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Metropolitan San Francisco and Los Angeles Earthquake Loss Studies: 1980 Assessment

By

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The Hibernia bank building.
1906 San Francisco, California earthquake
Photograph by W.C. Mendenhall

BACK COVER:

East side of Howard Street near Seventeenth Street.
The three-story house dropped from its south foundation
wall and leaned against its neighbor.
1906 San Francisco, California earthquake
Photograph by G.K. Gilbert

METROPOLITAN SAN FRANCISCO AND LOS ANGELES EARTHQUAKE LOSS STUDIES: 1980 ASSESSMENT

by

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Introduction

This report was prepared as a result of the President's request that his Science Advisor, Dr. Frank Press, conduct a review of disaster preparedness for and consequences of a major California earthquake. The review has been carried out through an ad hoc committee of the National Security Council. This report is a contribution to that review.

Consequences of the maximum probable earthquake to occur on each of two faults in each of the metropolitan Los Angeles and San Francisco areas were developed in two reports prepared, in part, by the authors in 1972 and 1973; these reports evaluated the probable number of casualties and those left homeless, together with effects to selected important facilities, and economic loss.

> "A Study of Earthquake Losses in the San Francisco Bay Area", A Report Prepared for the Office of Emergency Preparedness by the National Oceanic and Atmospheric Administration (NOAA), 1972.
>
> "A Study of Earthquake Losses in the Los Angeles, California, Area", A Report Prepared for the Federal Disaster Assistance Administration, Department of Housing and Urban Development by NOAA, 1973.

Henceforth these two reports will be cited as the NOAA studies and reports.

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Since the publication of the NOAA reports, continued inflation, urban redevelopment, and population growth have resulted in changes to the original source data and to the inventories in these two metropolitan areas. It was appropriate to review these inputs to determine what might be required for an update of the previous findings, and then to implement the update.

This report is in two parts. Part A relates to casualties, homeless, and effects to certain disaster-response capabilities. Part A should be used in conjunction with the two previously cited studies for clarity and continuity. The expected monetary losses in the event of the same or similar postulated earthquakes considered in the two NOAA reports is also estimated. Part B discusses the estimated direct economic losses which might be expected in the event of any of the four postulated earthquakes.

The findings of this report were originally submitted in draft form to meet the deadline of the ad hoc committee of the National Security Council. The purpose of this more formal report is to present the previously submitted information in a format suitable for wider distribution and also in a form that is more useable for application to disaster-response planning. To do this, the numbers on casualties and monetary losses have been re-examined in somewhat greater detail than those given for the original submission. However, the findings given herein differ only negligibly with those previously presented, and then only with respect to casualties and homeless when broken down to county or sub-county. Dwelling monetary losses have been added.

PART A

CASUALTIES, HOMELESS, AND DAMAGE

The two study areas for this report remain unchanged from those used in the NOAA reports and are restated here for convenience. They are also shown in Figures 1, 2, and 3.

1. Metropolitan San Francisco Area:
   - Alameda County
   - Contra Costa County
   - Marin County
   - Napa County
   - San Francisco County
   - San Mateo County
   - Santa Clara County
   - Solano County
   - Sonoma County

2. Los Angeles and Orange Counties, except that the counties of Riverside, San Bernardino, and Ventura were added for the inventory of hospitals only.

The same maximum probable earthquakes selected for the NOAA reports were used for the purpose of updating, although the magnitude 7.5 is now considered to be the maximum probable size for the Hayward fault. All magnitudes in this report are M_S (surface wave) magnitudes. In addition, it was convenient to again include the effects for earthquakes less than the maximum probable in northern California. The probable earthquakes evaluated were:

Northern California:
- San Andreas fault: $M_S = 8.3$, $M_S = 7$, and for many items $M_S = 6$.
- Hayward fault: $M_S = 7.5$ and for many items $M_S = 6$.

Southern California:
- San Andreas fault: $M_S = 8.3$
- Newport - Inglewood fault: $M_S = 7.5$

The scope of the updating did not include any significant amounts of field effort directed towards the re-examination of inventories, except for an overview of dams. The source data for the two NOAA reports were reviewed and in general they were found to remain reasonably adequate when extrapolated on

the basis of population changes. Time constraints did not allow the use of more sophisticated extrapolation methods. Principal sources of new and revised information for this updating were as follows:

Demographic and Inventory Updating Sources:

1. Association of Bay Area Governments (ABAG), Bay Area Council, Berkeley, California

2. The Regional Planning Commission, County of Los Angeles, Los Angeles, California.

3. Security Pacific National Bank, Research Department, San Francisco and Los Angeles, California.

4. Marketing Research Department, Los Angeles Times, Inc., Los Angeles, California.

5. Department of Finance, Population Research Unit, Sacramento, California.

Reservoir and Dam Updating Sources:

1. Office of Emergency Services, Planning and Operations, Sacramento, California.

2. Resources Agency, Department of Water Resources, Sacramento, California.

3. City of Los Angeles, Department of Water and Power, Los Angeles, California.

Major Hospital Updating Sources:

1. Department of Health, State of California, Sacramento, California.

2. Office of the State Architect, Department of General Services, Sacramento, California.

Personnel in the foregoing offices were contacted in person or by phone, or both.

Several were contacted more than once.

Demographic Changes and Their Applications

A basic assumption was made that residential population changes were proportional to building inventory changes between the 1972/73 NOAA reports and 1980. As a corollary, we also assumed that the percentage change in inventory by class of construction would parallel population change. (Class of construction is correlatable with earthquake-caused deaths and injuries as well as building damage.) Population change as indicated by class of construction would be reflected in mercantile occupancies, particularily shopping centers vs. population growth. We further presumed that industrial growth would be proportional to population growth. This may be questioned in some areas where the industrial lands have become fully developed and their occupancy remains constant, but nearby populations might have changed in either direction. Other exceptions exist, such as office buildings in downtown San Francisco which may not accurately reflect population change. For another example, because of declining birth rates, the public school population is not growing; indeed, some schools have been closed. Therefore, the inventory of school buildings remains essentially unchanged from those used in previous studies even though the population distribution around the schools has changed slightly. New major hospitals reflect improved State of California laws enacted since the San Fernando 1971 shock. Although these new hospitals are limited in number, they do represent improved situations since they were designed to remain functional after the shock insofar as practical. While there has been substantial growth in both metropolitan areas, particularly in the outlying developing communities, in our judgment it has not been sufficiently out-of-proportion to population growth or to changes in construction characteristics to warrant alternative

extrapolation methods. In summary, population extrapolation methodology was used, modified by judgment based on personal knowledge of changes in regional conditions.

The results of the 1980 Census are not yet available. However, acceptable population data are constantly being gathered by the State of California, with the latest available being those of the January 1, 1980. Based on this information for each study area, overall population has increased by about 10% since the 1972 and 1973 reports were prepared (these previous reports used the 1970 Census). In detail, the growths were not uniform within either study area.

Table 1 shows current population data for the San Francisco metropolitan area, Table 2 is for Los Angeles and Orange Counties. In the previous NOAA study, Los Angeles County had been subdivided into 9 areas (Figure 3) which did not exactly coincide with all political boundaries; a nominal amount of data extrapolation was required to obtain the populations for Los Angeles and Orange Counties given in Table 2. A comparative examination with the previous Los Angeles study will show that some areas have declined in population. Tables 3, 4, and 5 give the estimated 1980 population of major cities in the two study areas.

