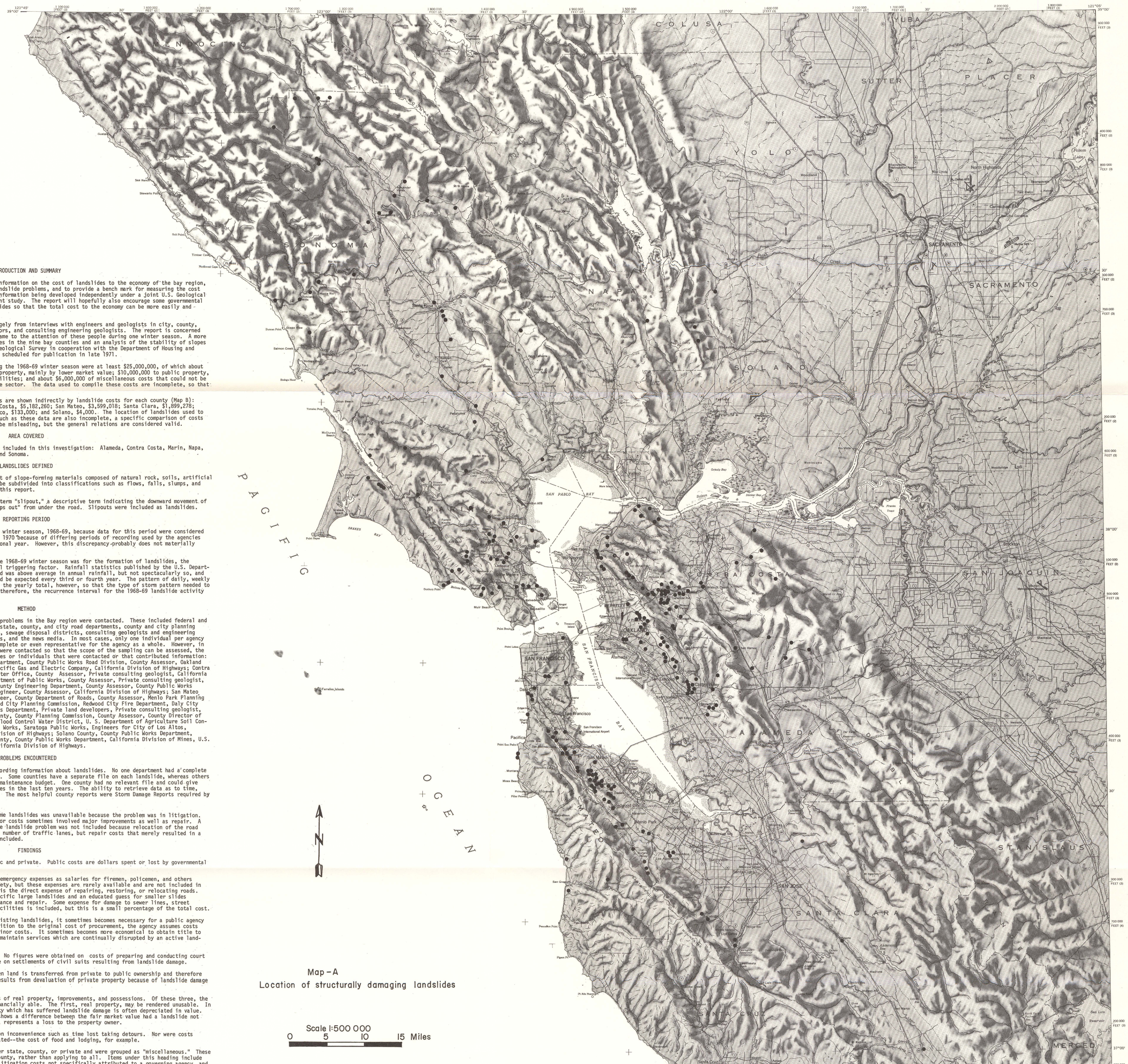
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

MISCELLANEOUS FIELD STUDIES
MAP MF-327



Map-A
Location of structurally damaging landslides

Scale 1:500 000
0 5 10 15 Miles

Map-B
Cost of landslide damage by counties

Scale 1:1 000 000
0 10 20 30 Miles

INTRODUCTION AND SUMMARY

The purpose of this report is to document information on the cost of landslides to the economy of the bay region, to show which general areas have the greatest landslide problems, and to provide a bench mark for measuring the cost effectiveness of landslide and slope stability information being developed independently under a joint U.S. Geological Survey-Department of Housing and Urban Development study. The report will hopefully also encourage some governmental agencies to keep more complete records on landslides so that the total cost to the economy can be more easily and accurately obtained.