Reassessed Results Exclusive of Dams

Reassessed results for a number of catagories covered in the NOAA studies are given in Tables 6 through 21 and are listed below:

Metropolitan San Francisco Area:

- Table 6: Deaths and Hospitalized Injuries
- Table 7: Non-Hospital Clinical Laboratories
- Table 8: Transportation Problems and Their Effects on Medical Personnel
- Table 9: Ambulance Service Impairment
- Table 10: Nursing Homes and Related Facilities
- Table 11: Long Term Homeless

Table 12: Inventory of Major Hospitals
Table 13: General Hospital Bed Loss

Metropolitan Los Angeles - Orange Counties:
Table 14: Deaths and Hospitalized Injuries
Table 15: Non-Hospital Clinical Laboratories
Table 16: Deaths to Health Manpower
Table 17: Ambulance Service Impairment
Table 18: Nursing Homes
Table 19: Long Term Homeless
Table 20: Inventory of Major Hospitals
Table 21: General Hospital Damage

Results shown in these tables are extrapolations on the basis of population changes, modified by information gained from the previously cited sources and further modified judgmentally from personal knowledge gained by field inspections and from other sources. Exposure in "Nursing Homes" has increased because there are more homes, in turn because life expectancy of the general public has been prolonged on the average. Data on "Public Schools", "Bloodbanks", "Public Utilities", and "Fire Following Earthquake" remain essentially unchanged and therefore are not repeated here. "Communications" and "Transportation" were excluded from this study since they were to be evaluated by others. Items such as the "HRDI Modules" and "PDH Units" were no longer considered since they were phased out in 1973.

Bed capacity data for all major general hospitals were collected for all hospitals with 99 beds or more in the San Francisco Study Area and the Los Angeles Study Area (expanded to include three additional counties of Riverside, San Bernardino, and Ventura). Bed data on military hospitals and Veterans Administration Hospitals were not readily available and are therefore not included due to time constraints.

Scenarios and supplemental data obtained from the original reports may be modified as required by Tables 6 through 21.

Dams and Reservoirs

Since publication of the previous studies, legislation on the safety of downstream populated areas below dams under State of California jurisdiction has been mostly implemented. State-approved inundation maps are on file at the Office of Emergency Services (OES) in Sacramento, California. These maps designate areas "within which death or personal injury would....result from partial or total failure of a dam". Legislation also stated that OES "shall review such procedures to determine whether adequate public safety measures exist for the evacuation and control of populated areas below the dams, and shall make recommendations with regard to the adequacy of such procedures to the concerned public safety agency..."

Updated state-compiled data were reviewed. As in the original studies, federally owned dams were not included in the review since at that time it was judged that they did not pose a significant life hazard in the two study areas.

Copies of all inundation maps for the dams and reservoirs listed in Tables 22 and 23 were received from OES except for Calaveras and San Andreas Dams in the San Francisco area and Chatsworth Dam in the Los Angeles area. (Chatsworth Reservoir is currently empty.) Figures 3 an 4 give the locations of all major dams and reservoirs. All dams and reservoirs listed in Tables 22 and 23 were either looked at in July of 1980 or personal knowledge made it unnecessary to do so.

Since publication of the previous reports, many of the water storage dams listed in Tables 22 and 23 have been re-evaluated for seismic stability using the latest analytical methods. Those dams that were assessed to be hazardous have been, or will be, modified to conform to the currently required standards of safety. For example in the San Francisco area, the San Leandro Dam has

been completely rebuilt and the San Pablo Dam has been substantially improved. Chabot Dam is being reconstructed at this writing. In the Los Angeles area, Lower Franklin Reservoir has been drained and the dam is no longer in operation; bids are currently being advertised for a reconstruction contract in late 1980. Fairmont Dam has been operated at a reduced water level since 1966 and a construction contract for a new dam and reservoir is anticipated to be let in 1981. Thus, the probability of dam failure has been significantly reduced since publication of the earlier studies.

It is very reasonable to assume that the recently constructed major dams and those which have been modified in recent years have incorporated adequate seismic safety criteria. However, the consequence of error may be very significant. Therefore, for disaster planning purposes only, the number of probable homeless and dead resulting from a failure of a dam is given in Tables 24 and 25. Also for planning purposes, at most one dam failure should be considered even though it is not a probable event. The selected dam may be chosen on a random basis. All of the tabled loss figures represent the worst risk conditions based on generalized assumptions regarding inundation areas, rates of flow, and similar criteria.

PART B

MONETARY LOSSES

The study areas for monetary losses were the same as those used in Part A, except that the area in southern California was extended to include the counties of San Bernardino, Kern, Riverside, and Ventura with those of Los Angeles and Orange. The subject matter in Part B has been expanded using unpublished information, except that the dwelling information was updated from previously published studies. Monetary losses were not extensively covered in the two NOAA studies.

The same earthquakes and causative faults were used for the monetary loss studies (Part B) as for those for casualties (Part A).

Source Materials

Required source data must include the magnitudes of the postulated earthquakes, locations of the earthquakes on causative faults, the isoseismals (expected damage patterns as a function of distance from the fault), the dollar quantification of the damage patterns by class of building construction, and dollar loss summation.

The source materials with respect to losses should be selected so as to appropriately reflect losses that will be useful to the user, i.e. public organizations. Therefore, an "impersonal loss" definition must be used. Impersonal loss is taken to mean a loss to be paid by others and not by the individual or organization involved. For example, a dent in an automobile fender, if not covered by insurance, may not be repaired and the owner may consider it negligible although somewhat unsightly; the owner probably would have a different viewpoint if an insurance policy covering this loss had been purchased. Similarly, minor earthquake cracking in the plastered or gypsumboard walls of wood frame dwellings cannot be considered as a life hazard, albeit unsightly. The owner may repaint the walls for $50 by doing the work himself; this "personal" loss might be placed at $50 since only out-of-pocket expenses were considered. If, however, the repainting was done by professionals, perhaps $500 would be involved. The monetary losses in this study are considered on an impersonal basis in order to provide consistency and also provide a guide to cost should government become involved in repairs or replacement.

Monetary source data in northern California was carefully considered. Twenty sources were examined, including those of the California Board of Equalization and those of the county assessors of the 9 counties in the San Francisco Bay Area; all were fruitless. Assessor data are often regarded to be potentially superior sources: the following is quoted from a Steinbrugge and Lagorio report (1975):

> "Dollar value data for improvements on land were received from each county assessor's office in the test area. When correlated with use code designations, improvement values for individual counties could be classified for some specific occupancies but normally not with construction classes. Therefore, data commonality throughout the test area did not exist, and judgmental interpretations are required for summing total regional values for any occupancy. Further interpretations are required for relationships to construction classes...."
>
> "There is virtually no consistency among assessors' offices in the methods used in reporting statistics for specific classes of buildings. Appraisal of residential property occurs on a different basis than commercial or industrial developments...."
>
> "In conclusion, while assessor data provide an excellent source of dollar values, they are gathered on a different basis in each county, are not adequately segregated by construction class...."

* Steinbrugge, K. V., and Lagorio, H., 1975, Building classifications and relationships among losses, intensities, and classes: Report to U.S. Geological Survey, v. 1, 88 p. and appendices.

The method used in this study has been to survey unpublished fire insurance data and adapt them to earthquake useage. These data required interpretation by the authors based, in part, on the knowledge developed during the preparation of the two aforementioned NOAA studies.

Computational Methodology

The initial data were fire insurance property values by county for northern California and an assumed 8.3 magnitude earthquake on the San Andreas fault. These values included dwellings, commercial buildings, manufacturing plants, warehouses, offices, and all other fire-insured properties. These property values were increased to include non-insured private property as well as increased to include under-insured property. Adjustments were made on a judgment basis to include the value of Federal, State of California, and local government-owned buildings. Intensities from the NOAA reports isoseimal maps were converted into loss factors, or the percent loss based on an impersonal definition basis. These percentages were multiplied by the property values to obtain the total impersonal loss by county in the study area, then summed to obtain the total aggregate loss. In this process, values were adjusted to compensate for inflation to 1980.

Building contents for the aforementioned San Andreas earthquake were analyzed in a similar manner to derive the total contents aggregate loss.

Loss computation methodology for a major earthquake on the Hayward fault followed the same computational patterns as those for the San Andreas fault.

Southern California provided a different problem in that basic insurance data had not been developed. However, a first-order estimate can be made by extrapolations based on population differences and estimated differences in the geographic distribution of the buildings by class of construction.

Dwellings

Methodologies for determining dwelling losses may be found in"

"Studies in Seismicity and Earthquake Damage Statistics, 1969", plus Appendices A and B in separate volumes. A report prepared by Environmental Science Services Administration, U.S. Department of Commerce, 1969.

"Estimation of Earthquake Losses to Single Family Dwellings", by W. Rinehart, S. T. Algermissen, and Mary Gibbons. USGS Open File Report No. 76-156, 1976.

A number of supplemental or related unpublished reports exist.

The computational methodology was to update residential values increased by inflation from those values determined in previous studies using replacement values (i.e., excluding land values). Loss factors as a function of isoseismal maps prepared by the USGS were next applied, with results as indicated in the next section.

Findings

The findings are summarized in Table 26. The "Total Loss" figures do not include transportation or communication systems, do not include dams or military installations, and do not include consequential loss such as unemployment, loss of taxes, shutdown of factories outside of California due to loss of supplies (such as might happen in the electronics industry), and automobile damage. "Dwelling Loss" is a component of "Total Loss", and should not be added again to the total.

"Total Loss" and "Dwelling Loss" figures were derived from different data bases and partially different methodologies. A comparison between results, however, appears to be reasonable.

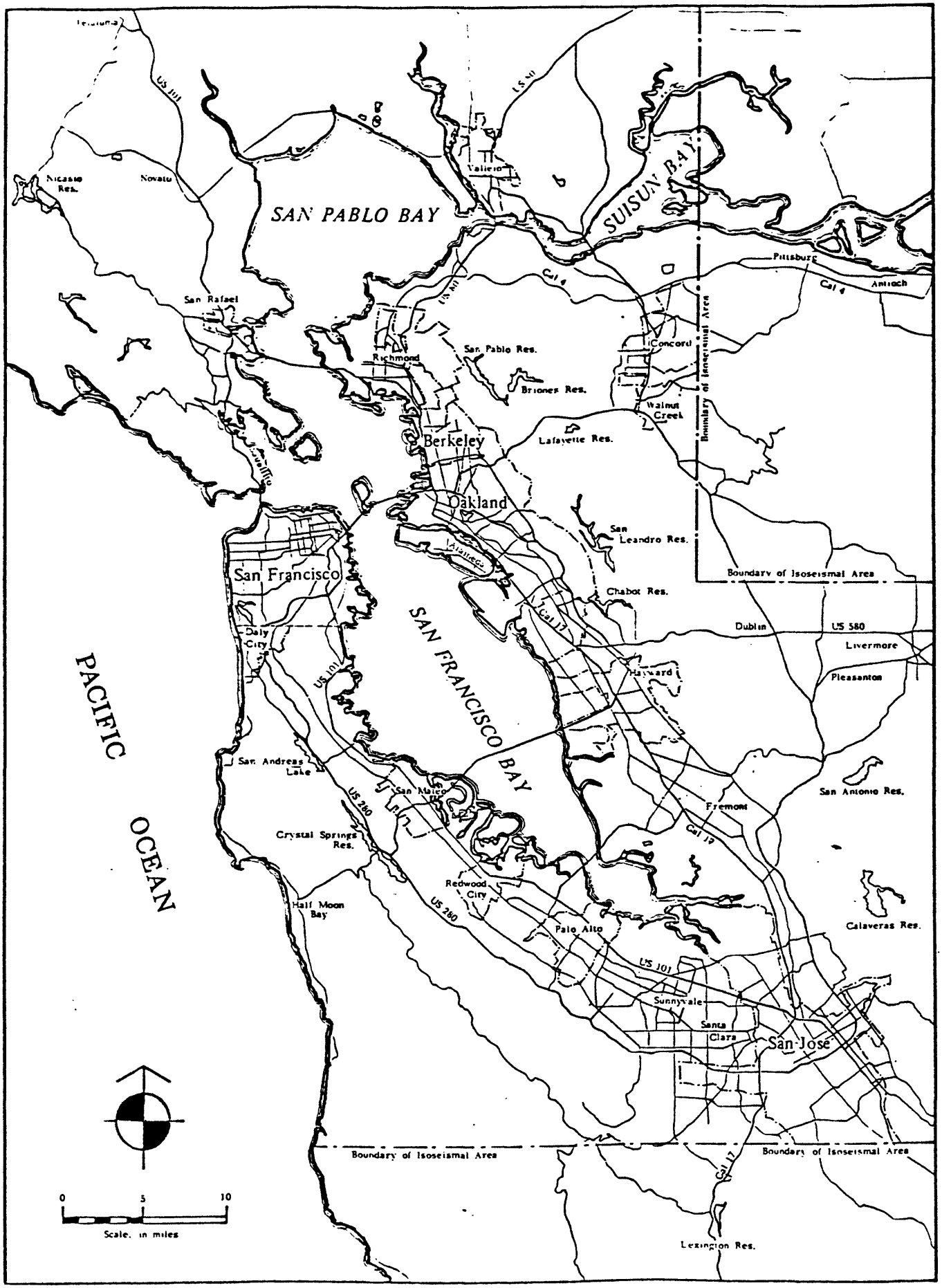

FIGURE 1. Metropolitan San Francisco Study Area.