Information for this report was derived largely from interviews with engineers and geologists in city, county, and state government, county planners and assessors, and consulting engineering geologists. The report is concerned almost solely, therefore, with landslides that came to the attention of these people during one winter season. A more comprehensive and separate study of all landslides in the nine bay counties and an analysis of the stability of slopes for planning purposes are underway by the U.S. Geological Survey in cooperation with the Department of Housing and Urban Development. Some parts of this study are scheduled for publication in late 1971.

Landslide costs for nine bay counties during the 1968-69 winter season were at least $25,000,000, of which about $9,000,000 was direct loss or damage to private property, mainly by lower market value; $10,000,000 to public property, chiefly for repair or relocation of roads and utilities; and about $6,000,000 of miscellaneous costs that could not be easily classified in either the public or private sector. The data used to compile these costs are incomplete, so that the total cost could be many times greater.

Areas with greatest known landslide problems are shown indirectly by landslide costs for each county (Map B): Sonoma, $6,433,750; Alameda, $5,396,700; Contra Costa, $5,182,260; San Mateo, $3,599,018; Santa Clara, $1,899,278; Napa, $1,478,000; Marin, $1,054,950; San Francisco, $133,000; and Solano, $4,000. The location of landslides used to compile the statistics is shown on Map A. Inasmuch as these data are also incomplete, a specific comparison of costs and landslide areas from county to county could be misleading, but the general relations are considered valid.

AREA COVERED

Nine San Francisco Bay Region counties were included in this investigation: Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma.

LANDSLIDES DEFINED

Landslides are downward and outward movement of slope-forming materials composed of natural rock, soils, artificial fills, or combinations thereof. Landslides can be subdivided into classifications such as flows, falls, slumps, and others, but no such differentiation was made in this report.

Agencies reporting landslide data used the term "slipout," a descriptive term indicating the downward movement of a roadway as fill or the underlying surface "slips out" from under the road. Slipouts were included as landslides.

REPORTING PERIOD

Most of the data in this report are for one winter season, 1968-69, because data for this period were considered the most readily obtainable. Some data are from 1970 because of differing periods of recording used by the agencies interviewed--fiscal year, calendar year, or seasonal year. However, this discrepancy probably does not materially affect the total cost estimate.

In order to determine how representative the 1968-69 winter season was for the formation of landslides, the assumption was made that rain was their principal triggering factor. Rainfall statistics published by the U.S. Department of Commerce indicate that the 1968-69 period was above average in annual rainfall, but not spectacularly so, and that the total amount of rain that did fall could be expected every third or fourth year. The pattern of daily, weekly or monthly rainfall may be more significant than the yearly total, however, so that the type of storm pattern needed to trigger the landslides is still not known, and, therefore, the recurrence interval for the 1968-69 landslide activity is not well established.

METHOD

Agencies that might have data on landslide problems in the Bay region were contacted. These included federal and state agencies with geologists on their staffs, state, county, and city road departments, county and city planning commissions, county assessors, utility companies, sewage disposal districts, consulting geologists and engineering geology firms, real estate brokers and developers, and the news media. In most cases, only one individual per agency was contacted, and his information may not be complete or even representative for the agency as a whole. However, in order to establish for the record what agencies were contacted so that the scope of the sampling can be assessed, the following is a county by county listing of offices or individuals that were contacted or that contributed information: Alameda County, County Public Works Planning Department, County Public Works Road Division, County Assessor, Oakland City Engineers, Private consulting geologist, Pacific Gas and Electric Company, California Division of Highways; Contra Costa County, County Design Office, County Disaster Office, County Assessor, Private consulting geologist, California Division of Highways; Marin County, County Department of Public Works, County Assessor, Private consulting geologist, California Division of Highways; Napa County, County Engineering Department, County Assessor, County Public Works Department; San Francisco, San Francisco City Engineer, County Assessor, California Division of Highways; San Mateo County, County Planning Commission, County Engineer, County Department of Roads, County Assessor, Menlo Park Planning Department, Menlo Park Sanitary District, Redwood City Planning Commission, Redwood City Fire Department, Daly City Department of Public Works, Millbrae Public Works Department, Private land developers, Private consulting geologist, California Division of Highways; Santa Clara County, County Planning Commission, County Assessor, County Director of Public Works, County Road Maintenance, County Flood Control Water District, U. S. Department of Agriculture Soil Conservation Service, San Jose Department of Public Works, Saratoga Public Works, Engineers for City of Los Altos, Pacific Gas and Electric Company, California Division of Highways; Solano County, County Public Works Department, County Assessor, County Farm Advisor; Sonoma County, County Public Works Department, California Division of Mines, U.S. Corps of Engineers, Healdsburg Public Works, California Division of Highways.

PROBLEMS ENCOUNTERED

Counties vary widely in their method of recording information about landslides. No one department had a complete record relating to landslides within that county. Some counties have a separate file on each landslide, whereas others include landslide cleanup and repair in a total maintenance budget. One county had no relevant file and could give only an estimate of the amount spent on landslides in the last ten years. The ability to retrieve data as to time, location, and cost of landslides varied greatly. The most helpful county reports were Storm Damage Reports required by the Federal Government for disaster relief.

Information on the existence and cost of some landslides was unavailable because the problem was in litigation. The apportioning of costs was another problem, for costs sometimes involved major improvements as well as repair. A $10 million road project necessitated by a severe landslide problem was not included because relocation of the road also included modernization and expansion of the number of traffic lanes, but repair costs that merely resulted in a better road surface than the original one were included.

FINDINGS

Two categories of costs are reported--public and private. Public costs are dollars spent or lost by governmental agencies, costs ultimately paid by the taxpayer.

Public landslide costs should include such emergency expenses as salaries for firemen, policemen, and others responsible for protecting public health and safety, but these expenses are rarely available and are not included in this report. Most of the public landslide cost is the direct expense of repairing, restoring, or relocating roads. This includes expenses readily attributed to specific large landslides and an educated guess for smaller slides included within budgets for routine road maintenance and repair. Some expense for damage to sewer lines, street lighting, sidewalks, and other publicly owned facilities is included, but this is a small percentage of the total cost.

To further protect property or to repair existing landslides, it sometimes becomes necessary for a public agency to obtain title to privately owned land. In addition to the original cost of procurement, the agency assumes costs for erosion control, weed abatement, and other minor costs. It sometimes becomes more economical to obtain title to property and have it vacated than to attempt to maintain services which are continually disrupted by an active landslide.

Litigation results in another public cost. No figures were obtained on costs of preparing and conducting court proceedings and only limited data were available on settlements of civil suits resulting from landslide damage.

Another public cost is lost tax revenue when land is transferred from private to public ownership and therefore removed from the tax roll. Revenue loss also results from devaluation of private property because of landslide damage and a subsequent lowering of tax on the land.

Private costs are those resulting from loss of real property, improvements, and possessions. Of these three, the last two can be replaced if an individual is financially able. The first, real property, may be rendered unusable. In addition to the direct costs of repairs, property which has suffered landslide damage is often depreciated in value. Reappraisal by the tax assessor's office which shows a difference between the fair market value had a landslide not occurred, and the valuation since one did occur, represents a loss to the property owner.

No attempt was made to put a dollar value on inconvenience such as time lost taking detours. Nor were costs explored which resulted from a home being evacuated--the cost of food and lodging, for example.

Some costs could not be classified as either state, county, or private and were grouped as "miscellaneous." These were costs that might be specifically for one county, rather than applying to all. Items under this heading include slide damage where responsibility is disputed, litigation costs not specifically attributed to a governing agency, and costs to the Federal Government, cities, utility companies, sanitation districts, and water districts.