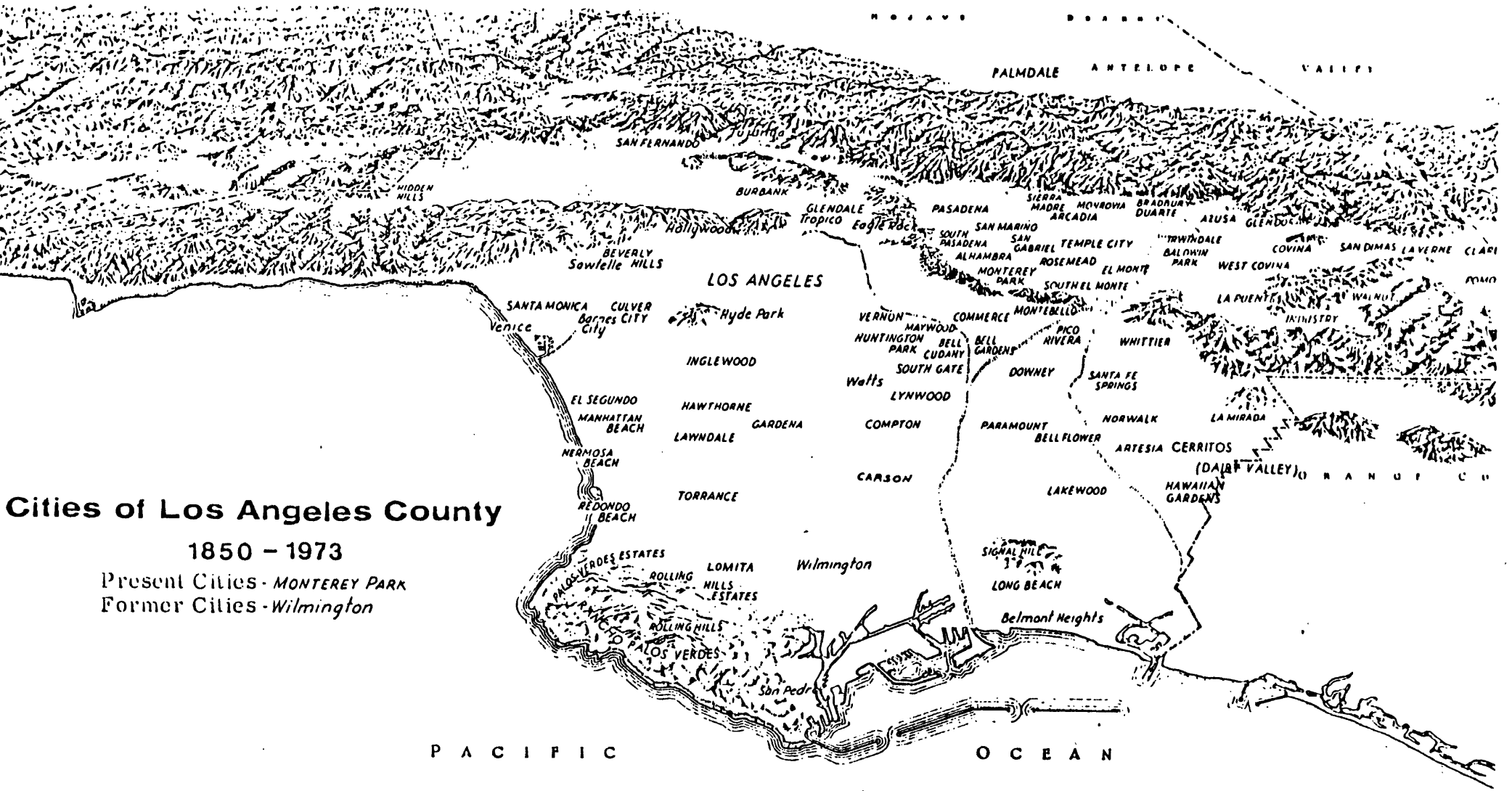

FIGURE 2. Los Angeles County. Graphic by the Regional Planning Commission, Los Angeles County.

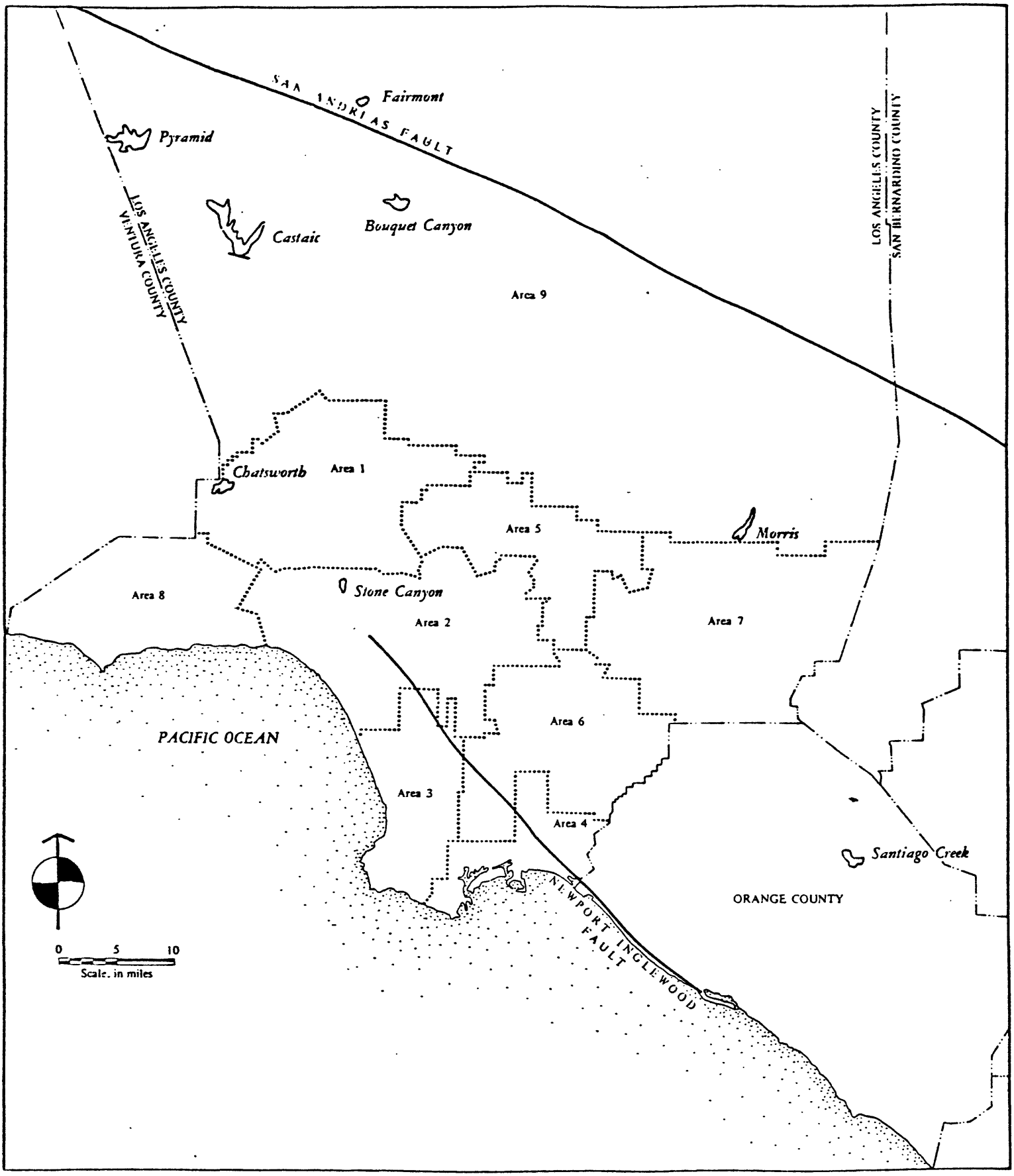

FIGURE 3. Los Angeles and Orange Counties showing reservoirs and 9 study areas within Los Angeles County.