COUNTY LANDSLIDE MAP

The map of landslides (Map A) generally shows only those slides that were structurally damaging during the 1968-69 reporting period. Inasmuch as information about the location, year of occurrence, and extent of damage is incomplete, some slides that occurred before the reporting period, or that did not damage structures, may be included. The exceptions probably do not change the overall landslide distribution pattern shown on the map, however.

Landslides recorded are those that ranged in size from a few tens to several hundreds of feet in maximum dimension and mostly those that came to the attention of government officials or engineering geologists. There are undoubtedly slides missed because the person having information was not contacted, because the landslide occurred in a rural area where the owner repaired the damage himself, or because the existence of landslide problems has not been reported.

Individual county record

Alameda County

Identified costs were as follows:

Public Costs		$ 443,000
state highways	$ 53,000	
county costs	390,000	
Private Costs		4,929,700
property depreciation	3,942,900	
repair and physical loss	986,800	
Miscellaneous		24,000
utility company	12,000	
litigation	12,000	
Total		$5,396,700

State and county costs are basically those given for roadway repair. The amount of $3,942,900 listed under private cost represents the loss of property value on 710 parcels of land due to landslide damage.

The majority of recorded landslides occurred in the area bounded by Highway 580 (and its southern extension, Highway 238) on the west and the crest of the hills on the east (see Map B). This area is in general the western hilly slopes of the Diablo Range where development has extended inland from the adjacent flatlands.

Fifty-eight landslides were recorded, of which thirteen were corroborated by field inspection. The most costly single slide is the one in Oakland called variously the "Wilshire Heights" or "London Road" slide. Some 26 properties were included in the slide itself with 21 other parcels immediately adjacent to it.

Castro Valley and the Berkeley Hills show concentrations of landslides. While not as large as the London Road slide, they are numerous.

Contra Costa County

Identified costs were as follows:

Public costs		$3,652,190
state highways	$1,970,000	
county costs	1,682,190	
Private costs		1,440,070
property depreciation	1,295,070	
repair and physical loss	145,000	
Miscellaneous (litigation)		90,000
Total		$5,182,260

Road maintenance accounts for a large portion of the total county expense. Only four slides were reported by the California Division of Highways, but one cost more than $1,000,000.

Mapping of recorded landslides shows a concentration in the Orinda-Lafayette region, with a less dense pattern from El Cerrito up through El Sobrante. A smaller number of reports originates from throughout the county. None of the city agencies within the county were contacted, yet reported slides were numerous. Had local governments been contacted, it is probable that the total number of landslides would be higher.

Seventy landslides were recorded, of which 26 were visited.

Marin County

Identified costs were as follows:

Public costs		$ 842,950
state highways	$164,000	
county costs	678,950	
Private costs		82,000
damage and repair	57,000	
corrective work	25,000	
Miscellaneous		130,000
Total		$1,054,950

Public costs included seven entries for state highways totaling $164,000 and 28 entries for county roads amounting to more than $571,350. The remainder of the county cost is for general road maintenance related to landslides.

Private costs are based upon records of only two slides--obviously not a representative total for the county.

Sixty-six landslides were recorded, of which 21 were field checked. The western portion of the county was not visited.

Napa County

Identified costs were as follows:

Public costs		$ 428,000
state highways	$ 48,000	
county costs		
yearly maintenance	200,000	
additional for 1969	180,000	
Private costs		800,000
(property depreciation)		
Miscellaneous costs		250,000
(development roads)		
Total		$1,478,000

Public costs include one reported slide on Highway 128 at an estimated cost of $48,000. The remainder of the public costs are those involving county roads. The maintenance figure is an estimate of the yearly amount spent, while the $180,000 represents specific costs during 1969.

Private costs involve only one landslide area north of Napa. Property devaluation due to damage amounts to $800,000. The cost for water utilities and sanitary facilities is not known. A cost estimate of $250,000 to bring roads within the subdivision up to county standards was obtained. Since it is not known who will pay these costs, the estimate was placed under miscellaneous.

No additional landslide damage was reported in the county.

San Francisco County

Identified costs were as follows:

Public costs		$ 33,000
(state highways)		
Private costs		100,000
(property damage)		
Total		$133,000

Cost information is based upon information from the California Division of Highways and newspaper articles.

Nine slide areas were named, of which five were corroborated in the field.

San Mateo County

Identified costs were as follows:

Public costs		$1,195,500
state highways	$735,000	
county costs	448,500	
tax loss	12,000	
Private costs		1,245,518
property depreciation	583,056	
damage and repair	662,462	
Miscellaneous		1,158,000
(mostly litigation)		
Total		$3,599,018

The $448,500 of county cost is for slide repair or stabilization. Reappraisal of land due to landslide damage showed a drop in valuation of $583,056. This amount is included as private loss. The assessed valuation is 25 percent of this amount or approximately $145,000. Using a rate of $12.00 per $100 assessed valuation, this represents a tax loss of over $17,000.

Private cost includes the previously mentioned $419,156 in devaluated property value due to landslide damage. This is not a county-wide figure but represents the amount for one subdivision. Similar depreciation in San Bruno and Daly City amounts to $163,900. Data for the southern part of the county were not obtained.

The $1,158,000 of miscellaneous expenses is due almost entirely to lawsuits being processed or pending due to landslide damage. Until final settlements it is not known whether these costs will be public or private or the exact amount of damages.

The landslide map shows two areas of concentration of reported slides--along the coast in Daly City and in the hills east of the San Andreas rift zone from San Bruno to Redwood City. The lack of reported slides in much of the county is probably due to the limited development in those areas. Where development has progressed, landslides have proven to be a continuing problem.

Seventy landslides were reported, of which 25 were field checked.

Santa Clara County

Identified costs were as follows:

State highways		$ 148,000
County costs		904,758
Private costs		491,520
depreciated property	$484,520	
home repair	7,000	
Miscellaneous		355,000
litigation	213,000	
utilities	20,000	
subdivision	122,000	
Total		$1,899,278

The most troublesome problem is a continuing slide located in the lower foothills east of San Jose. Problems in the area have required relocation of a major access road, repair to houses and lots, and replacement and relocation of utility services. Loss in property value alone due to slide damage or to proximity to the slide area amounts to over $400,000. Assuming a tax rate of $12.00 per $100 of assessed valuation (25 percent of the market value) a loss in taxes of $12,000 is evident. (This $12,000 was not included in total figures since the tax rate was assumed, based on that in other locations.)

Outlet towers in county reservoirs must be raised every five to ten years at a cost of $3,000 to $4,000 each. This is due partly to sediment behind the dam and partly to design changes. As the amount of sediment increases, the water-holding capacity of the dam decreases. The dollar loss is equal to the decrease in water-holding capacity. Water is worth $8 to $10 an acre foot. Unfortunately the total amount lost cannot be computed, since the amount of siltation in the county reservoirs was not available.

Santa Clara County had a low incidence of reported landslides. Those sources contacted had only twelve reports in their files--ten of these involved roadways.

Too few landslides were reported to develop any pattern showing areas of occurrence. Open space land which might show tendencies for sliding was not examined. Two towns, Los Altos and Saratoga, were contacted with negative results except for three road-connected slides in Saratoga, which were included.

Solano County

Identified costs were as follows:

State highways		--
County costs		$4,000
Private costs		--
Miscellaneous		--
Total		$4,000

Only three landslides were reported as occurring on county roads during the study period, and these were minor. The county assessor's office reported no reappraisal of property due to landslides, nor was that office aware of any landslide problems.

Much of the southwestern portion of the county is open grassland used for grazing. Landslides may occur on this land, disrupting fences, pipes and roadways, but they are usually repaired by the rancher who keeps no record of time and material on a job by job basis.

The portion of the county north of Vacaville was not field checked.

Sonoma County

Identified costs were as follows:

Public costs		$2,533,550
state highways	$1,844,800	
county costs	688,750	
Private costs		unknown
Miscellaneous		3,900,200
dam	3,525,000	
road to dam	375,200	
Total		$6,433,750

Those costs listed as public costs are exclusively for road repair. One landslide on U.S. 101 just north of Cloverdale cost $1,900,000, while the others were of lesser amounts.