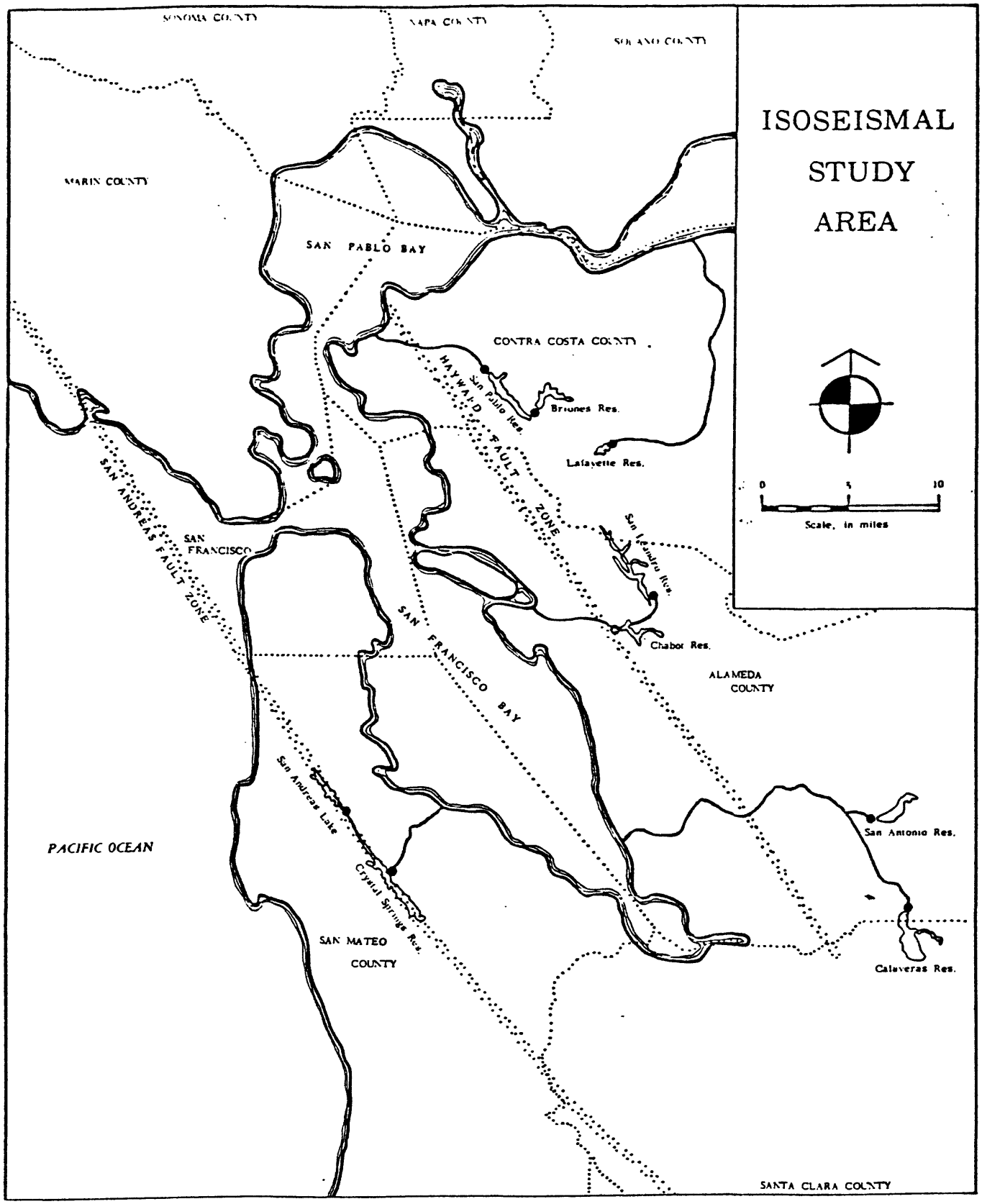

FIGURE 4. Dams and reservoirs in the San Francisco study area.

Table 1.--Population of San Francisco study area as of January 1, 1980

County	Population
Alameda	1,098,500
Contra Costa	645,300
Marin	225,200
Napa	93,400
San Francisco	642,900
San Mateo	589,200
Santa Clara	1,265,200
Solano	225,500
Sonoma	284,400
Total	5,069,600

Source: "Population Estimates of California Cities and Counties", Report 80 E-1, Population Research Unit, Department of Finance, State of California. May 1, 1980. Sacramento, California.

Table 2.--Population of Los Angeles and Orange Counties as of January 1, 1980

County		Population
*Los Angeles		7,163,100
Area 1	1,092,611	
Area 2	1,898,973	
Area 3	693,066	
Area 4	442,890	
Area 5	652,897	
Area 6	1,288,126	
Area 7	932,703	
Area 8	39,476	
Area 9	122,358	
Orange		1,896,200
	Total	9,059,300

*See Figure 3

Source: Adapted from "Population Estimates of California Cities and Counties", Report 80-E-1, Population Research Unit, Department of Finance, State of California. May 1, 1980. Sacramento, California.

Table 3.--Population of cities in Los Angeles County--as of January 1, 1980.

City	Population	Area	City	Population	Area
Alhambra	62,500	5	Lawndale	23,750	3
Arcadia	46,750	5	Lomita	20,000	3
Artesia	15,300	6	Long Beach	345,300	4
Azusa	26,650	7	Los Angeles	2,817,800	1,2,3,4
Avalon	1,910	--	Lynwood	40,850	6
Baldwin Park	47,950	7	Manhattan Beach	31,250	3
Bell	23,000	6	Maywood	18,500	6
Bellflower	52,200	6	Monrovia	30,450	7
Bell Gardens	32,050	6	Montebello	49,900	6
Beverly Hills	33,250	2	Monterey Park	52,300	5
Bradbury	870	7	Norwalf	83,700	6
Burbank	84,700	5	Palmdale	12,700	9
Carson	79,100	6	Palos Verdes Estates	14,850	3
Cerritos	51,200	6	Paramount	31,800	6
Claremont	28,500	7	Pasadena	106,800	5
Commerce	10,050	6	Pico Rivera	50,500	6
Compton	75,700	6	Pomona	87,600	7
Covina	33,250	7	Rancho Palos Verdes	38,200	3
Cudahy	17,300	6	Redondo Beach	63,600	3
Culver City	38,000	2	Rolling Hills	2,110	3
Downey	86,700	6	Rolling Hills Estate	7,875	3
Duarte	15,950	7	Rosemead	40,750	7
El Monte	68,400	7	San Dimas	24,150	7
El Segundo	15,100	3	San Fernando	15,250	1
Gardena	44,650	3	San Gabriel	29,500	5
Glendale	135,100	5	San Marino	13,450	5
Glendora	37,100	7	Santa Fe Springs	15,350	6
Hawaiian Gardens	10,200	6	Santa Monica	88,600	2
Hawthorne	54,500	3	Sierra Madre	12,100	5
Hermosa Beach	19,150	3	Signal Hill	6,550	4
Hidden Hills	1,730	1	South El Monte	15,950	7
Huntington Park	39,800	6	South Gate	61,600	6
Industry	630	7	South Pasadena	23,400	5
Inglewood	91,200	3	Temple City	30,000	7
Irwindale	750	7	Torrance	126,700	3
La Canada Flintridge	19,300	5	Vernon	230	6
Lakewood	80,200	6	Walnut	11,950	7
La Mirada	44,100	6	West Covina	78,700	7
Lancaster	48,100	9	Whittier	69,500	6
La Puente	30,550	7	Unincorporated	942,000	
La Verne	23,450	7			
			Total	7,163,100	

Table 4.--Population of cities in Orange County as of January 1, 1980

City	Population
Anaheim	211,700
Brea	28,650
Buena Park	63,900
Costa Mesa	81,600
Cypress	40,400
Fountain Valley	54,200
Fullerton	101,900
Garden Grove	120,100
Huntington Beach	172,200
Irvine	63,500
Laguna Beach	16,900
La Habra	44,800
La Palma	15,050
Los Alamitos	11,300
Newport Beach	65,300
Orange	87,900
Placentia	35,300
San Clemente	26,400
San Juan Capistrano	18,400
Santa Ana	189,000
Seal Beach	26,800
Stanton	23,300
Tustin	33,950
Villa Park	7,375
Westminster	70,800
Yorba Linda	29,150
Unincorporated areas	256,500
Total	1,896,200

Source: "Population Estimates of California Cities and Counties", Report 80 E-1, Population Research Unit, Department of Finance, State of California. May 1, 1980. Sacramento, California.

Table 5.--Population of selected cities in the 9 county San Francisco study area as of January 1, 1980

	Population
Alameda County	
Alameda	69,200
Berkeley	110,400
Fremont	127,300
Hayward	95,100
Oakland	327,300
San Leandro	67,100
Contra Costa County	
Concord	105,100
Richmond	70,800
Walnut Creek	54,600
Marin County	
Novato	42,550
San Rafael	44,300
Napa County	
Napa	48,800
San Francisco City and County	642,900
San Mateo County	
Daly City	74,000
Redwood City	56,000
San Mateo	80,300
South San Francisco	49,650
Santa Clara County	
Mountain View	58,200
Palo Alto	54,100
San Jose	610,400
Santa Clara	85,000
Sunnyvale	107,200
Solano County	
Fairfield	58,100
Vacaville	42,450
Vallejo	75,400
Sonoma County	
Petaluma	32,750
Santa Rosa	78,300

Source: "Population Estimates of California Cities and Counties", Report 80 E-1, Population Research Unit, Department of Finance, State of California. May 1, 1980. Sacramento, California.

Table 6.--Deaths and Hospitalized Injuries--S.F. Study Area. Exclusive of dam failures.
(Revised Table 50 from 1972 study.)

Fault	Magnitude	Time of Day	Deaths				Hospital Injuries			
			Schools	Hospitals	Other Sources	Total	Schools	Hospitals	Other Sources	Total
San Andreas	8.3	2:30 a.m.	0	600	2,500	3,100	0	1,760	10,120	11,880
		2:00 p.m.	2,100	1,450	6,640	10,190	580	4,400	27,060	32,040
		4:30 p.m.	200	1,450	9,720	11,370	600	4,400	39,340	44,340
	7	2:30 a.m.	0	110	440	550	0	330	1,760	2,090
		2:00 p.m.	350	250	1,170	1,770	1,300	770	4,620	6,690
		4:30 p.m.	40	250	1,900	2,190	100	770	11,970	12,840
Hayward	7.5	2:30 a.m.	0	330	810	1,140	0	990	3,260	4,250
		2:00 p.m.	1,400	770	1,210	3,380	3,400	2,310	4,840	10,550
		4:30 p.m.	100	770	1,580	2,450	300	2,310	6,340	8,950

Note: The ratio of non-hospitalized injuries to deaths is 30:1 in all cases.

Table 7.--Non-hospital Clinical Laboratories--S.F. Study Area. Nonfunctional due to earthquake damage.*
(Revised Table 36 from 1972 study.)

Fault	Earthquake Magnitude	County											
		San Francisco San Mateo		Santa Clara		Contra Costa Alameda		Marin		Napa Solano Sonoma		Totals	
		%	No.	%	No.	%	No.	%	No.	%	No.	%	No.
San Andreas	8.3	60	53	40	22	30	20	40	6	10	2	43	103
	7	30	26	20	11	15	10	20	3	5	1	21	51
	6	15	13	5	3	-	0	-	0	-	0	7	16
Hayward	7.5	15	13	30	17	40	26	25	4	15	2	26	62
	6	-	0	15	8	20	13	5	1	-	0	9	22

* Functional loss based on damage to buildings and equipment.
(Equipment and stock losses will be somewhat less than the tabled values; for the purposes of this report, no differentiation will be made.)

Table 8.--Transportation problems and their effects on medical personnel--San Francisco study area. Personnel assumed to be away from hospital or place of employment.

(Revised Table 25 from the 1972 study)

Fault	Earthquake magnitude	Percent personnel absence		Physician and surgeon absence	
		*Bridge closure	**Other problems	*Bridge closure	**Other problems
San Andreas	8.3	6%	2%	720	240
	7.0	3%	1%	360	120
	6.0	0%	0%	0	0
Hayward	7.5	2.5%	2%	300	240
	6.0	0%	0%	0	0

*Absence for 1 or more days.

**Absence for 1 or more hours, but not more than 8 hours. Due to failure of rapid transit systems, landslide, fallen overpasses, etc.

Note: The figures in this table apply to uninjured personnel; total absence figures must include injuries and deaths.

Table 9.--Ambulance service impairment--San Francisco Bay Area

(Revised Table 41 from the 1972 study)

Earthquake magnitude	Ambulances out of service	
	Number of vehicles	Percent of total
8.3	37	12%
7 or 7.5	1	2%
6.0	1	-

Note: This table applies to earthquakes on San Andreas or Hayward faults. The impairments due to San Andreas fault earthquakes will be on the west side of the Bay and impairments due to Hayward fault earthquakes will be on the east side of the Bay.

Table 10.--Nursing homes and related facilities--San Francisco study area. One story structures which will be structurally unsafe. Functional impairments are not included.

(Revised Table 44 from the 1972 study)

Fault	Earthquake magnitude	Lost beds by counties			
		San Francisco and San Mateo	Santa Clara	Contra Costa and Alameda	Marin
San Andreas	8.3	777	490	174	26
	7.0	518	245	--	--
	6.0	259	50	--	--
Hayward	7.5	104	490	1,305	65
	6.0	--	50	435	--

Table 11.--Long Term Homeless--S.F. Study Area. Homeless due to potential dam failure must be added to these figures; see section on "Dams and Reservoirs" for locations.
(Revised Table 61 from the 1972 study.)

County	San Andreas Fault M=8.3	San Andreas Fault M=7	Hayward Fault M=7.5
Alameda			
Wet season	2,150	1,000	17,000
Dry season	2,150	1,000	26,500
Contra Costa			
Wet season	350	*	9,700
Dry season	350	*	12,100
Marin			
Wet season	1,500	*	3,800
Dry season	650	*	1,000
Napa			
Wet season	*	*	*
Dry season	*	*	*
San Francisco			
Wet season	14,800	5,500	4,200
Dry season	17,500	5,500	4,200
San Mateo			
Wet season	9,600	9,600	700
Dry season	10,200	9,600	700
Santa Clara			
Wet season	4,000	1,800	12,600
Dry season	4,600	1,800	12,600
Solano			
Wet season	*	*	*
Dry season	*	*	*
Sonoma			
Wet season	400	*	*
Dry season	400	*	*

*Negligible (less than 100)

"Dry Season" includes homeless from landslide plus conflagration.

Table 12.--Inventory of major hospitals--San Francisco study area with capacities of 99 beds or more

County	Type of hospital facility: General No.	General Total bed cap.	Mental health No.	Mental health Total bed cap.
Alameda	20	4,575	--	---
Contra Costa	8	1,812	--	---
Marin	8	1,200	1	2,312
Napa	3	1,088	--	---
San Francisco	17	6,897	see note (1)	
San Mateo	9	2,416	--	---
Santa Clara	11	4,099	1	1,901
Solano	4	537	--	---
Sonoma	3	488	1	2,083
Totals:	83	23,112	3	6,296

Note:

(1) One mental health hospital reported previously in the 1972 NOAA San Francisco area study has been reduced to a 77 bed capacity and is therefore no longer included in this study.

(2) Data includes university hospitals, university medical centers, convalescent hospitals, etc.

Sources:

(a) Program - FIS127: Facilities Information System, March 26, 1980. Department of Health, State of California, Sacramento, California.

(b) Office of the State Architect, Department of General Services, State of California, Sacramento, California.

Table 13.--General hospital bed loss - San Francisco study area with bed capacities of 99 or greater

County	San Andreas Fault			Hayward fault	
	8.3	7.0	6.0	7.5	6.0
Alameda	549	105	5	2,050	1,354
Contra Costa	54	---	---	176	---
Marin	681	523	---	305	---
Napa	670	490	22	479	---
San Francisco	4,297	690	---	---	---
San Mateo	1,360	1,136	290	128	---
Santa Clara	3,240	1,452	---	1,344	---
Solano	32	---	---	31	8
Sonoma	1,543	722	---	337	---
Totals:	12,426	5,118	317	4,850	1,362

Note: Does not include military or VA hospital bed losses.