No private costs due to damage were determined. Four or five houses were reported to have been either removed or demolished on "Walking Mountain" near Santa Rosa; however, no one contacted was sure how many, when, or their value. The same was true for loss on Fitch Mountain Road east of Healdsburg.

The construction of Warm Springs Dam by the U.S. Corps of Engineers presents an atypical cost within this county. The total cost of the dam is reported to be $75 million. Its rated capacity is 381,000 acre feet (a.f.). A capacity of 18,000 a.f. is allotted for slide debris. This 18,000 a.f. is 4.7% of the total capacity. If the capacity of a dam is a function of its cost, then 4.7% of the total cost, or $3,525,000, is due to landslide conditions. Although included entirely in the 1968-69 cost estimate, this cost might better be prorated over the life of the structure. Not included is a similar allotment of 18,000 a.f. for sedimentation. How much of the sedimentation would be due to upstream landslides is not known.

Construction of the dam has forced partial relocation of Warm Springs Road. Landslide problems have required modifications in construction of this road amounting to $375,200. This amount was also classed as miscellaneous.

Both Santa Rosa and Healdsburg reported no major landslide problem.

Forty-five slides were recorded, of which 39 were field checked.

Total for Nine Bay Area Counties

Table 1 give the following totals for the area studied.

Public costs		$10,184,948
state highways	$4,995,800	
county costs	5,177,148	
tax revenue lost	12,000	
Private costs		9,088,808
depreciated property	7,105,546	
other	1,983,262	
Miscellaneous		6,120,200
Total		$25,393,956

The total of roughly $25 million is a minimum figure. Lack of information has resulted in incomplete or missing data in many instances. This is true for several counties as well as for several of the categories in the table. Had these data been available, or had an estimate of these missing costs been made, the total would be higher. If as much as 80% of the total for each county is recorded (and that is probably a high estimate) the remaining 20% would amount to $5 million. Added to this is the unexplored cost to irrigation canals, communication companies, utility districts and incorporated cities, which may total another $5 to $8 million. Based upon data received and a projection to include missing amounts, a conservative estimate of loss in the Bay area would be $35 million.

ACKNOWLEDGMENTS

This report obviously would not have been possible without cooperation and help from many individuals in the agencies and organizations listed previously. The list is too long to mention these individually, but their efforts are greatly appreciated. In addition, Gregory E. Douglas assisted in the field checks and helped prepare material for several sections in this report. Bette R. Hamachi also kindly helped in the preparation of this material. Carl M. Wentworth and Raymond T. Laird offered many valuable suggestions for improving the manuscript. Donald R. Nichols and the Association of Engineering Geologists, San Francisco section, kindly facilitated access to consulting firms with data on landslide costs.

TABLE 1

	Public Costs: State Costs	Public Costs: County Costs A Roads & Purchases	Public Costs: County Costs B Tax Loss	Private Costs: A Property Depreciation	Private Costs: B Other	Misc.	Total
Alameda	$ 53,000	$ 390,000		$3,942,900	$986,800	$ 24,000	$5,396,700
Contra Costa	1,970,000	1,682,190		1,295,070	145,000	90,000	6,182,260
Marin	164,000	678,950			82,000	130,000	1,054,950
Napa	48,000	380,000		800,000		250,000	1,478,000
San Francisco	33,000				100,000		133,000
San Mateo	735,000	448,500	$12,000	583,056	662,462	1,158,000	3,599,018
Santa Clara	148,000	904,758		484,520	7,000	355,000	1,899,278
Solano	none	4,000		none			4,000
Sonoma	1,844,800	688,750				3,900,200	6,433,750
Totals	$4,995,800	$5,177,148	$12,000	$7,105,546	$1,983,262	$5,907,200	$25,180,956
P.G. & E for Bay area							213,000
						Total	$25,393,956

MAPS SHOWING DISTRIBUTION AND COST BY COUNTIES OF STRUCTURALLY DAMAGING LANDSLIDES IN THE SAN FRANCISCO BAY REGION, CALIFORNIA, WINTER OF 1968-69

by

Fred A. Taylor and Earl E. Brabb

1972