Table 14.--Deaths and Hospitalized Injuries--LA/Orange Study. Hospitalized injuries to deaths is 4:1, nonhospitalized injuries to deaths is 30:1. (Revised Table 57 from 1973 study.)

Fault	Area	Deaths 2:30 a.m.	Deaths 2:00 p.m.	Deaths 4:30 p.m.
San Andreas	Los Angeles County			
(M=8.3)	Area 1	380	880	960
	Area 2	620	5,690	6,260
	Area 3	160	330	370
	Area 4	100	520	570
	Area 5	230	680	750
	Area 6	450	1,030	1,040
	Area 7	340	840	930
	Area 8	5	15	15
	Area 9	60	140	150
	Sub-Total	2,345	10,125	11,045
	Orange County	620	1,310	1,450
	Total	2,965	11,435	12,495
Newport-Inglewood	Los Angeles County			
(M=7.5)	Area 1	510	1,130	1,250
	Area 2	950	10,190	11,200
	Area 3	350	760	840
	Area 4	240	1,790	1,970
	Area 5	280	650	720
	Area 6	640	1,400	1,540
	Area 7	400	770	850
	Area 8	10	20	20
	Area 9	50	90	100
	Sub-Total	3,430	16,800	18,490
	Orange County	950	2,060	2,265
	Total	4,380	18,860	20,755

Table 15.--Non-hospital Clinical Laboratories--LA/Orange study. Non-functional due to earthquake damage.*
(Revised Table 42 from 1973 report.)

County	San Andreas Fault Magnitude = 8.3		Newport-Inglewood Fault Magnitude = 7.5	
	Number	Percentile	Number	Percentile
Los Angeles				
Area 1	22	40%	42	75%
Area 2	53	30%	140	80%
Area 3	2	10%	15	80%
Area 4	3	10%	23	80%
Area 5	24	50%	26	55%
Area 6	20	40%	41	80%
Area 7	19	70%	8	30%
Area 8	0	0%	0	0%
Area 9	7	80%	1	10%
Sub-Total	150	36%	296	72%
Orange	28	25%	78	70%
Totals	178	34%	374	71%

* Based on damage to buildings and equipment. (Equipment and stock losses will be somewhat less than the tabled values; for the purposes of this report, no differentiation will be made.)

Table 16.--Deaths to health manpower--Los Angeles/Orange study

(Revised Table 27 from 1973 report)

County	San Andreas fault magnitude = 8.3		Newport-Inglewood fault magnitude = 7.5	
	Physicians and surgeons	Registered nurses	Physicians and surgeons	Registered nurses
Los Angeles				
Area 1	1	5	2	7
Area 2	20	36	35	65
Area 3	1	2	1	5
Area 4	1	3	5	12
Area 5	2	5	2	3
Area 6	1	6	1	8
Area 7	1	5	1	5
Area 8	0	0	0	0
Area 9	0	1	0	1
Sub-total	27	63	47	106
Orange	2	8	2	11
Totals	29	71	49	117

Table 17.--Ambulance service impairment--Los Angeles/Orange study

(Revised Table 47 from 1973 report)

County	Services parked inside*	Services not functional			
		San Andreas fault magnitude = 8.3		Newport-Inglewood fault magnitude = 7.5	
		Number of services	Percent of total services	Number of services	Percent of total services
Los Angeles					
Area 1	4	1	N.C.**	1	N.C.**
Area 2	9	1		4	
Area 3	5	0		1	
Area 4	5	0		1	
Area 5	7	0		1	
Area 6	6	1		3	
Area 7	4	1		0	
Area 8	1	0		0	
Area 9	5	1			
Sub-total	46	5	4%	11	8%
Orange	11	1	4%	2	7%
Totals	57	6	4%	13	8%

*Based on 40% of all services in study area which have ambulances parked inside of buildings.

**"Not computed" for 9 Areas in Los Angeles County as individual percentages are negligible.

Table 18.--Nursing homes--Los Angeles/Orange study

(Revised of Table 50 from 1973 report)

County	Magnitude of postulated earthquake: San Andreas fault magnitude = 8.3 — Lost beds	Magnitude of postulated earthquake: Newport-Inglewood fault magnitude = 7.5 — Lost beds
Los Angeles		
Area 1	240	480
Area 2	328	984
Area 3	128	257
Area 4	148	296
Area 5	142	142
Area 6	204	408
Area 7	347	178
Area 8*	--	--
Area 9	119	24
Sub-total	1,656	2,769
Orange	300	600
Totals	1,956	3,369

*None in Area 8.

Table 19.--Long term homeless--Los Angeles/Orange study exclusive of dam failure and fire.

(Update of Table 105 from 1973 report)

County	San Andreas fault magnitude = 8.3	Newport-Inglewood fault magnitude = 7.5
Los Angeles		
Area 1	9,000	20,000
Area 2	3,000	54,000
Area 3	*	18,000
Area 4	*	12,000
Area 5	6,000	1,000
Area 6	11,000	35,000
Area 7	17,000	1,000
Area 8	*	*
Area 9	4,000	*
Sub-total	50,000	141,000
Orange	2,000	51,000
Totals	52,000	192,000

*Negligible

Table 20.--Inventory of major hospitals--Los Angeles study area with capacities of 99 beds or more

County	Type of hospital facility: General No.	General Total bed cap.	Mental health No.	Mental health Total bed cap.
Los Angeles				
Area 1	18	3,771	--	----
Area 2	32	11,339	1	166
Area 3	10	2,978	--	----
Area 4	9	2,982	--	----
Area 5	10	2,852	--	----
Area 6	18	3,753	1	1,078
Area 7	11	2,401	1	1,902
Area 8	1	126	--	----
Area 9	5	792	--	----
Sub-totals	114	30,994	3	3,146
Orange	32	6,780	1	1,690
Riverside	25	3,843	--	----
San Bernardino	29	4,946	1	1,410
Ventura	11	1,747	1	1,751
Totals:	211	48,310	6	7,997

Note: Data includes university hospitals, university medical centers, convalescent hospitals, etc.

Sources:
(a) Program - F1S127: Facilities Information System, March 26, 1980. Department of Health, State of California, Sacramento, California.

(b) Office of State Architect, Department of General Services, State of California, Sacramento, California.

Table 21.--General hospital damage--Los Angeles study area

with capacities of 99 beds or more

County	San Andreas fault, Magnitude = 8.3					Newport-Inglewood fault, Magnitude = 7.5				
	Bed loss		Impairment (or non-functioning) In percent of total			Bed Loss		Impairment (or non-functioning) In percent of total		
	%	No.	Elevators	Commun.	Aux. Power	%	No.	Elevators	Commun.	Aux. power
Los Angeles										
Area 1	12.4%	468	17%	0%	1%	38.7%	1,460	55%	14%	20%
Area 2	15.9%	1,803	16%	0.5%	2%	48.8%	5,533	64%	13%	24%
Area 3	2.8%	83	3%	0%	0%	48.0%	1,430	51%	19%	29%
Area 4	3.8%	113	6%	0%	1%	50.0%	1,490	58%	20%	30%
Area 5	11.7%	334	16%	0%	1%	27.2%	776	29%	6%	10%
Area 6	16.9%	634	15%	0.7%	3%	46.5%	1,745	35%	18%	31%
Area 7	45.6%	1,095	46%	17%	26%	14.5%	348	19%	0%	1%
Area 8	0%	0	0%	0%	0%	0%	0	0%	0%	0%
Area 9	4.6%	36	7%	0%	0.5%	35.0%	277	5%	0%	7%
Sub-totals		4,566					13,059			
Orange	13.4%	906	16%	0%	1.3%	43.5%	2,950	46%	15%	23%
Riverside	61.4%	2,360	61%	27%	47%	0%	0	0%	0%	0%
San Bernardino	73.3%	3,254	73%	48%	55%	0.3%	14	0%	0%	0%
Ventura	11.6%	202	18%	18%	9.7%	1.3%	22	2%	0%	0%
Totals:		11,288					16,045			

Note: Does not include military or VA hospital bed losses.

Table 22.--Physical characteristics of selected dams in San Francisco area.
(Data from Bulletin No. 17-79, Dept. Water Resources, State of California.)

Dam	Storage (acre-feet)	Height (feet)	Crest Length (feet)	Type	Year Completed
Anderson (1)	91,300	235	1,430	Earth & rock	1950
Austrian (2)	6,200	185	700	Earth	1950
Briones (3)	67,500	273	2,100	Earth	1964
Calaveras (4)	100,000	210	1,200	Earth & rock	1925
Chabot (5)	12,600	135	450	Earth	1892
Coyote (6)	24,500	140	980	Earth & rock	1936
Del Valle (7)	77,100	222	880	Earth	1968
James Turner (8)	50,500	193	2,160	Earth	1964
Lafayette (9)	3,500	132	1,200	Earth	1929
Lexington (10)	21,430	205	810	Earth	1953
Lower Crystal Springs (11)	54,000	140	600	Concrete gravity	1888
San Andreas (12)	18,500	107	727	Earth	1870
San Pablo (13)	43,193	170	1,250	See Note 13	1920
New Upper San Leandro (14)	42,000	182	1,300	Earth	1977

Note:
(1) Studied and analyzed but no work done to date.
(2) Upstream from Lexington Dam.
(3) Not received thorough dynamic analysis to date. Upstream from San Pablo Dam.
(4) Embankment rehabilitated and improved during last 10 years. Discharges through Niles Canyon.
(5) Operated at reduced water level. Dam being completely rebuilt. New work to be completed in 1981.
(6) No additional work completed to date. Upstream from Anderson Dam.
(7) Discharges through Niles Canyon.
(8) Discharges through Niles Canyon.
(9) Studies have been made in early 1970's. No additonal work done to date.
(10) Undergoing study and analysis. Has been empty at times, currently full and in operation.
(11) Currently under dynamic analysis. No additional work done to date. Survived 1906 earthquake.
(12) No additional work done to date. Upstream from Lower Crystal Springs Dam.
(13) Modified in 1980. Being filled for operation in 1981.
(14) New dam. Old dam breached and no longer acting as a dam. Upstream from Lake Chabot.

Table 23.--Physical characteristics of selected dams in Los Angeles area.
(Data from Bulletin No. 17-79, Dept. Water Resources, State of California.)

Dam	Storage (acre-feet)	Height (feet)	Crest Length (feet)	Type	Year Completed
Bouquet Canyon (1)	36,500	190	1,180	Earth	1934
Castaic	350,000	340	5,200	Earth	1973
Castaic Forebay (2)	30,000	180	1,910	Earth	1972
Chatsworth (3)	9,886	45	2,700	Hydraulic fill	1918
Fairmont (4)	7,507	121	4,300	Hydraulic fill	1912
Morris (5)	35,171	245	750	Concrete gravity	1935
Pyramid	179,000	386	1,080	Rock fill	1973
Santiago Creek (6)	25,000	136	1,425	Earth	1933
Stone Canyon (7)	10,370	185	1,150	Earth	1924,1956
Lower Franklin (8)	1,031	103	500	Hydraulic fill	1922
Mulholland (9)	4,036	195	933	Gravity	1924

Notes:
(1) Dynamic analysis completed. No further work scheduled.
(2) Upstream from Castaic.
(3) Currently empty.
(4) Operated at reduced water level since 1966. Construction contract for new reservoir to be let in 1981.
(5) No analysis completed to date. No additional work scheduled to date.
(6) Embankment dynamic analysis completed. Foundation analysis in progress.
(7) Dynamic analysis completed. No further work scheduled.
(8) Currently empty. Bids advertised for reconstruction in late 1980.
(9) Concrete gravity dam. To be analyzed in 1981. Lower Hollywood Reservoir.

Table 24.--Dead and homeless due to dam failure--Los Angeles study area

Dam	Potential homeless	Potential deaths	Location
Bouquet Canyon	121,000	8,300	Area 9 L.A.; Ventura Co.
Castaic	143,000	15,000	Area 9 L.A.; Ventura Co.
*Castaic Forebay	---	---	---
Fairmont	2,000	20	Area 9 L.A.
Morris	22,000	25	Areas 7 & 9 L.A.
**Pyramid	140,000	15,000	Area 9 L.A.; Ventura Co.
Santiago Creek	165,000	1,100	Orange County
Stone Canyon	120,000	1,500	Area 2 L.A.
Mulholland (Lower Hollywood)	132,000	6,000	Area 2 L.A.

*Located within one arm of Castaic Reservoir. Simultaneous failure of Castaic and Castaic Forebay would not significantly change the situation.

**Assumes failure would cause subsequent failure of San Felicia Dam (Ventura County) and inundation area would be result of combined flow from both reservoirs into Santa Clara River.

Table 25.--Dead and homeless due to dam failure- San Francisco study area

Dam	Maximum potential individuals exposed Day	Night	Maximum Potential deaths Day	Night	**Probable potential deaths Day	Night
Lafayette	105,000	100,000	12,000	8,000	8,000	6,000
San Pablo, or Briones and San Pablo	54,000	56,000	32,000	33,000	22,000	28,000
Upper San Leandro	95,000	120,000	55,000	57,000	33,000	39,000
Lower Crystal Springs	67,000	63,000	33,000	34,000	22,000	28,000
Calaveras, James Turner, and Del Valle	138,000	150,000	33,000	37,000	22,000	26,000
only Calaveras	39,000	44,000	9,000	8,000	6,000	6,000
only Del Valley	23,000	26,000	17,000	21,000	11,000	14,000
Lexington	*	79,000	*	22,000	*	17,000
Anderson and Coyote	*	20,000	*	6,000	*	3,000

*Not available.

**"Probable" is defined as the more likely number on the basis of the probable exposed downstream population rather than the census count of all persons in the area.

Table 26.--Monetary losses. Losses in millions of 1980 dollars

Location	*Total loss		**Dwelling loss
	Buildings	Contents	
San Francisco metropolitan area			
San Andreas fault: M = 8.3	25,300	13,400	4,100
Hayward fault: M = 7.5	28,700	15,200	3,100
Los Angeles metropolitan area			
Newport-Inglewood fault: M = 7.5	40,700	21,500	***8,100
San Andreas fault: M = 8.3	16,300	8,600	***4,800

*See text for exclusions.

**One to four family dwellings, excluding loss to contents.

***Only Los Angeles and Orange counties.

Table 27.--Estimated annual earthquake losses* to one to four family dwellings in selected counties and areas of California

Areas	Losses (1980) (millions of dollars)
Nine San Francisco Bay Area Counties**	$115
Los Angeles and Orange Counties	136
Entire State	324

*Losses are in 1980 dollars, where losses are defined as the replacement cost of the dwellings. Losses are those associated with ground shaking only.

**Marin, Sonoma, Napa, Solano, San Francisco, Santa Clara, Contra Costa, Alameda, and San Mateo Counties.